Semiconductor Physics Division
Fachverband Halbleiterphysik (HL)

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Overview of Invited Talks and Sessions

(lecture rooms H3, H13, H14, H15, H16, and H17; poster D1 and D2)

Invited Talks

HL 28.1	Tue	14:00–14:30	H17	**Ga-assisted MBE grown GaAs nanowires and related quantum heterostructures** — •Anna Fontcuberta i Morral
HL 29.1	Tue	14:45–15:15	H17	**Quantum Dot Flash Memories: The best of two worlds** — •Andreas Marent, Tobias Nowozin, Dieter Bimberg
HL 44.1	Wed	14:00–14:30	H15	**Surface characterisation and reactivity of clean GaN(000±1) surfaces** — Pierre Lorenz, Richard Gutt, Marcel Himmerlich, Juergen A. Schaefer, •Stefan Krischok
HL 51.1	Thu	9:30–10:00	H17	**All-epitaxial inorganic/organic semiconductor hybrid heterostructures** — •Fritz Henneberger
HL 53.1	Thu	12:30–13:00	H15	**Self-lacing nanowires on semiconductor surfaces** — •Harold Zandvliet

Invited Talks of the Focussed Session: Strong Light Matter Coupling

Organizers: Jürgen Christen (Otto-von-Guericke-Universität Magdeburg), Erich Runge (Technische Universität Ilmenau)

HL 18.1	Tue	9:30–10:00	H13	**Strong light-matter interaction in quantum dot micropillar cavities** — •Stephan Reizenstein, Caroline Kistner, Steffen Münch, Christian Schneider, Micha Strauss, Philipp Franeck, Arash Rahimi-Iman, Tobias Heindel, Sven Höfling, Lukas Worschech, Alfred Forchel
HL 18.2	Tue	10:00–10:30	H13	**Strong light-matter coupling in GaN based semiconductors** — •Nicolas Grandjean
HL 18.5	Tue	11:15–11:45	H13	**Spectroscopy and Thermodynamics of Ultracold Excitons in a Potential Trap** — •Heinrich Stolz
HL 18.9	Tue	12:30–13:00	H13	**Novel polariton-based devices: Room temperature polariton laser and electrically controlled polariton parametric amplifier** — •Gabriel Christmann, Stavros Christopoulos, Christopher Coulson, Jeremy J. Baumberg
HL 25.1	Tue	14:00–14:30	H13	**Sub-cycle switching of ultrastrong light-matter interaction** — A. A. Anappara, A. Sell, G. Günter, G. Biasiol, L. Sorba, S. DeLiberato, C. Ciuti, A. Tredicucci, A. Leitenstorfer, •R. Huber

Invited and Topical Talks of the Focussed Session: Silicon Photonics

Organizer: Sangam Chatterjee (Philipps-Universität Marburg)

HL 42.1	Wed	14:00–14:30	H13	**Recent advances in silicon-based photonic devices** — •Delphine Marris-Morini, Laurent Vivien, Gilles Rasigade, Papichaya Chaisakul, Xavier Le Roux, Eric Cassan, Jean-Marc Fedeli, Daniel Chrastina, Giovanni Isella
HL 42.2	Wed	14:30–15:00	H13	**3D silicon photonic crystals** — •Georg von Freymann

HL 42.3	Wed	15:00–15:30	H13	**Miniband-related IR luminescence of Ge/Si quantum dot superlattices** — •Peter Werner
HL 42.4	Wed	15:30–16:00	H13	**Transient optical gain in Germanium quantum wells** — •Christoph Lange, Niko Köster, Martin Schäfer, Mackillo Kira, Stephan Koch, Danny Chrastina, Giovanni Isella, Hans von Känel, Hans Sigg, Sangam Chatterjee
HL 42.5	Wed	16:15–16:45	H13	**SiGe based quantum cascade systems: 10 years after.** — •Hans Sigg
HL 42.6	Wed	16:45–17:15	H13	**A Germanium Laser on Silicon** — •Jurgen Michel, Jifeng Liu, Lionel C. Kimerling, Xiaochen Sun, Rodolfo Camacho
HL 42.7	Wed	17:15–17:45	H13	**Monolithic integration of lattice-matched Ga(NAsP)-based laser device structures on (001) Silicon** — •Kerstin Volz, Wolfgang Stolz

Invited Talks of the Focussed Session: ZnO-based Semiconductors

Organizers: Axel Hoffmann (Technische Universität Berlin), Martin Eickhoff (Justus-Liebig-Universität Gießen)

HL 57.1	Thu	14:00–14:30	H17	**Exploring Zinc Oxide: From band structure towards devices** — •Bruno Meyer
HL 57.6	Thu	15:45–16:15	H17	**Interface Induced Gap States and ZnO Schottky Contacts** — •Steven M. Durbin, Martin W. Allen

Invited talks of the joint symposium SYGN

See SYGN for the full program of the Symposium.

SYGN 1.1	Mon	14:00–14:35	H1	**Models for spin-orbit coupling in graphene** — •Francisco Guinea
SYGN 1.2	Mon	14:35–15:10	H1	**Spin-orbit coupling and spin relaxation in carbon nanotube quantum dots** — •Ferdinand Kuemmeth
SYGN 1.3	Mon	15:10–15:45	H1	**Spin-orbit interaction in carbon nanotubes probed in pulsed magnetic fields** — •Sungho Jhang, Magdalena Marganska, Yurii Skourski, Dominik Preusche, Benoit Witkamp, Milena Grifoni, Herre van der Zant, Joachim Wosnitza, Christoph Strunk
SYGN 1.4	Mon	16:00–16:35	H1	**Wigner molecules and spin-orbit coupling in carbon-nanotube quantum dots** — •Massimo Rontani
SYGN 1.5	Mon	16:35–17:10	H1	**Spin relaxation and decoherence in graphene quantum dots** — •Guido Burkard
SYGN 1.6	Mon	17:10–17:45	H1	**Spin transport in graphene field effect transistors** — •Bart van Wees

Invited talks of the joint symposium SYPN

See SYPN for the full program of the Symposium.

SYPN 1.1	Thu	9:30–10:00	H1	**Growth and applications of N-polar (Al,Ga,In)N** — •Stacia Keller, Umesh K Mishra
SYPN 1.2	Thu	10:00–10:30	H1	**Green light-emitting diodes and laser heterostructures on semi-polar GaN(11-22)/sapphire substrates** — •Andre Strittmatter
SYPN 1.3	Thu	10:30–11:00	H1	**Pros and cons of green InGaN lasers on polar GaN substrates** — •Uwe Strauss, Adrian Avramescu, Teresa Lermer, Jens Müller, Christoph Eichler, Stephan Lutgen
SYPN 1.4	Thu	11:15–11:45	H1	**Molecular beam epitaxy as a method for the growth of free-standing zinc-blende GaN layers and substrates.** — •Sergei Novikov, Thomas Foxon, Anthony Kent
SYPN 1.5	Thu	11:45–12:15	H1	**Three-dimensional GaN for semipolar light emitters** — •Thomas Wunderer, Frank Lipski, Stephan Schwaiger, Ferdinand Scholz, Martin Feneberg, Klaus Thonke, Andrey Chuvilin, Ute Kaiser, Sebastian Metzner, Frank Bertram, Jürgen Christen, Clemens Vierheilig, Ulrich Schwarz

Invited talks of the joint symposium SYDF

See SYDF for the full program of the Symposium.

SYDF 1.1	Thu	14:45–15:15	H1	**Downfolded Self-Energy of Many-Electron Systems and the Hubbard U** — •Ferdi Aryasetiawan
SYDF 1.2	Thu	15:15–15:45	H1	**LDA+Gutzwiller method for correlated electron systems** — •Zhong Fang
SYDF 1.3	Thu	15:45–16:15	H1	**Localized and itinerant states in *d*/*f*-electron systems unified by *GW*@LDA+*U*** — •Hong Jiang
SYDF 1.4	Thu	16:30–17:00	H1	**Giant polaronic effects in solids and nanstructures** — •Andrea Marini
SYDF 1.5	Thu	17:00–17:30	H1	**Excitation energies with time-dependent density *matrix* functional theory** — •Evert Jan Baerends, Klaas J. H. Giesbertz, Oleg Gritsenko, Katarzyna Pernal
SYDF 1.6	Thu	17:30–18:00	H1	**Calculations of multipoles in magnetic metals and insulators** — •Lars Nordström

Sessions

HL 1.1–1.5	Sun	16:00–18:30	H2	**Tutorial: Modern Photovoltaics - Techniques beyond Silicon**
HL 2.1–2.4	Mon	10:15–11:15	H13	**Devices I**
HL 3.1–3.6	Mon	10:15–11:45	H14	**Preparation and Characterization**
HL 4.1–4.9	Mon	10:15–12:45	H15	**Photovoltaics I: mainly CIGS**
HL 5.1–5.8	Mon	10:15–12:30	H17	**Ultra-fast Phenomena**
HL 6.1–6.6	Mon	10:15–13:15	H2	**Nanophotonics - Devices I (Focused Session together with DS)**
HL 7.1–7.10	Mon	10:15–13:00	H18	**Graphene 1 (Joint Session with TT)**
HL 8.1–8.9	Mon	10:15–12:30	H8	**Organic Electronics and Photovoltaics I (Joint Session with DS/CPP/O)**
HL 9.1–9.5	Mon	11:30–12:45	H13	**SiC**
HL 10.1–10.7	Mon	14:00–15:45	H13	**Devices II**
HL 11.1–11.14	Mon	14:00–17:45	H14	**Transport**
HL 12.1–12.6	Mon	14:00–15:30	H15	**Group-III-Nitrides: Optical Properties I**
HL 13.1–13.14	Mon	14:00–17:45	H17	**Quantum Dots and Wires: Preparation and Characterization I**
HL 14.1–14.7	Mon	14:00–17:45	H2	**Nanophotonics - Devices II (Focused Session with DS)**
HL 15.1–15.6	Mon	14:00–15:30	H8	**Organic Electronics and Photovoltaics II (Joint Session with DS/CPP/O)**
HL 16.1–16.6	Mon	16:00–17:30	H13	**Diamond**
HL 17.1–17.7	Mon	16:00–17:45	H15	**Organic Semiconductors: Solar Cells I (Joint Session with DS/CPP/O)**
HL 18.1–18.9	Tue	9:30–13:00	H13	**Focussed Session: Strong Light Matter Coupling I**
HL 19.1–19.13	Tue	9:30–13:00	H14	**Spin-controlled Transport I**
HL 20.1–20.12	Tue	9:30–12:45	H15	**Organic Semiconductors: Transistors and OLEDs**
HL 21.1–21.7	Tue	9:30–11:15	H17	**Quantum Dots and Wires, Optical Properties I: Nitrides**
HL 22.1–22.12	Tue	9:30–12:45	H21	**Graphene 2 (Joint Session with TT)**
HL 23.1–23.10	Tue	10:30–13:00	H2	**Plasmonics and Nanophotonics I (Joint Session with DS/O)**
HL 24.1–24.5	Tue	11:30–12:45	H17	**Quantum Dots and Wires, Optical Properties II: Single Photon Sources**
HL 25.1–25.6	Tue	14:00–15:45	H13	**Focussed Session: Strong Light Matter Coupling II**
HL 26.1–26.8	Tue	14:00–16:15	H14	**Spin-controlled Transport II**
HL 27.1–27.9	Tue	14:00–16:15	H15	**GaN Preparation and Characterization**
HL 28.1–28.1	Tue	14:00–14:30	H17	**Invited Talk: A. Fontcuberta i Morral**
HL 29.1–29.1	Tue	14:45–15:15	H17	**Invited Talk: A. Marent**
HL 30.1–30.6	Tue	15:00–16:30	H2	**Plasmonics and Nanophotonics II (Joint Session with O/DS)**
HL 31.1–31.47	Tue	18:30–20:30	Poster D1	**Poster I: Devices, Quantum Dots and Quantum Wires**
HL 32.1–32.26	Tue	18:30–20:30	Poster D1	**Poster I: Group II - Oxides**
HL 33.1–33.15	Tue	18:30–20:30	Poster D1	**Poster I: Transport, including Magnetic-Field Effects**
HL 34.1–34.39	Tue	18:30–20:30	Poster D2	**Poster I: III-V Semiconductors**
HL 35.1–35.5	Wed	9:30–10:45	H13	**New Materials: Optoelectronic and Photovoltaic Applications**
HL 36.1–36.13	Wed	9:30–13:00	H14	**Ge, GeSi, and Si**

HL 37.1–37.12	Wed	9:30–12:45	H15	**Quantum Dots and Wires: Optical Properties III**
HL 38.1–38.13	Wed	9:30–13:00	H17	**ZnO and Related Semiconductors**
HL 39.1–39.8	Wed	9:30–11:45	H3	**Photovoltaics II**
HL 40.1–40.11	Wed	10:30–13:15	H32	**Plasmonics and nanooptics III**
HL 41.1–41.7	Wed	11:00–12:45	H13	**Quantum Dots and Wires: Preparation and Characterization II**
HL 42.1–42.7	Wed	14:00–17:45	H13	**Focussed Session: Silicon Photonics**
HL 43.1–43.7	Wed	14:00–15:45	H14	**Electronic Structure and Atomistic Modeling**
HL 44.1–44.1	Wed	14:00–14:30	H15	**Invited talk: S. Krischok**
HL 45.1–45.12	Wed	14:30–17:45	H15	**Group-III-Nitrides: Optical Properties II**
HL 46.1–46.14	Wed	14:00–17:45	H17	**Quantum Dots and Wires: Transport**
HL 47.1–47.5	Wed	16:00–17:15	H14	**New Materials: mainly thermoelectric and nanomechanical Properties**
HL 48.1–48.12	Thu	9:30–12:45	H13	**Semiconductor Lasers**
HL 49.1–49.13	Thu	9:30–13:00	H14	**Optical Properties**
HL 50.1–50.10	Thu	9:30–12:15	H15	**Graphene and Carbon Nanotubes**
HL 51.1–51.1	Thu	9:30–10:00	H17	**Invited Talk: F. Henneberger**
HL 52.1–52.11	Thu	10:00–13:00	H17	**Heterostructures**
HL 53.1–53.1	Thu	12:30–13:00	H15	**Invited Talk: H. Zandvliet**
HL 54.1–54.7	Thu	14:00–15:45	H13	**Photonic Crystals: Theory**
HL 55.1–55.7	Thu	14:00–15:45	H14	**Quantum Dots and Wires, Optical Properties IV: Spin**
HL 56.1–56.14	Thu	14:00–17:45	H15	**Non- and Semi-polar Group-III-Nitrides**
HL 57.1–57.13	Thu	14:00–18:00	H17	**Focussed Session: ZnO-based Semiconductors**
HL 58.1–58.7	Thu	16:00–17:45	H13	**Photonic Crystals: Experiment**
HL 59.1–59.7	Thu	16:00–17:45	H14	**Quantum Dots and Wires, Optical Properties V**
HL 60.1–60.39	Thu	18:00–20:00	Poster D1	**Poster II: Optical Properties, incl. Photonic Crystals and Ultrafast Phenomena**
HL 61.1–61.45	Thu	18:00–20:00	Poster D1	**Poster II: Materials, Interfaces and Heterostructures**
HL 62.1–62.34	Thu	18:00–20:00	Poster D2	**Poster II: Photovoltaics and Organic Semiconductors**
HL 63.1–63.10	Fri	10:15–13:00	H13	**III-V Semiconductors**
HL 64.1–64.10	Fri	10:15–13:00	H14	**Quantum Dots and Wires: Optical Properties VI**
HL 65.1–65.9	Fri	10:15–12:45	H15	**GaN-based Devices**
HL 66.1–66.4	Fri	10:15–11:15	H17	**ZnO-based Devices**
HL 67.1–67.7	Fri	10:15–12:15	H16	**Organic Semiconductors: Solar Cells II (Joint Session with DS/CPP/O)**
HL 68.1–68.5	Fri	11:30–12:45	H17	**II-VI Semiconductors: mainly Optical Properties**

Annual General Meeting of the Semiconductor Physics Division

Wednesday 18:00 H13

- Bericht
- Stichwortkatalog
- Verschiedenes

HL 1: Tutorial: Modern Photovoltaics - Techniques beyond Silicon

Chair: Wichard J. D. Beenken, Institut für Physik, Technische Universität Ilmenau

Time: Sunday 16:00–18:30 Location: H2

Tutorial HL 1.1 Sun 16:00 H2

CdTe thin-film solar cells — •Heinrich Metzner — Institut für Festkörperphysik, FSU Jena, Max-Wien-Platz 1, 07743 Jena

The global industrial production of CdTe solar modules exceeds one Gigawatt per year and so CdTe is probably the most successful thin-film technology of recent years.

In the tutorial, the specific features of the technology are elucidated which make it so competitive. Moreover, the open questions in the materials science of the CdTe-CdS-hetero-structure are discussed and key-issues are identified which are believed to potentially bring the CdTe solar cells to efficiencies well above 20 %.

Tutorial HL 1.2 Sun 16:30 H2

CIGS thin-film solar cells — •Stefan Paetel — Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden Württemberg (ZSW), Industriestraße 6, 70565 Stuttgart, Germany

This talk covers the current status and understanding of high-efficiency $Cu(In,Ga)Se_2$ solar cells. Starting with the principal setup of these cells the various parts of the multilayer system will be introduced: substrate, back-contact, absorber, buffer and front contact. This includes the structural, optical and electronic properties of the materials. Furthermore relevant deposition methods are presented along with module manufacturing issues.

Tutorial HL 1.3 Sun 17:00 H2

Dye-sensitized solar cells — •Sven Rühle — Institute for Nanotechnology and Advanced Materials, Dept. of Chemsitry, Bar Ilan University, Ramat Gan 52900, Israel

Dye-sensitized solar cells (DSSCs) are a low cost alternative to crystalline silicon p-n junction photovoltaic cells. DSSCs consist of a mesoporous nanocrystalline wide bandgap semiconductor (usually TiO_2) that is sintered onto a transparent conducting substrate (TCO). The nanocrystals are covered with a dye-monolayer and the pores are filled with a redox electrolyte which is in contact with a Pt counter electrode. Upon illumination light is absorbed by the dye molecules and electrons are injected from the excited dye state into the TiO_2 conduction band while the dye is regenerated by the electrolyte. Electrons diffuse through the mesoporous film to the TCO front contact while positive charges are transported by the redox species to the counter electrode. In DSSCs efficient charge separation occurs at the TiO_2/dye/electrolyte interface and build-in electrostatic fields play a minor role for cell operation in contrast to p-n junction solar cells. The basic principles of DSSC operation will be reviewed and theoretical efficiency limitations will be discussed.

Tutorial HL 1.4 Sun 17:30 H2

Organic solar cells based on small molecules — •Moritz Riede — IAPP, Technische Universität Dresden, Germany

In recent years organic solar cells based on polymers or small molecules have received increasing attention from both science and industry, making it a very dynamic field of research. On the one hand, there are a number of open questions on the fundamental physics, e.g. the process of free charge carrier generation. On the other hand, there is the perspective of low cost solar power due to easy solar cell preparation, low-cost materials and processing technologies, and the possibility of producing large-area flexible devices on plastic substrates. Currently there are two main preparation technologies: solution processing and vacuum thermal deposition. This tutorial will focus on the main principles and concepts of the latter one. Despite its limitations to small molecules due to the thermal evaporation process, vacuum deposition has several distinct advantages: small molecules can be purified to a high degree, molecular doping of the organic layers is possible via co-evaporation, the layer thickness can be controlled well and stacked structures, e.g. for tandem solar cells, are easily accessible. Currently, metal-phthalocyanines and C_{60} are used as standard absorbers, but also new and promising materials have been introduced in recent years. Continuous material and device optimisation has lead to certified efficiencies of more than 6% on an device area exceeding $1cm^2$. Finally, an outlook on possible production routes is given.

Tutorial HL 1.5 Sun 18:00 H2

Polymer Solar Cells — •Harald Hoppe — Institut für Physik, Technische Universität Ilmenau, Germany

Milestones in the development of conjugated polymer-based solar cells are reviewed. The presentation will cover an introduction to elementary photo-physical processes and fundamental working principles of polymer solar cells. Furthermore, processes limiting the individual photovoltaic parameters are discussed. Interesting examples of structure-property-relationships on the super-, inter- and intramolecular scale are given and demonstrate the necessity for multi-scale approaches in the optimization of polymer solar cells. Finally, several so far utilized donor-acceptor material systems are briefly reviewed.

HL 2: Devices I

Time: Monday 10:15–11:15 Location: H13

HL 2.1 Mon 10:15 H13

Improvement of TFET perfomance by spacer technology — •Marc Dressler, Helmut Lochner, Carolin Axt, Ronny Schindler, Josef Biba, Oliver Hammer, Florian Palitschka, Dorota Kulaga-Egger, Rudolf Nüssl, Tanja Stimpel-Lindner, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

Due to the International Technology Roadmap for Semiconductors (ITRS) the successive downscaling leads to various problems. Some of these problems are caused by limited prospects of photo lithography. Despite resolution enhancement technics like phase shift marks or optical proximity correction the ability to create self-adjusting structures below the resolution limit forces increasing attention. In this work lateral Tunnel-FETs were fabricated. The usage of TFETs are also suitable for short channel devices, because its functionality is based on the well known quantum-mechanical effect of band to band tunneling. To solve the problems of small structures some capable technical tricks are used, e.g. the spacer-technology. Due to these spacer most critical structures (e.g. gate) are self-aligned. A protective function for sensitive gate dielectrics is an additional achievement. To challenge the high demands for the following doping via diffusion a nitride-spacer with specific parameters was developed. The differences between this TFET and common lateral devices without spacer are shown by electrical characterization. The results will be confirmed by characterization abilities like SIMS and REM.

HL 2.2 Mon 10:30 H13

Advanced device performance of TFETs by embedded silicon germanium alloys — •Helmut Lochner, Peter Iskra, Martin Schlosser, Dorota Kulaga-Egger, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

Due to increasing problems by downscaling conventional transistor concepts like the MOSFET, the semiconductor industry is searching for promising new device technologies, such as the Tunnel-FET. Making a virtue out of necessity the TFET takes advantage of the band to band tunneling effect, which is constricting conventional devices. Although the leakage currents can be significant reduced, the ON-current requested by the ITRS (International Technology Roadmap for Semiconductors) cannot be fulfilled. In order to solve this demerit, several solutions are discussed. An efficient way to minimize the deficit is to integrate SiGe alloys in the tunneling region. On the one hand the smaller band gap of SiGe yields in a smaller tunneling gap and consequently in a higher tunnel probability. On the other hand the strained SiGe layer acts as a diffusion barrier. As a consequence the maximum

doping concentration at the tunnel region and the sharpness of the doping profile are increasing hand by hand with the resulting ON current. To verify these effects, several TFETs featuring different alloys were fabricated. Electrical measurements like input and output characteristics are confirming these conclusions. The theoretical boarders are pointed out by means of numeric simulations.

HL 2.3 Mon 10:45 H13

SOD as self-acting passivation for lateral TFETs — •Carolin Axt, Helmut Lochner, Marc Dressler, Ronny Schindler, Josef Biba, Rudolf Nüssl, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

According to the ITRS (International Technology Roadmap for Semiconductors)the TFET is a promising successor of the MOSFET. The major problems of current MOSFETs are caused by short channel effects, which results in high OFF-currents. The TFET reverses these unfavorable tunnel currents into useful trait. To investigate new device concepts lateral TFETs were fabricated. Because TFET action is closely connected with extremely high-doped surface layer for source/drain, we used Spin-On-Dopand (SOD) technics. In the common process flow, the SOD-layer has to be removed difficult without affecting the gate oxide. In a changed technological process sequence we used the SOD layer as isolation instead of removing it. The loss of solvent caused by thermodiffusion might result in cracks within the SOD-layer. Metal can enter these cracks while depositing and structuring the contacts. As a result, a short circuit between source or drain and gate are caused. Therefore, photo-resist was implemented to serves as an additional passivation, which ensures a plenary insulation of the doped areas. The results of these transistors with a combined SOD-resist passivation were compared with other lateral TFETs by electrical characterization. Input and output characteristics as well as SIMS measurements and REM graphics are shown.

HL 2.4 Mon 11:00 H13

Properties of an interface layer created by Boron-SOD diffusion — •Ronny Schindler, Josef Biba, Marc Dressler, Carolin Axt, Helmut Lochner, Dorota Kułaga-Egger, Tanja Stimpel-Lindner, Florian Palitschka, Oliver Hammer, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The common manner of doping silicon in industry is ion implantation. Besides the high costs this doping method has problems to create shallow surface doping layers as they will be needed for future device generations. We investigate an alternative doping by using Spin-On-Dopants (SOD), where a dopant consisting liquid oxide is deposited on the silicon surface. After solidification the dopant atoms (boron, phosphorous) are driven from the oxide into the silicon by high-temperature diffusion process. As previous experiments have shown, phosphorus performs well, but if boron is used, an etch-resistant layer is left after the process on the surface. The nature and properties of this layer have not been investigated for a full understanding, but it creates problems in device fabrication. For clarification of this problem we fabricated MOS-diodes by using SOD. We tried to find out, if and how this layer can be removed, by using dry etching and wet etching methods. Finally we characterized the different diodes electrically, with and without this layer, to compare which removal technique is the most effective and how strong the influence of this layer is.

HL 3: Preparation and Characterization

Time: Monday 10:15–11:45 Location: H14

HL 3.1 Mon 10:15 H14

In situ AFM characterization of e-beam exposed PMMA — Hans Koop[2], •Daniel Schnurbusch[1], Michael Müller[1], Tobias Gründl[1], Markus C. Amann[1], Khaled Karrai[2], and Alexander W. Holleitner[1] — [1]Walter Schottky Institut und Physik Department, TUM Garching, Germany — [2]attocube systems AG, Königinstraße 11a RGB, 80539 München, Germany

PMMA (poly-methyl methacrylate) is a standard polymer used as a resist for high-resolution e-beam lithography. We demonstrate how to probe in-situ the exposure properties of PMMA by an atomic force microscope (AFM). To this end, an AFM is integrated in a scanning electron microscope, and the PMMA is characterized by the AFM after e-beam exposure. Our method allows us to directly image and characterize the exposed areas of the PMMA before the resist is developed. We present a systematic investigation of this novel approach, which may result in a reliable way to evaluate e-beam exposed resists before further post-processing.

HL 3.2 Mon 10:30 H14

Focused ion beam lithography for rapid prototyping of metallic films — •Patrick Osswald, Josef Kiermaier, Markus Becherer, and Doris Schmitt-Landsiedel — Lehrstuhl für Technische Elektronik, TU München, Munich, Germany

We present FIB-lithography methods for rapid and cost-effective prototyping of metal structures covering the deep-submicron- to the millimeter-range in a single lithography cycle.

Focused ion beam (FIB) systems are widely used in semiconductor industry and research facilities for both analytical testing and prototyping. A typical application is to apply electrical contact to micron-sized sensors/particles by FIB induced metal deposition. However, as for E-beam lithography, patterning times for large area bonding pads are unacceptably long, resulting in cost-intensive prototyping.

In this work, we optimized FIB lithography processing for negative and positive imaging mode to form metallic structures for large-areas down do the sub-100 nm range. For negative lithography features are defined by implanting Ga^+-ions into a commercial photo resist, without affecting the underlying structures by impinging ions. The structures are highly suitable for following lift-off processing due to the undercut of the resist.Metallic feature size of down to 150 nm are achievable. For positive lithography a PMMA resist is exposed in FIB irradiation. Due to the very low dose ($3 \cdot 10^{12}$ ions/cm^2) the writing time for an e.g. 100 μm x 100 μm square is approx. 15 seconds. The developed resist is used for subsequent wet chemical etching, obtaining a 100 nm resolution in metal layers.

HL 3.3 Mon 10:45 H14

In situ PES analysis of ultra-thin ZnO layers grown by atomic layer deposition — •Eike Janocha and Christian Pettenkofer — Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin

Atomic layer deposition (ALD) is known for being a deposition technique allowing the growth of very thin films with excellent thickness and stoichiometry control due to its self-limiting growth characteristics. Zinc oxide (ZnO) layers have been grown by alternating exposure of highly reactive diethylzinc (DEZ) as a metal-precursor and water as oxidizing agent in an UHV environment on Si(111) substrates. After the deposition process, in situ X-ray photoelectron spectroscopy (XPS) and ultraviolet photoelectron spectroscopy (UPS) has been carried out without removing the samples out of the UHV environment. This allows a reliable analysis of the film thickness and interface chemistry and gives us the possibility of determining the temperature regime where the atomic layer deposition process shows its self-limiting character, known as the ALD window. Furthermore, we investigated the initial growth of the ZnO layers on various substrates and we are able to show that there is layer-by-layer growth, characteristic for atomic layer deposition, after formation of the first ZnO monolayer.

HL 3.4 Mon 11:00 H14

In situ characterization of VPE prepared Si(100) surfaces via RAS — •Sebastian Brückner, Henning Döscher, Anja Dobrich, Oliver Supplie, Christian Höhn, and Thomas Hannappel — Helmholtz- Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin

The epitaxial growth of III-V semiconductors on silicon substrates is a major challenge for the integration of opto- and micro-electronic devices. The first crucial step in the III-V on Si hetero epitaxy consists of a substrate preparation ensuring complete removal of oxides and a suitable atomic surface structure. It has been shown in UHV that reflection anisotropy spectroscopy (RAS) is a powerful tool to charac-

terize Si(100) surfaces. The spectra of nominal and vicinal Si(100) substrates differ strongly due to the influences of terrace and step structures on the signal. Also adsorbates like hydrogen and oxygen show a strong impact on the spectra. We applied in situ RAS in our MOVPE reactor to characterize and control the preparation of Si(100) with 0.1°, 2° and 6° offcuts towards <111> direction. During the oxide removal process the RA spectra change from a baseline spectrum of the oxidized surface to the typical clean Si(100) spectrum. We were able to observe this change in situ by transient RAS measurements. In addition the adsorption of hydrogen on the Si surface during cool down was studied. A dedicated contamination free sample transfer system from MOVPE environment to UHV enabled us to benchmark the RA spectra with results from various surface science instruments.

HL 3.5 Mon 11:15 H14

Strain measurements on semiconductors: Raman experiments and simulation — •Andreas Talkenberger[1], Gert Irmer[1], Martin Abendroth[2], Christian Röder[1], and Cameliu Himcinschi[1] — [1]TU Bergakademie Freiberg, Institute for Theoretical Physics, Leipziger Str. 23, 09596 Freiberg, Germany — [2]TU Bergakademie Freiberg, Institute for Mechnics and Fluid Dynamics, Lampadiusstr. 4, 09596 Freiberg, Germany

The characterisation of strains in semiconductors is crucial for microelectronic and photovoltaic applications. However, even for some widely used semiconductors the elastic properties are not well understood. For example, due to the lack of high-quality GaN bulk material it was not yet possible to determine the elastic constants with good precision.
Using Raman scattering we present a method which allows the determination of phonon deformation potentials in semiconductors derived from phonon frequency shifts under biaxial stress. The stress was applied by three-point bending and calculated by means of beam theory. In order to establish the technique we first investigated well studied semiconductor materials, e.g. silicon and gallium arsenide. The phonon deformation potentials found are in good agreement with earlier published values. Additionally, the strain fields were calculated by finite element methods.
The authors would like to thank the European Union (EFRE) as well as the Free State of Saxony for financial support.

HL 3.6 Mon 11:30 H14

High temperature dielectric function of Silicon, Germanium and GaN — •Martin Leyer, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

In the last few years accurate values for the optical properties of silicon, germanium and GaN at high temperatures have become important as a reference for in-situ analysis, e.g. reflectometry. Precise temperature dependent dielectric measurements are necessary for the growth of GaInP/GaInAs/Ge triple-junction solar cells and the hetero epitaxy of GaN on silicon and sapphire.

We performed spectroscopic ellipsometry (SE) measurements of the dielectric function of silicon, germanium and GaN between 1.5 eV and 6.5 eV in the temperature range from 300 K to 1300 K. The Samples were deoxidized chemically or by heating. High resolution SE spectra were taken every 50 K while cooling down to room temperature. The temperature dependence of the critical energies is compared to literature. Measurements for germanium showed a shift of the E_2 critical point of ∼0.1 eV toward lower energies. The reason for this behavior is a non-negligible oxide layer on the samples in the literature.

HL 4: Photovoltaics I: mainly CIGS

Time: Monday 10:15–12:45 Location: H15

HL 4.1 Mon 10:15 H15

Investigation of Cu(In,Ga)Se_2 using Monte Carlo and the Cluster Expansion technique — •Christian D. R. Ludwig[1], Thomas Gruhn[1], Claudia Felser[1], and Johannes Windeln[2] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-University, 55099 Mainz — [2]IBM Germany, Mgr. Technology Center ISC EMEA, 55131 Mainz

CIGS based solar cells are among the most promising thin-film techniques for cheap, yet efficient modules. They have been investigated for many years, but the full potential of CIGS cells has not yet been exhausted and many effects are not understood. For instance, the band gap of the absorber material Cu(In,Ga)Se_2 varies with Ga content. The question why solar cells with high Ga content have low efficiencies, despite the fact that the band gap should have the optimum value, is still unanswered. We are using Monte Carlo simulations in combination with a cluster expansion to investigate the homogeneity of the In-Ga distribution as a possible cause of the low efficiency of cells with high Ga content. The cluster expansion is created by a fit to ab initio electronic structure energies. The results we found are crucial for the processing of solar cells, shed light on structural properties and give hints on how to significantly improve solar cell performance. Above the transition temperature from the separated to the mixed phase, we observe different sizes of the In and Ga domains for a given temperature. The In domains in the Ga-rich compound are smaller and less abundant than the Ga domains in the In-rich compound. This translates into the Ga-rich material being less homogeneous.

HL 4.2 Mon 10:30 H15

CdS-Photodoping in Quantum Efficiency Spectra of Chalcopyrite Thin Film Solar Cells — •Heiner Lendzian[1], Janet Neerken[1], Martin Knipper[1], Ingo Riedel[1], Jürgen Parisi[1], Stefan Jost[2], Thomas Dalibor[2], Jörg Palm[2], and Alejandro Avellán[2] — [1]Energy- and Semiconductor Research Laboratory, Department of Physics, Carl von Ossietzky University of Oldenburg, D-26111 Oldenburg, Germany — [2]AVANCIS GmbH & Co. KG, Otto-Hahn-Ring 6, Gebäude 31, D-81739 Munich, Germany

Understanding the electronic properties of the CdS buffer layer typically employed in chalcopyrite thin film solar cells is a key challenge in the pursuit of high device performance. Photodoping of the CdS layer appears to alter the conduction band offset at the CdS/absorber interface by more than 100meV and causes substantial changes in the spectral shape of the external quantum efficiency under forward voltage bias. This contribution examines the nature of CdS-photodoping by means of quantum efficiency measurements for varied temperatures, photon flux densities and excitation frequencies. Rapid photodoping is linked to hole traps inside the CdS buffer similar to those believed to be responsible for cross-over in current-voltage-measurements. The results emphasize the strong influence of CdS-photodoping on chalcopyrite solar cell performance and grant insight into its dynamic nature.

HL 4.3 Mon 10:45 H15

Characterisation of CuInSe2-based solar cells with different buffer layers — •Anton Werth[1], Jörg Ohland[1], Ingo Riedel[1], Jürgen Parisi[1], and Juan Rechid[2] — [1]Abteilung EHF, Institiut für Physik, Carl von Ossietzky Universität, Carl-von-Ossietzky-Straße 9-11, D-26129 Oldenburg — [2]CIS Solartechnik GmbH & Co. KG, c/o Aurubis AG Hovestr. 50 20539 Hamburg

The optoelectronic properties of the buffer layer in chalcopyrite solar cells may present strong efficiency limitation due to parasitic absorption, interface states and band discontinuities in respect of the light absorber. In this work we investigated CuInSe2-based (CIS) solar cells processed on flexible steel substrates with In2S3 and CdS buffer layers by means of temperature dependent current-voltage (J-V) measurements at varying illumination intensity and external quantum efficiency (EQE) measurements. Under illumination the J-V curves of both cell types exhibit distinct "s"-shape non-ideality (roll over) at temperatures below 260K. The occurrence of the "s"-shape in the 4th and/or 1st quadrant is explained by an heuristic model which relates the band discontinuity being present at the buffer CIS interface to limitation of the minority carrier extraction and injection. Further, we employed the suns-Voc method to extract the diode parameters saturation current and diode ideality from the J-V characteristics under illumination (small effect of series resistance) in order to identify clues on dominant surface or bulk recombination. We conclude that interface recombination is less dominant in the investigated samples independent of the used buffer material.

HL 4.4 Mon 11:00 H15

Optoelectronic properties of Cu(In,Ga)$(S,Se)_2$ thin film so-

lar obtained from varied chalcogenization processes — •Robin Knecht, Martin Knipper, Ingo Riedel, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany

Thin film solar cells made of the chalcopyrite compound semiconductor Cu(In,Ga)(S,Se)$_2$ (CIGSSe) exhibit strong potential for achieving high efficiency at relatively low production costs. While large scale production of CIGSSe-modules has been launched in different companies the transfer of high laboratory cell efficiencies to the module scale is still a major challenge. In order to improve module efficiencies optimisation of the large scale production process presents a major issue.

In this work the influence of chalcogenization (selenisation and sulfurisation) parameter variation on the device characteristics was studied using temperature and illumination dependent current-voltage profiling, external quantum efficiency measurements as well as temperature dependent capacitance-voltage measurements. From these measurements we derived important characteristics of the light absorber like activation energy of the recombination current, estimation of the absorber band gap as well as the doping concentration along with the diffusion potential. These studies were completed by defect spectroscopy for analysis of defect formation in the absorber material. The results obtained from these investigations are compared for samples exposed to different conditions of the chalcogenization process.

15 Min. Coffee Break

HL 4.5 Mon 11:30 H15

Vergleichende Charakterisierung von Homo- und Heterojunction- $CuIn_{0,4}Ga_{0,6}Se_2$ **Solarzellenstrukturen auf Glassubstrat** — •Kristin Wendt[1], Thomas Hempel[1], Jürgen Christen[1], Kay-Michael Günther[1], Mutsumi Sugiyama[2] und Shigefusa Chichibu[3] — [1]Institut für Experimentelle Physik, Otto-von-Guericke Universität Magdeburg, Deutschland — [2]Department of Electrical Engineering, Tokyo University of Science, Japan — [3]Institute of Multidisciplinary Research of Advanced Materials, Tohoku University, Japan

Das Materialsystem $Cu(In,Ga)Se_2$ ist aufgrund des variablen Bandabstandes, ein vielversprechendes Material für die Herstellung von Dünnschichtsolarzellen. Das Interesse liegt dabei auf der Entwicklung alternativer Pufferschichten und der Realisierung einer Homojunction durch Dotierung des Absorbers $Cu(In,Ga)Se_2$. In den vorgestellten Untersuchungen werden optische und elektrooptische Messungen an Homojunction- bzw. Heterojunction- $CuIn_{0,4}Ga_{0,6}Se_2$ -Strukturen auf Glassubstrat mit unterschiedlichen Pufferschichten vorgestellt. Durch temperatur- und anregungsdichteabhängige Photolumineszenzmessungen wird das Lumineszenzverhalten der über thermische Evaporation prozessierten $CuIn_{0,4}Ga_{0,6}Se_2$ -Schichten verglichen. Die $CuIn_{0,4}Ga_{0,6}Se_2$ -Strukturen zeigen dabei eine breitbandige Lumineszenz im Bereich von 1,08eV bis 1,28eV mit einer Halbwertsbreite im Bereich von 0,08eV bis 0,10 eV. Eine spektrale Änderung der Lumineszenz wurde weder mit veränderter Anregungsleistung noch mit Veränderung der Temperatur beobachtet.

HL 4.6 Mon 11:45 H15

Influence of sodium on the electrical properties of flexible CIGSe solar cells — •Felix Daume[1,2], Stefan Puttnins[1,2], Hendrik Zachmann[1], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, 04288 Leipzig, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

Thin film solar cells based on Cu(In,Ga)Se$_2$ (CIGSe) absorbers can be deposited on flexible substrates such as metal or plastic foils hence making new innovative applications and a fabrication in continuous roll-to-roll production lines feasible. Efficiencies up to 15.6 % were demonstrated for CIGSe cells on polyimide foil. The extrinsic incorporation of sodium into CIGSe solar cells based on sodium free substrates such as polyimide is indispensable to achieve high efficiencies. Despite its significance there is no comprehensive understanding of how sodium exactly influences the electrical and structural properties of CIGSe yet.

Via capacitance spectroscopy and I-V-measurement we characterized CIGSe solar cells on polyimide from a roll-to-roll fabrication with different amounts of sodium introduced during the CIGSe deposition. The net doping profiles were derived from C-V-measurements. An increase of the net doping with higher sodium content in the CIGSe is observed along with the decrease of the width of the space charge region. Additionally, differences in the spatial distribution of the doping for those CIGSe absorbers were found. These observations from capacitance spectroscopy are supplemented by I-V data showing an increase in V_{OC} and thus in efficiency with increasing sodium content.

HL 4.7 Mon 12:00 H15

Current blocking and current collection in CIGSe solar cells depending on sodium content — •Stefan Puttnins[1,2], Felix Daume[1,2], Hendrik Zachmann[1], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, 04288 Leipzig, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 5, 04103 Leipzig, Germany

IV-curves of thin film solar cells often show non-idealites like voltage dependent carrier collection and current blocking behaviour. Sodium is long known to improve the efficiency of Cu(In,Ga)Se$_2$ solar cells by increasing V_{OC} and FF. However, the way in which sodium influences the electrical properties is still under discussion.

We investigated the influence of sodium on voltage dependent carrier collection and current blocking behaviour. Losses caused by incomplete photocurrent collection can be reduced by increased sodium content in the CIGSe layer. Current blocking behaviour like the rollover effect is less pronounced with increased sodium content.

The influences were analyzed both in detailed illumination intensity and temperature dependent IV-measurements as well as by extensive statistical analysis over thousands of produced flexible CIGSe solar cells. Theoretical models for this dependency were simulated with SCAPS-1D and show good agreement with respective measurements.

HL 4.8 Mon 12:15 H15

Cu poor phases at Cu(In,Ga)Se2/CdS interfaces — Andreas Klein, Thomas Schulmeyer, Ralf Hunger, and •Tobias Adler — TU Darmstadt, Institute of Materials Science, Petersenstrasse 32, 64287 Darmstadt

The absorber surfaces and interfaces in Cu(In,Ga)Se2 (CIGS) thin film solar cells are affected by Cu-poor phases like Cu(In,Ga)3Se5 or Cu(In,Ga)5Se8, which are often referred to as ordered vacancy compounds. We have performed photoemission studies of de-capped CIGS surfaces and their interface with CdS. The band alignments and temperature dependent binding energy shifts provide evidence that interfaces of In-rich CIGS films are Cu-poor, while interfaces of Ga-rich CIGS films are stoichiometric.

HL 4.9 Mon 12:30 H15

Interface properties of Cd-free buffer layers on on CIGSe thin film solar cells — •J.P. Theisen[1], F. Erfurth[1], L. Weinhardt[1], R. Duarte[2], M. Bär[2], T. Niesen[3], J. Palm[3], N. Barreau[4], F. Couzinié-Devy[4], J. Kessler[4], and F. Reinert[1,5] — [1]University of Würzburg, Experimental Physics VII, Würzburg, Germany — [2]Helmholtz Institut, Berlin, Germany — [3]Avancis GmbH, München, Germany — [4]Institut des Matériaux , Nantes, France — [5]Forschungszentrum Karlsruhe GmbH, Gemeinschaftslabor für Nanoanalytik, Karlsruhe, Germany

In order to replace the toxic Cadmium, the substitution of the CdS buffer layer in thin film solar cells based on Cu(In,Ga)(S,Se)$_2$ (CIGSSe) is of great interest. Alternative buffer layers like (In,Al)$_2$S$_3$, In$_2$S$_3$, or (Zn$_{1-x}$,Mg$_x$)O deposited by conventional sputter and chemical bath deposition techniques, have shown efficiencies close to or comparable to those of CdS containing solar cells. To understand the chemical and electronic properties of these buffer layers and its influence on the absorber, we studied the buffer-absorber interface using photoelectron spectroscopy (XPS, UPS) and inverse photoelectron spectroscopy (IPES). The combination of these non-destructive techniques provides detailed information about the chemical properties of the studied surface, as well as can be used for a direct determination of the conduction and valence band alignment at the heterojunction. Band-gap values at the surface as derived by UPS and IPES are also verified by electron energy loss spectroscopy (EELS). The results will be discussed in conjunction with the respective cell parameters.

HL 5: Ultra-fast Phenomena

Time: Monday 10:15–12:30 Location: H17

HL 5.1 Mon 10:15 H17

Microscopic description of non-linear polarization spectra of light-harvesting complexes — •Mario Schoth[1], Marten Richter[1], Thomas Renger[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Theoretische Biophysik, Johannes Kepler Universität Linz, Austria

Ultrafast spectroscopic techniques, such as nonlinear polarization spectroscopy [1], are used to investigate photosynthetic systems of higher plants. Performed in the frequency domain, non-linear polarization spectroscopy (NLPF) permits simultaneous measurements of dephasing and energy relaxation rates up to tens of femtoseconds. Within a Bloch equation approach [2], we calculate NLPF spectra of light-harvesting complexes such as the water-soluble chlorophyll binding protein complex (WSCP) microscopically. Hereby, we include self-consistently structural data for the optical transition energies of pigments in protein environments and the spectral density of exciton-vibrational coupling [3]. Furthermore, the influences of inhomogeneous broadening of transition energies are discussed.

[1] W. Beenken, V. May, J. Opt. Soc. Am. B. 14, 11, 2804 – 2810 (1997)
[2] M. Richter, T. Renger, G. Renger, A. Knorr, J. Chem. Phys. 127, 075105 (2007)
[3] T. Renger et al., J. Phys. Chem. B, 111, 10487 – 10501 (2007)

HL 5.2 Mon 10:30 H17

Microscopic theory of two-dimensional THz spectroscopy in quantum well systems — •Sebastian Eiser[1], Marten Richter[1], Carsten Weber[1], Thi Uyen-Kahn Dang[1], Wilhelm Kuehn[2], and Andreas Knorr[1] — [1]Institute of Theoretical Physics, TU-Berlin, Germany — [2]Max Born Institute, Berlin, Germany

Pump-probe and n-wave-mixing experiments are important in order to reveal information about microscopic coupling mechanisms and structural/dynamical relationships. Varying the time delay between the incident pulses and recording the real time dynamics makes the technique inherently two-dimensional. It has been demonstrated in the THz regime [1] that with the combination of a collinear beam setup and electro-optical sampling all orders of n-wave-mixing can be observed at the same time. We have developed a theoretical model for a corresponding nonlinear two-dimensional spectroscopy. We numerically solve the equations of motions within a density-matrix approach, focusing on the influence of the electron-phonon interaction [2] on the nonlinear dynamics. Our investigations are performed on GaAs/AlGaAs quantum wells and show good agreement to experimental findings.

[1] W. Kuehn *et al.*, J. Chem. Phys. **130**, 1 (2009)
[2] S. Butscher *et al.*, Phys. Status Solidi B **241**, 11, R49 (2004)

HL 5.3 Mon 10:45 H17

The spatial structure of longitudinal and transversal fields in focussed terahertz beams — •Stephan Winnerl, Ralf Hubrich, Falk Peter, Harald Schneider, and Manfred Helm — Forschungszentrum Dresden-Rossendorf, Postfach 510119, 01314 Dresden, Germany

While for many applications the terahertz (THz) frequency range is the least technologically developed region of the electromagnetic spectrum, which is often referred to as the THz gap, this region offers unique research opportunities. For example, coherent detection of single cycle and few cycle pulses has been developed in the THz range and is now extended to the full infrared range.

Here we apply coherent detection via electro-optic sampling in ZnTe crystals of different orientation to study amplitude and phase of longitudinal and transversal field components in focused terahertz beams. The THz radiation is generated by two types of scalable photoconductive emitters. The electrode pattern is optimized for generation of linearly polarized beams in one case and radially polarized beams in the second case. We show that these beams can be described well as Bessel Gauss beams, which are solutions of the vector Helmholtz equation. Consistent with the theory we observe a larger amplitude and a smaller spot size for the longitudinal component of a radially polarized beam as compared to a similarly focused linearly polarized beam.

HL 5.4 Mon 11:00 H17

high-power soliton-induced supercontinuum generation and tunable sub-10-fs VUV pulses from kagome-lattice HC-PCFs — •song-jin im, anton husakou, and joachim herrmann — Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2a, D-12489 Berlin, Germany

We propose and theoretically study a novel approach for high-power optical supercontinuum generation in argon-filled kagome lattice hollow core-photonic crystal fibers (HC-PCFs). Argon-filled hollow waveguides with a kagome-lattice cladding are especially interesting for high-power spectral broadening because of anomalous dispersions in the visible and ultraviolet, large core diameters, and high ionization threshold of argon. We predict the generation of high-coherence two-octave broad spectra, with spectral peak power densities of MW/nm up to five orders of magnitude higher than in solid-core PCFs, and with high average coherence of 0.9999. The underlying mechanism differs in an important aspect from that in solid-core PCFs where the supercontinuum arises by the emission of several fundamental solitons; in contrast, in the case of a kagome lattice HC-PCF it arises from a single high-order soliton. A second predicted phenomenon is that the output radiation contains a sub-10-fs vacuum-ultraviolet pulse which carries about 20% of input energy corresponding to few tens of μJ. The spectrum of this pulse is a narrow-band VUV peak which can be tuned by pressure from 400 nm to 120 nm. These high-energy VUV pulses can be identified as the non-solitonic radiation from a high-order soliton at the stage of maximum compression.

15 Min. Coffee Break

HL 5.5 Mon 11:30 H17

Time resolved investigation and resonant sub harmonic driving of confined acoustic phonon modes in freestanding silicon membranes — Mike Hettich[1], •Axel Bruchhausen[1], Raphael Gebs[1], Florian Hudert[1], Daniel Issenmann[1], Olivier Schecker[1], Reimar Waitz[1], Artur Erbe[1], Elke Scheer[1], Adnen Mlayah[2], Jean-Roch Huntzinger[3], and Thomas Dekorsy[1] — [1]Department of Physics and Center of Applied Photonics, Universität Konstanz, Germany — [2]CEMES-CNRS, Université de Toulouse, France — [3]GES-UMR 5650, CNRS, Université Montpellier 2, France

The vibrational dynamics of thin silicon membranes have been investigated by asynchronous optical sampling (ASOPS)[1].

The small thickness of the silicon membranes leads to a confinement of the acoustic phonon modes and therefore to a discretization of the phonon frequency spectrum. Odd harmonics of the fundamental mode (19 GHz for a 221nm thick membrane) up to the 25th order have been observed [2].

In order to measure the phonon lifetimes which exceed the measurement window of 1.2ns the repetition rates of the pump and probe laser are tuned to a subharmonic of the fundamental mode. By using this approach the phonon modes are resonantly driven and in analogy to a mechanical resonator the lifetime and the quality factor of the phonon modes can be determined. We observe a Q-factor of 500 which is a significant value for a nanomechanical resonator at room temperatur.

[1] A. Bartels et al., Rev. Sci. Instr. 78, 035107 (2007).
[2] F. Hudert et al., Phys. Rev. B 78, 201307(R) (2009).

HL 5.6 Mon 11:45 H17

Experimental and theoretical investigations of photocurrents in non-centrosymmetric semiconductor quantum wells — •Huynh Thanh Duc[1], Jens Förstner[1], Torsten Meier[1], Shekar Priyadarshi[2], Ana Maria Racu[2], Klaus Pierz[2], Uwe Siegner[2], and Mark Bieler[2] — [1]Department of Physics and CeOPP, University Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

We compute photocurrents generated by femtosecond single-color laser pulses in non-centrosymmetric semiconductor quantum wells by combining a 14x14 k.p band structure theory with multi-band semiconductor Bloch equations [1]. The transient photocurrents are investigated experimentally by measuring the associated Terahertz emission [2]. The dependencies of the photocurrent and the Terahertz emission on the excitation conditions are discussed for (110)-oriented GaAs quan-

tum wells. The comparison between theory and experiment shows a good agreement.

[1] M. Bieler, K. Pierz, U. Siegner, P. Dawson, H. T. Duc, J. Förstner, and T. Meier, Proc. SPIE, 7214, 721404 (2009).

[2] M. Bieler, K. Pierz, and U. Siegner, J. Appl. Phys. 100, 083710 (2006).

HL 5.7 Mon 12:00 H17

Time-resolved photoluminescence from undoped GaAs/$Al_{0.35}Ga_{0.65}As$ quantum wells quenched by pulsed mid-infrared radiation — •Sabine Zybell[1], Harald Schneider[1], Martin Wagner[1], Stephan Winnerl[1], Klaus Köhler[2], and Manfred Helm[1] — [1]Forschungszentrum Dresden-Rossendorf, Dresden, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Freiburg, Germany

There is much interest in the development of ultrafast devices with possible applications in optoelectronics. An important goal consists in ultrafast control of luminescence in light-emitting devices; it is therefore interesting to investigate the effect of abrupt changes in the carrier distribution on the luminescence signal. We present an experimental study of the effects of mid-infrared radiation (MIR) on the photoluminescence (PL) from undoped AlGaAs/GaAs quantum wells. Electron-hole pairs, created by weak near-infrared light pulses, were excited in the system while a delayed MIR pulse induces an ultrafast redistribution of free carriers that results in abrupt quenching of the PL with a subsequent PL recovery. The source of the MIR laser pulses was the free-electron laser facility FELBE at the Forschungszentrum Dresden-Rossendorf. In combination with the synchroscan streak camera, collecting the PL from the electron-hole recombination, it turned out to be a great spectroscopic tool for time-resolved measurements. Using a simple fit function we found PL recovery times between 40 and 150 ps depending on the MIR intensity.

HL 5.8 Mon 12:15 H17

Attosecond dynamics of plasmon formation — •Andrey Moskalenko, Yaroslav Pavlyukh, and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Nanotechnikum-Weinberg, Heinrich-Damerow-St. 4, 06120 Halle, Germany

Using ab-initio methods we calculate the frequencies of collective excitations for a variety of finite systems, such as fullerenes and quasi-spherical large molecules [1]. To unravel how this collective dynamics unfolds upon fast excitations, based on our ab-initio results we developed a method, in the spirit of [2], that captures the ultrafast formation of plasmon modes due to the mean-field fluctuations. The results are illustrated for a pump-probe setup using attosecond XUV pulses.

[1] Y. Pavlyukh and J. Berakdar, Chem. Phys. Lett. 468, 313 (2009).

[2] K. Morawetz, P. Lipavsky, and M. Schreiber, Phys. Rev. B 72, 233203 (2005).

HL 6: Nanophotonics - Devices I (Focused Session together with DS)

Time: Monday 10:15–13:15 Location: H2

Topical Talk HL 6.1 Mon 10:15 H2

Tunable Hollow Waveguides and Their Device Applications — •Fumio Koyama — P&I Laboratory, Tokyo Institute of Technology, 4259-R2-22, Nagatsuta, Midori-ku, Yokohama 226-8503, Japan

We proposed a tunable hollow optical waveguide with a variable air core toward a new class of photonic integrated circuits. We present various unique features in hollow waveguides and the combination with microelectro-mechanical system (MEMS). We describe the design and fabrication of tunable hollow waveguides with a variable air core. We demonstrated low loss and polarization insensitive waveguides. The result shows a possibility of a giant change of over $\sim 10\%$ in propagation constant with a variable air core. We also present a wide variety of device applications based on hollow waveguides, which include tunable Bragg reflectors, tunable lasers, dispersion compensators and so on. In particular, a hybrid-integrated tunable in-plane laser based on HCG-DBR hollow waveguide was demonstrated. A giant tuning range of 52 nm in wavelength has been demonstrated with SMSR of 30 dB. An expected advantage of HWG laser can be its athermal operation resulting from the air-core guiding. A fully monolithic version of the presented device with MEMS tuning can solve alignment issues to offer further large tuning range. Their simplicity and scalability may open up applications in large-scale photonic integration and in realizing other optical functions.

Topical Talk HL 6.2 Mon 10:45 H2

Self-organized quantum dots as single and entangled photon emitters — •Erik Stock[1], Waldemar Unrau[1], Anatol Lochmann[1], Jan Amaru Töfflinger[1], Andrei Schliwa[1], Irina Ostapenko[1], Murat Öztürk[1], Sven Rodt[1], Till Warming[1], Askhat K. Bakarov[2], Aleksandr I. Toropov[2], Ilia A. Derebezov[2], Vladimir Haisler[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU-Berlin, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, 630090 Novosibirsk, Russia

The development of semiconductor based single photon and entangled photon emitters with high efficiency will be a fundamental element for quantum key distribution systems. We have developed InGaAs/GaAs quantum dot (QD) based Resonant-Cavity LEDs (RC-LED). The resonant cavity leads to an increased external quantum efficiency and due to the Purcell effect to an increased spontaneous emission rate allowing us to electrically pump the single QD at 1 GHz repetition rate.

The biexciton-exciton recombination cascade can be used for the generation of entangled photon pairs, if the finestructure splitting (FSS) of the exciton bright states is less than the homogenous line width. Using 8-band k·p theory we predict that symmetric QDs grown on (111) GaAs substrate will demonstrate a vanishing FSS. Mikrophotoluminescence spectroscopy on single QDs grown on (111) GaAs demonstrates a FSS < 10 μeV limited by the spectral resolution of our setup. This work was partly funded by the SFB 787 and the SfP 982735.

Topical Talk HL 6.3 Mon 11:15 H2

Nanostructures for Novel Quantum Cascade Structures — •K. Unterrainer, W. Parz, T. Moldaschl, A. Benz, G. Fasching, A.M. Andrews, and G. Strasser — Photonik Institut und Zentrum für Mikro&Nanostrukturen, Technische Universität Wien, A-1040 Wien

In this contribution we will discuss carrier relaxation in quantum wells and quantum dots and its importance for THz quantum cascade lasers (QCLs). THz QCLs have shown rapid improvements of their emission power and wavelength control. However, the operation temperature is still limited to cryogenic temperatures. All attempts to overcome this limitation involve the control of carrier relaxation. Optical phonon relaxation together with other elastic processes determine the non-radiative recombination. We use time-resolved near-infrared pump and THz probe experiments to study carrier dynamics and find that carrier-carrier scattering causes fast relaxation in quantum wells. The subsequent reduction of the doping concentration in QCLs has led to considerably reduced threshold currents. However, the temperature performance has only increased marginal. A further reduction of scattering is only possible by reducing the phase space. As a first step, we have applied a strong magnetic field causing in-plane quantization. The emission intensity of THz QCLs as function of the applied magnetic field shows an increase of the emission power and a decrease of the threshold. Thus, quantum dots should improve the performance of QCLs significantly. We investigate carrier relaxation between sub-levels and study the design requirements for quantum dot cascade structures.

Topical Talk HL 6.4 Mon 11:45 H2

Quantum dot single-photon sources — •Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, 70569 Stuttgart, Allmandring 3, Germany

Exploiting the quantum properties of the light which is emitted from semiconductor nanostructures has the potential of enabling many new applications in the field of photonics and quantum information technology, such as secure communication, imaging and lithography techniques beyond the diffraction limit, as well as photonic quantum computing. Many of these applications require the generation of triggered single photons or even indistinguishable photons. Single quantum dots

in microcavities open this possibility. In my talk, I will discuss the fascinating physic as well as the current status of such light sources.

Topical Talk HL 6.5 Mon 12:15 H2

The Two Conflicting Narratives of Metal-Optics — •Eli Yablonovitch — University of California, Berkeley, CA 94720, USA

There are two conflicting narratives of Electromagnetics in metals:

1. The microwave circuit narrative in which metals, distributed capacitors, and distributed inductors function together in a high frequency circuit, albeit as distributed components. Here there is a rich tradition of various electromagnetic functions, including the antenna function.

2. This is countered by the optical-plasmonic narrative, in which metallic electromagnetics is thought to be dominated by plasmons, electromagnetic normal modes in which the inertia of the electrons plays a major role.

Given that Electromagnetics is generally invariant with frequency, it is not clear why there need to be two separate narratives. Is metal-optics simply the high frequency version of microwave electromagnetics? There is great benefit in unifying our understanding of the two regimes of metallic electromagnetics, and to distinguish the occasional role of electron inertia.

We find that some of the most important metal-optics functions are best understood as extensions of microwave electromagnetics: Antennas, for example, have been thoroughly under-estimated, and are well-poised to change the rules of optical physics.

Topical Talk HL 6.6 Mon 12:45 H2

Fundamental formulation of nanoplasmonic lasers — •Shun Chuang — University of Illinois, Department of Electrical and Computer Engineering, 1406 West Green Street, Urbana, Illinois, 61801, USA

The smallest laser conventionally requires an optical cavity with a size of one half of the effective wavelength in all three directions, which is often referred as the diffraction limit of the cavity. To make a laser with an active volume smaller than the diffraction limit, an idea is to surround the optical waveguide with metals. In this case, the effective volume of the optical mode can be significantly reduced in spite of a higher intrinsic absorption due to the metal loss at optical frequencies. By placing the active materials such as quantum dots or quantum wells near the region of peak optical field, it is possible to enhance the spontaneous and stimulated emissions to overcome the intrinsic loss from metals.

In this talk, we will present a fundamental formulation for nanoplasmonic lasers, which accounts for the negative permittivity and dispersion of metal plasma in a nanocavity. We point out the importance of using the energy (instead of power) confinement factor. We then discuss the ideas of a Fabry-Perot type of plasmonic waveguide laser and a nano-bowtie optical antenna coupled to semiconductor quantum dots, which function as the gain medium.

HL 7: Graphene 1 (Joint Session with TT)

Time: Monday 10:15–13:00 Location: H18

HL 7.1 Mon 10:15 H18

Orbitally controlled Kondo effect of Co ad-atoms on graphene — •Tim Wehling[1], Alexander Balatsky[2], Mikhail Katsnelson[3], Alexander Lichtenstein[1], and Achim Rosch[4] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA — [3]Institute for Molecules and Materials, Radboud University of Nijmegen, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands — [4]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany

Based on ab-initio calculations we identify possible scenarios for the Kondo effect due to Co ad-atoms on graphene. For a Co atom absorbed on top of a carbon atom, the Kondo effect is quenched by spin-orbit coupling below an energy scale of $\sim$15 K. For Co with spin $S = 1/2$ located in the center of a hexagon, an SU(4) Kondo model describes the entanglement of orbital moment and spin at higher energies, while below $\sim$ 60 meV spin-orbit coupling leads to a more conventional SU(2) Kondo effect. The interplay of the orbital Co physics and the peculiar band-structure of graphene is directly accessible in Fourier transform tunneling spectroscopy or in the gate-voltage dependence of the Kondo temperature displaying a very strong, characteristic particle-hole asymmetry.

HL 7.2 Mon 10:30 H18

Revivals of quantum wave packets in graphene — •Viktor Krückl[1] and Tobias Kramer[1,2] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We investigate the propagation of wave-packets on graphene in a perpendicular magnetic field. The wave-packet evolution in graphene differs drastically from the one in an electron gas and shows a rich revival structure similar to the dynamics of highly excited Rydberg states [1]. We present a detailed analysis of the occurring collapses, revivals and fractional revivals analytically as well as numerically. In order to study the impact of disorder on the effect we apply our novel numerical scheme to solve the wave-packet propagation on the effective single-particle Dirac-Hamiltonian of graphene in the presence of random impurity potentials.

[1] Viktor Krueckl and Tobias Kramer, New J. Phys. **11** 093010 (2009)

HL 7.3 Mon 10:45 H18

Externally induced spin relaxation in graphene — •Jan Bundesmann[1], Michael Wimmer[1,2], and Klaus Richter[1] — [1]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Instituut-Lorentz, Universiteit Leiden, 2300 RA Leiden, The Netherlands

In the fast growing research field of spintronics graphene seems to be a promising candidate. From theory weak spin-orbit interaction is expected in pure carbon-based materials. However, experimental results and theoretical predictions differ by several orders of magnitude: spin lifetimes in the experiment are much smaller than, e. g., the ones obtained from recent DFT calculations [1].

In our calculations we will include also externally induced spin-orbit interactions. Sources for this might be impurities in the substrate or adsorbed atoms. For this investigation we set up a tight-binding model for graphene including intrinsic and Rashba-type spin-orbit interactions. By local variation of the Rashba parameter we model systems with the above introduced sources of spin-orbit interaction and study spin-orbit effects on quantum transport.

[1] M. Gmitra, S. Konschuh, C. Ertler, C. Ambrosch-Draxl and J. Fabian; arxiv:0904.3315

HL 7.4 Mon 11:00 H18

Coulomb interaction in graphene: Relaxation rates and transport — •Michael Schütt[1], Pavel Ostrovsky[2], Igor Gornyi[2], and Alexander Mirlin[1,2] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

We study electron transport in graphene with Coulomb interaction at finite temperatures by using Keldysh diagrammatics. In the case of clean graphene we obtain the total scattering rate, the transport scattering rate, and the energy relaxation rate at the Dirac point. Since the total scattering rate diverges graphene exhibits a non-Fermi-liquid behavior similar to disordered metals. Unlike metals clean graphene has a finite conductivity due to the Coulomb interaction. For conductivity we obtain the same analytic behavior as was found using the Boltzmann approach [1,2]. We analyze the plasmon spectrum of graphene and formulate quantum kinetic equations to describe transport in the crossover between the Coulomb interaction dominated regime and the disorder dominated regime.

[1] L. Fritz et al., Phys. Rev. B 78:085416 (2008).
[2] A. Kashuba, Phys. Rev. B 78:085415 (2008).

HL 7.5 Mon 11:15 H18

Is it possible to detect edge states in graphene quantum dots? — •Michael Wimmer[1], Anton R. Akhmerov[1], and Francisco Guinea[2] — [1]Instituut-Lorentz, Universiteit Leiden, The Netherlands

— [2]Instituto de Ciencia de Materiales de Madrid, Spain

We analyze the single particle states at the edges of graphene quantum dots of arbitrary shapes. By combining analytical and numerical arguments, we show that localized edge states, distinct from extended ones, exist in dots of all dimensions. The number of these states is proportional to the circumference of the dot measured in lattice constants. Perturbations breaking electron-hole symmetry shift the edge states away from zero energy but do not change their total amount.

15 min. break

HL 7.6 Mon 11:45 H18

Graphene: Relativistic transport in a nearly perfect quantum liquid — •Lars Fritz[1], Markus Mueller[2], Joerg Schmalian[3], and Subir Sachdev[4] — [1]Universitaet zu Koeln, Institut fuer theoretische Physik, Zuelpicher Strasse 77, 50937 Koeln — [2]The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, 34151 Trieste, Italy — [3]Department of Physics and Astronomy Iowa State University Ames, Iowa 50011, USA — [4]Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA

Electrons and holes in clean, charge-neutral graphene behave like a strongly coupled relativistic liquid. The thermo-electric transport properties of the interacting Dirac quasiparticles are rather special, being constrained by an emergent Lorentz covariance at hydrodynamic frequency scales. At small carrier density and high temperatures, graphene exhibits signatures of a quantum critical system with an inelastic scattering rate set only by temperature, a conductivity with a nearly universal value, solely due to electron-hole friction, and a very low viscosity. In this regime one finds pronounced deviations from standard Fermi liquid behavior. These results, obtained by Boltzmann transport theory at weak electron-electron coupling, are fully consistent with the predictions of relativistic hydrodynamics.

HL 7.7 Mon 12:00 H18

Hyperfine interaction and electron-spin decoherence in graphene and carbon nanotube quantum dots — •Jan Fischer[1], Bjoern Trauzettel[2], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Institute of Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We analytically calculate the nuclear-spin interactions of a single electron confined to a carbon nanotube or graphene quantum dot [1]. While the conduction-band states in graphene are p-type, the accordant states in a carbon nanotube are sp-hybridized due to curvature. This leads to an interesting interplay between isotropic and anisotropic hyperfine interactions. By using only analytical methods, we are able to show how the interaction strength depends on important physical parameters, such as curvature and isotope abundances. We show that for the investigated carbon structures, the ^{13}C hyperfine coupling strength is less than 1 μeV, and that the associated electron-spin decoherence time can be expected to be several tens of microseconds or longer, depending on the abundance of spin-carrying ^{13}C nuclei. Furthermore, we find that the hyperfine-induced Knight shift is highly anisotropic, both in graphene and in nanotubes of arbitrary chirality.

[1] J. Fischer, B. Trauzettel, D. Loss, Phys. Rev. B 80, 155401 (2009)

HL 7.8 Mon 12:15 H18

Spin transport in graphene with inhomogeneous spin-orbit coupling — •Dario Bercioux[1] and Alessandro De Martino[2] — [1]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany

Recent theoretical [1] and experimental [2] works have shown that spin-orbit couplings in graphene can play a relevant role. Motivated by these results, we address the problem of spin transport in graphene through spin-orbit nanostructures, *i.e.* regions of inhomogeneous spin-orbit coupling on the nanometer scale. In analogy with the case of usual two-dimensional electron gases, we discuss the phenomenon of spin-double refraction [3,4] and its consequences on the spin polarization. In particular we study the transmission properties of a single- and a double-interface between a normal region and a region with finite spin-orbit coupling, and analyze the polarization properties of these systems. In addition, for the case of the single interface, we consider the formation of bound states localized at the interface, analogous to the states occuring at the edges of graphene in the weak topological insulator regime discussed by Kane and Mele [5].

[1] D. Huertas-Hernando, *et al.*, Phys. Rev. Lett. **103**, 146801 (2009).
[2] A. Varykhalov, *et al.*, Phys. Rev. Lett. **101**, 157601 (2008).
[3] V. M. Ramaglia, *et al.*, Eur. Phys. J. B **36**, 365 (2003).
[4] V. M. Ramaglia, *et al.*, J. Phys.: Condens. Matter **16**, 9143 (2004).
[5] C. L. Kane and E. J. Mele, Phys. Rev. Lett. **95**, 226801 (2005).

HL 7.9 Mon 12:30 H18

Edge effects in quantum transport and quasiparticle spectra of graphene nanostructures — •Jürgen Wurm[1,2], Klaus Richter[1], and Inanç Adagideli[2] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Faculty of Engineering and Natural Sciences, Sabancı University, Orhanlı - Tuzla, 34956, Turkey

In this work, we focus on the spectral and transport properties of graphene nanostructures. In recent work, we studied the effects of edges on the transport and spectral properties of graphene quantum dots, as well as on the conductance of graphene nanoribbons numerically [1,2]. Some edges can lead to effective time reversal symmetry breaking, others are effective intervalley scatterers. In this work, we develop a theory that is capable of handling such effects in graphene nanostructures. We do this in two steps. First, we derive an exact expression for the Green function of a graphene flake, where each term in this expansion corresponds to the specific number of times the quasiparticle hits the edge. Second, we use the Green function to calculate: (i) the spectra for closed systems and (ii) the conductance of open systems. In particular, we focus on phase coherent effects, such as the weak localization correction to the average conductance, and the universal conductance fluctuations. Moreover, we show how the size of these effects depends on the edges.

[1] J. Wurm et al., Phys. Rev. Lett. **102**, 056806 (2009)
[2] J. Wurm et al., New J. Phys. **11**, 095022 (2009)

HL 7.10 Mon 12:45 H18

Charge transport in disordered superconductor-graphene junctions — •Georgo Metalidis[1], Dmitry Golubev[2], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, D-76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruher Institut für Technologie, D-76021 Karlsruhe, Germany

We consider the charge transport through superconductor-graphene tunnel junctions, including the effect of disorder. Coherent scattering on elastic impurities in the graphene layer can give rise to multiple reflections at the graphene-superconductor interface, and can thereby increase the probability of Andreev reflection, leading to an enhancement of the subgap conductance above its classical value. Although the phenomenon is known already from heterostructures involving normal metals, we have studied how graphenes peculiar dispersion relation influences the effect.

HL 8: Organic Electronics and Photovoltaics I (Joint Session with DS/CPP/O)

Time: Monday 10:15–12:30 Location: H8

HL 8.1 Mon 10:15 H8

Colour tuneable light-emitting transistor — •Eva J. Feldmeier, Christian Melzer, and Heinz von Seggern — Electronic Materials Department, Institute of Materials Science Technische Universität Darmstadt, Petersenstraße 23, 64287 Darmstadt, Germany

In recent years the interest in ambipolar organic light-emitting field-effect transistors has increased steadily as the devices combine switching behaviour of transistors with light emission. Usually, small molecules and polymers with a band gap in the visible spectral range serve as semiconducting materials. Mandatory remain balanced injection and transport properties for both charge carrier types to provide full control of the spatial position of the recombination zone of electrons

and holes in the transistor channel via the applied voltages. As will be presented here, the spatial control of the recombination zone opens new possibilities towards light-emitting devices with colour tuneable emission.

In our contribution an organic light-emitting field-effect transistors is presented whose emission colour can be changed by the applied voltages. The organic top-contact field-effect transistor is based on a parallel layer stack of acenes serving as organic transport and emission layers. The transistor displays ambipolar characteristics with a narrow recombination zone within the transistor channel. During operation the recombination zone can be moved by a proper change in the drain and gate bias from one organic semiconductor layer to another one inducing a change in the emission colour. In the presented example the emission maxima can be switched from 530 nm to 580 nm.

HL 8.2 Mon 10:30 H8

Improved transport properties of p-i-i small molecule solar cells deposited on heated substrates — •Steffen Pfuetzner, Karl Leo, and Moritz Riede — Institut für Angewandte Photophysik, Technische Universität Dresden

To achieve higher efficiencies in organic solar cells, ideally the open circuit voltage (V_{OC}), fill factor (FF) as well as the short current density (j_{SC}) have to be improved further. However, in bulk heterojunction (BHJ) solar cells jsc and the FF are typically limited by charge carrier recombination due to transport problems (e.g. low mobility, dead ends) in the BHJ. A suitable way to modify the BHJ layer morphology and to improve solar cell parameters is substrate heating during bulk layer deposition. Furthermore, j_{SC} can be enhanced by replacing C_{60} by C_{70}. We show that substrate heating at 90°C leads to improved FF and j_{SC} for a C_{60} and ZnPc containing BHJ solar cell with the following stack structure: ITO/p-Di-NPD/C_{60}:ZnPc/C_{60}/BPhen/Al. However, in case of similar C_{70}:ZnPc solar cells, no significant improvements are observed. Using SEM we show that the preferential aggregation by heating is completely suppressed by the p-doped underlayer Di-NPD. To force aggregation of the heated C_{70}:ZnPc bulk, 5 nm intrinsic ZnPc layer is deposited on the p-Di-NPD layer and verified by SEM. J-V characteristics show a drop in FF and Voc with the additional interlayer ZnPc. To overcome this problem probably caused by transport barriers to the neighboring layers, experiments with doped ZnPc are carried out.

HL 8.3 Mon 10:45 H8

Analysis of Chemical Degradation Mechanism of Phosphorescent Organic Light Emitting Devices by Laser-Desorption/Ionization Time-of-Flight Mass Spectrometry — •Ines Rabelo de Moraes, Sebastian Scholz, Björn Lüssem, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Str. 1, 01062 Dresden, Germany

Phosphorescent Organic Light Emitting diodes (OLEDs) have attracted much interest for their potential application in full color flat-panel displays and as an alternative lighting source. However, low efficiency, and the short operation lifetime, in particular in the case of blue emitting devices, are the major limitations for the current OLEDs commercialization. In order to overcome these limitations, a deep knowledge about the aging and the degradation mechanism is required [1]. Our work focuses on the chemical degradation mechanism of different iridium based emitter materials like FIrpic (light blue) and Ir(ppy)3 (green), commonly used in OLEDs. For this purpose, the devices were aged by electrical driving until the luminance reached 6% of the initial luminance. The laser-desorption/ionization time-of-flight mass spectrometry was used to determine specific degradation pathways.

[1] Hany Aziz, and Zoran D. Popovic, Chem. Mater. 16, 4522 (2004).

HL 8.4 Mon 11:00 H8

Spatially resolved, polarization dependent absorption and photocurrent measurements of pentacene based OFETs — •Christian Westermeier, Matthias Fiebig, and Bert Nickel — Department für Physik and CeNS, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München

Pentacene is a promising candidate for organic electronics and optoelectronic applications due to its high charge carrier mobility and strong absorption properties. Forming a triclinic herringbone structure, its optical properties are highly anisotropic [1]. Pentacene films show a thin-film-phase texture. The grains inducing the texture should absorb linear polarised light depending on their orientation with respect to the direction of polarisation.

Here we use local illumination of the transistor channel in a confocal laser scanning setup with a spatial resolution in the submicron regime [2]. The pentacene grains in the channel of our OFETs exhibit a size of a few microns in diameter. The absorption of separate grains is found to be strongly dependent on the polarisation of the incident light, as expected. Thus, the scanning technique allows for imaging of grain orientation with a submicron resolution over large areas.

Absorption being the initialising step to generate excitons is important for optoelectronic devices like solar cells and the photoresponse of transistors. The influence of polarisation on the spatially resolved photocurrent of pentacene OFETs will be discussed.

[1] M. Dressel, et al., Opt. Express 16, 19770-19778 (2008)
[2] M. Fiebig, et al., Appl. Phys. A 95, 1, 113-117 (2009)

HL 8.5 Mon 11:15 H8

In-situ Analysis of Charge Carrier Mobility in Field Effect Transistors During Organic Semiconductor Deposition — •Christopher Keil, Dominik Klaus, Jan Hartel, and Derck Schlettwein — Institute of Applied Physics, Justus-Liebig-University Giessen, Germany. email:schlettwein@uni-giessen.de

Films of $F_{16}PcCu$ prepared by physical vapour deposition under high vacuum conditions were characterized in situ during the growth from the monolayer range up to about 100 nm. The charge carrier mobility in the linear and saturation region as well as the threshold voltage were investigated in real time at deliberate film thickness by help of a real time analysis software routine. The organic films were deposited on thermally grown silicon oxide which also acts as gate dielectric. The underlying Si wafer served as a bottom gate electrode and structured inter-digital metal source- drain contacts were prepared by photolithography. Different channel lengths and widths as well as different metal contacts were used to determine the influence of semiconductor/metal contacts on the characteristics of the field effect transistors.

HL 8.6 Mon 11:30 H8

Investigation of contact properties of organic field effect transistors — •M. Grobosch[1], I. Hörselmann[2], S. Scheinert[2], M. Knupfer[1], and G. Paasch[1] — [1]IFW Dresden, D-01069 Dresden, Germany — [2]Technical University Ilmenau, D-98684 Ilmenau, Germany

Source/drain contacts in OFETs based on a solution prepared modified P3HT were characterized by combined X-ray and ultra violet photoemission spectroscopy (XPS, UPS) and electrical measurements of the OFET whereas the sample preparation for the different measuring principles has been realized in parallel differing in the layer thickness of the polymer. By means of UPS a reduced work function could be demonstrated for different prepared, sputtered, and as-received Au contacts in agreement with previous publications. Furthermore the chemistry and the electronic structure of the interfaces between Au metal deposited onto thin films of solution prepared modified P3HT on sputtered Au contacts have been studied. From the observed well defined molecular orbitals we have found an interface dipole of +1.5 eV and a hole injection barrier of about 0.6 eV. However, one cannot expect such a high barrier from the measured characteristics of the OFET because the currents are not contact limited. Clarifying the reason for such a discrepancy we have carried out two-dimensional simulations. These results confirm clearly for a barrier of 0.6 eV strongly reduced drain currents would be measured. The difference in the layer thickness can be the reason for the measured difference but further investigations are necessary to explain more in detail this phenomenon.

HL 8.7 Mon 11:45 H8

Improving the mobility of the CuPc OFETs by variing the substrate preparation — •Iulia G. Korodi[1], Daniel Lehmann[1], Michael Hietschold[2], and Dietrich R. T. Zahn[1] — [1]Semiconductor Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Solid Surfaces Analysis Group, Chemnitz University of Technology, D-09107 Chemnitz, Germany

Top-contact organic field-effect transistors (OFETs) using Copper Phthalocyanine (CuPc) as active layer were produced under high vacuum conditions ($p \leq 5 \times 10^{-7}$ mbar). 20 nm thick organic films were deposited by Organic Molecular Beam Deposition on highly p-doped Si(100) substrates with 100 nm SiO_2 as the gate dielectric. Source and drain electrodes of gold were deposited through a shadow mask on top of the organic layer with the substrate cooled by liquid nitrogen.
The performance of the OFETs was tested in vacuum as well as in

atmosphere. The highest mobility of CuPc OFETs was found to be $\mu_{vacuum} = (1.5 \pm 0.6)\,10^{-3}\,\mathrm{cm}^2/\mathrm{Vs}$. When the substrate was modified by applying an elevated temperature (130 °C) during deposition of the CuPc film the mobility of the OFETs increased by a factor of ≈ 6. The threshold voltage was also improved from a value of $V_{Th} = -(15.0 \pm 0.3)\,\mathrm{V}$ to $V_{Th} = -(9.6 \pm 1.4)\,\mathrm{V}$ for deposition at room and elevated substrate temperatures, respectively. A similar effect on the electrical characteristics was found after modifying the gate dielectric with a self-assembled monolayer of n-octadecyltrichlorosilane. The improved OFET performance with the variation of the substrate conditions will be discussed.

HL 8.8 Mon 12:00 H8

Electrical characterization of operating OFETs using Kelvin Probe Force Microscopy — •Franziska Lüttich, Harald Graaf, Iulia G. Korodi, Daniel Lehmann, Dietrich R. T. Zahn, and Christian von Borczyskowski — Center for nanostructured Materials and Analytics, Chemnitz University of Technology, Germany

We present recent results on n-type organic field effect transistors (OFETs) using Atomic Force Microscopy (AFM) and Kelvin Probe Force Microscopy (KPFM). These studies allow the local potential in the channel of OFETs during operation to be determined. The transistor structures investigated differ in gate insulator treatment and substrate temperature during evaporation of the organic material.
All investigated top-contact OFETs were fabricated under high-vacuum conditions ($p < 4 \cdot 10^{-7}$ mbar) by evaporating PDI8-CN_2 on top of a p-doped silicon substrate covered by a SiO_2 layer. Gold-electrodes were evaporated through a shadow mask on top of the organic layer. The gate insulator modification was implemented prior to the substrate transfer into the vacuum chamber. For this purpose monolayers of N-octadecyltrichlorosilane (OTS) resulting in hydrophobic surfaces were employed. In the case of deposition at elevated temperature the substrate was kept at 130°C.
These variations of preparation influence the structural and electronic properties of the OFET and result in changes of the charge carrier mobility. The effects observed indicate tuning possibilities for organic devices leading to increased charge carrier mobility.

HL 8.9 Mon 12:15 H8

Experimental study and time dependent modeling of OFETs with solid electrolyte gate dielectrics — •Katharina Schätzler[1], Klaus Schmidt[1], Walter Fix[1], Gottfried Döhler[1], and Heiko Weber[2] — [1]PolyIC GmbH & Co. KG, Fürth — [2]Lehrstuhl für Angewandte Physik, Friedrich-Alexander-Universität, Erlangen

We successfully investigated and simulated organic field effect transistors (OFETs) with a solid organic insulator containing ionic salt. It is already well known that electrolytes as gate dielectrics in OFETs offer low operating voltages by means of a high capacitance. Hence, the charge carrier density is increased in the channel region of the semiconductor. However, the drain-source current I_{ds} shows a strong time dependency because of the limited mobility of the ions. Consequently we developed a time dependent model for the spatial distribution of the ionic current within the insulator matrix. The ionic current of both cations and anions splits in a diffusion and a drift process. The model very precisely reproduces the time as well as the ion concentration dependency of I_{ds}. Parameters like ion and semiconductor mobility are extracted and are in good agreement with parameters extracted from experimental OFET and capacitance characteristics.

HL 9: SiC

Time: Monday 11:30–12:45 Location: H13

HL 9.1 Mon 11:30 H13

Temperature dependence of damage formation in Ag ion irradiated 4H-SiC — •Thomas Bierschenk[1], Elke Wendler[1], Werner Wesch[1], Johan Malherbe[2], and Erich Friedland[2] — [1]Institute of Solid State Physics, Friedrich Schiller University of Jena, Jena, Germany — [2]Department of Physics, University of Pretoria, Pretoria, South Africa

Rutherford backscattering spectrometry in channelling mode was used to study the defect formation in Ag ion irradiated SiC. The 4H-SiC samples were irradiated with 360 keV Ag^+ ions at different temperatures between 15 and 800 K over a wide range of fluences ($10^{11} \ldots 2 \times 10^{16}$ cm^{-2}). The results can be divided into two groups:
(i) For temperatures between 15 and 475 K the amorphisation of the implanted layer was reached. The over-all cross section of defect production at very low fluences, which comprises the formation of point defects and amorphous clusters, is almost identical in this temperature range. Differences in damage evolution occur for higher fluences and suggest that the relative contribution of amorphous clusters within a single ion impact decreases with rising temperature.
(ii) For implantation temperatures between 625 and 800 K no amorphisation was found even for the highest applied fluence. Due to the balance of production and recombination of point defects the defect concentration exhibits a distinctive plateau for medium ion fluences before increasing to saturation well below amorphisation. At this final stage our results indicate a mixture of point defect clusters and extended defects.

HL 9.2 Mon 11:45 H13

Analysis of the Temperature-Dependence of the Leakage Current of 3C-SiC p^+-n Diodes Caused by Extended Defects — •Bernd Zippelius[1], Michael Krieger[1], Heiko B. Weber[1], Gerhard Pensl[1], Takamitsu Kawahara[2], and Hiroyuki Nagasawa[2] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7/A3, D-91058 Erlangen, Germany — [2]SiC Development Center, Hoya Corporation, 1-17-16 Tanashioda, Sagamihara, Kanagawa 229-1125, Japan

A large leakage current (I_R) is observed at reverse bias (V_R) in 3C-SiC p^+-n diodes. This leakage current is caused by a high density of stacking faults (SFs). We used an n-type 3C-SiC epilayer (thickness = 13 μm, [N] = 7×10^{15} cm^{-3}) and implanted Al ions to form the p-emitter (ϕ = 100 μm), which is surrounded by 6 guard rings (depth = 1 μm, [Al] = 1×10^{18} cm^{-3}). Al contacts are deposited on the emitter. The temperature dependence of I_R is studied in the temperature range from 100 K to 295 K. The extended defects under the contacts were investigated by Electron Beam Induced Current (EBIC) and Photo Emission Microscopy (PEM). It turns out that I_R is thermally activated for reverse voltages $V_R < |170|$ V. We propose that within this voltage range I_R originates from thermally assisted tunneling of electrons and holes from band-like states of the SFs into the conduction and valence band, respectively. For $V_R > |170|$ V, the thermal barrier is strongly reduced and direct tunneling dominates. These dependences are simulated in the framework of a simplified model which qualitatively describes the temperature behaviour of the experimental data.

HL 9.3 Mon 12:00 H13

Electrical activation of B^+-ions implanted into 4H-SiC — •Thanos Tsirimpis, Michael Krieger, Gerhard Pensl, and Heiko Weber — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstrasse 7/A3, D-91058, Erlangen, Germany

Boron (B) acceptors reside on Si lattice sites in SiC and have an activation energy of ΔE(B)= 300 meV. In comparison to the heavier Al acceptors, implanted B^+-ions cause less damage in SiC, however, care has to be taken during the required subsequent annealing step, because B atoms are a strong diffusing species in SiC. In order to suppress the transient-enhanced B diffusion, two possible solutions have been reported in the literature. (a) The leading and trailing edge of the implanted B profile is encircled by implanted Gaussian carbon profiles. (b) A two-step annealing process at 900°C and at an additional elevated temperature T_A is conducted. In this paper, both techniques are evaluated by means of resistivity and Hall-effect measurements, and the electrical activation of Boron is discussed.

HL 9.4 Mon 12:15 H13

Apparently large ideality factors of MASS-diodes on the basis of the t-BN/SiC system — •Marc Brötzmann, Ulrich Vetter, and Hans Hofsäss — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

A common feature of many heterojunction diodes is an anomalously

large ideality factor above n=2 which has been observed in performed electrical characterizations. As the origin of such high ideality factors is not yet understood, we developed a quantitative model for the unusual diode characteristics on the basis of Metal - Amorphous Semiconductor - Semiconductor diodes (MASS-diodes) [1,2]. In this work, we investigate electrical properties of such diodes on the basis of heterostructure consisting of a crystalline semiconductor material, i.e. 6H-SiC, covered with a thin semiconducting film of amorphous or disordered material such as turbostratic boron-nitride (t-BN). These heterojunctions exhibit a pronounced rectifying behavior, low saturation current and low parasitic currents. Moreover, we observe an apparently giant ideality factor reaching values of $n > 25$. We demonstrate that the I-V characteristics of these MASS-heterojunctions are well described by a serial arrangement of an ideal Schottky-diode, a Frenkel-Poole type resistance and an Ohmic contact resistance, emulating a p-n- or Schottky diode characteristic with giant ideality factor.

[1] M. Brötzmann *et al.*, JAP 106, 063704 (2009)
[2] M. Brötzmann *et al.*, Proc. ICFSI 12 in PSS C, accepted (2009)

HL 9.5 Mon 12:30 H13

Electrical and Chemical Passivation of SiC Surfaces by Halogen Termination — •Sebastian Schoell, Marco Hoeb, Marianne Auernhammer, John Howgate, Martin S. Brandt, Martin Stutzmann, and Ian D. Sharp — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

Despite the technological maturity of SiC, few methods of chemical and electronic passivation of its surfaces are available. Treatment of SiC with HF yields OH-terminated surfaces with high defect densities. Here, we demonstrate plasma processing methods which yield F- and Cl-terminated (0001) 6H-SiC surfaces. X-ray photoelectron spectroscopy (XPS) reveals a significant reduction of oxygen, and corresponding increase of F- or Cl-core level intensities, following halogen termination. XPS core level shifts are consistent with surface photovoltage (SPV) measurements which show approximately flat band surface potentials (< 50 meV). Temperature programmed desorption (TPD) was performed and exhibited sharp peaks above 600 °C, indicating covalent surface termination rather than sub-surface incorporation of F and Cl. Measurements of both XPS and SPV as a function of ambient exposure time reveal slow oxidation with the magnitude of surface band bending increasing with time constants of approximately 40 hrs. Thus, halogen termination of SiC provides a practical method for both electronic and chemical passivation which has the potential to improve existing technological processes. Furthermore, this work offers the possibility for formation of self-assembled organic monolayers based on fluorine and chlorine chemistry.

HL 10: Devices II

Time: Monday 14:00–15:45 Location: H13

HL 10.1 Mon 14:00 H13

Ballistic rectification in an asymmetric Si/SiGe cross junction with modulated electron density — •Daniel Salloch[1], Ulrich Wieser[1], Ulrich Kunze[1], and Thomas Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerCrysler Forschungszentrum Ulm, D-89081 Ulm

We demonstrate a substantial efficiency increase in an injection-type ballistic rectifier due to a modulated electron density in its active region. The rectifier is a nanoscale four-terminal Ψ-shaped cross junction [1] fabricated from a high-mobility Si/SiGe heterostructure. Two nanoscale Schottky gates are locally deposited on top of the central stem above and below the cross junction. In addition to the inertial-ballistic rectified voltage, which will develope between the upper and lower end of the central stem if a current is injected between the branches [1], a hot-electron thermopower voltage [2] establishes across the saddle-point potential formed below the local gate for negative gate-voltages [3]. At $T = 4.2$ K we observe an increase of the rectified signal due to the superposed hot-electron thermopower for negative gate voltages. Depending on the position of the constriction in the stem, a sign reversal of the output signal is also demonstrated. Both signals are experimentally separated in a modified device geometry.

[1] M. Knop *et al.*, Appl. Phys. Lett. **88**, 082110 (2006)
[2] L. W. Molenkamp *et al.*, Phys. Rev. Lett. **65**, 1052 (1990)
[3] D. Salloch *et al.*, Appl. Phys. Lett. **94**, 203503 (2009)

HL 10.2 Mon 14:15 H13

Dot-Field Effect Transistor: Using locally strained silicon for MOSFET applications — •Jürgen Moers[1], Julian Gerharz[1], Gregor Mussler[1], Cleber Biasotto[2], Vladimir Jovanovic[2], Lis Nanver[2], and Detlev Grützmacher[1] — [1]Institute for Bio and Nanosystems, Research Centre Jülich, D-52425 Jülich, Germany — [2]DIMES, TU Delft, Mekelweg 4, 2628 CD Delft, The Netherlands

Typical dimensions of electronic devices have been scaled into the sub-50nm range. The use of trained silicon for carrier mobility enhancement is a route to meet the challenges occurring at those dimensions. By means of templated self assembly of SiGe-dots on prepatterned substrates and epitaxial overgrowth a silicon layer is created, which is strained on top of the SiGe-dots and their near vicinity. Integrating the MOSFET on the dot will use the strain to improve the device performance.

During processing special emphasis has to be laid on the overlay accuracy and low thermal budget processing to prevent intermixing of the strained silicon layer with the SiGe-dot. While the gate dielectric was deposited by CVD the activation of dopants was done by laser annealing.

DotFET devices with gate lengths between 50 and 200 nm and gate widths between 100 and 300 nm were fabricated with 15 nm SiON as gate dielectric. First measurements show an improved current drivability in respect to reference devices processed on the same wafer, indicating the suitability of this device concept. Further improvements can be reached by removing the SiGe-dot from beneath the gate.

HL 10.3 Mon 14:30 H13

Ammonium hydroxide (NH_4OH) as etch-stop chemical for highly boron-doped silicon δ-layers — •Oliver Hammer, Florian Palitschka, Helmut Lochner, Tina Kubot, Dorota Kulaga-Egger, Daniel Beckmeier, Carolin Axt, Josef Biba, Ronny Schindler, Marc Dressler, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The downscaling process in current microelectronics results in smaller devices and thinner layers. A proper etch-stop for such thin layers, e.g. boron-doped δ-layer (<10nm) in a vertical device, becomes more and more challenging. Therefore an etchant with an exceedingly high selectivity to boron-doped silicon is needed. Only two wet-chemical silicon etchants, TMAH and the not common NH_4OH, are capable for CMOS technology and are not too highly toxic. The major advantage of NH_4OH in comparison to TMAH is its high selectivity of 1:8000 for intrinsic silicon with respect to boron-doped silicon. The disadvantages are formation of hillocks and more pronounced surface roughness compared to TMAH. We optimize etching parameters by variation of the etch temperature, the concentration of NH_4OH in water and the ratio of 2-propanol in the solution to achieve an etch-stop at a δ-layer without breaking it. Recent experiments show that a solution of TMAH and 2-propanol decreases the surface roughness and the formation of hillocks. Due to this we also perform tests with 2-propanol in a NH_4OH solution. Finally we etch a bulk unipolar device (BUD) to determine the electrical characteristics of the exposed δ-layer.

HL 10.4 Mon 14:45 H13

Interface Defect Study by GIDL Current and Charge Pumping Measurements on MOSFET Devices — •Guntrade Roll[1], Stefan Jakschik[1], Andre Wachowiak[2], Matthias Goldbach[2], and Lothar Frey[3] — [1]Namlab gGmbh, D-01187 Dresden — [2]Qimonda, D- 01099 Dresden — [3]Fraunhofer IISB, D-91058 Erlangen

The continued improvement in CMOS technology requires the scaling of transistor dimensions while maintaining acceptable leakage currents. One key to performance enhancement is a good process control of the gate oxide to silicon interface properties, such as a low defect density and reduced oxide regrowth. The Gate Induced Drain leakage (GIDL) enhances power consumption when the gate is turned off. The GIDL current increases as the interface oxide thickness is reduced, due to

electric field increase. Another factor which varies the GIDL leakage is the interface trap density at the gate edge.

We report the investigation of two types of samples. First the dependence of the interface traps on the carbon content in the ultra shallow Source/Drain junction of PFETs is evaluated using a lateral profiling Charge Pumping technique. The electrical measurements reveal an increase of GIDL current by carbon co-implantation.

In the second set of samples the spacer material and the gate etch parameters of devices with high-k dielectric are varied. This reduces the interface oxide regrowth and decreases the GIDL current. We present a correlation between GIDL current and Charge Pumping measurements and compare both the influence of the electric field and the interface trap density on the leakage.

HL 10.5 Mon 15:00 H13

Application of a parameter extraction method for MOSFETs — •Josef Biba, Dorota Kułaga-Egger, Torsten Sulima, and Walter Hansch — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

For statistical process control in industrial production of semiconductors it is important to obtain MOSFET parameters, which are not directly accessible. An effective but merely known method to determine the effective channel length and the channel resistance is the one of Kazuo Terada and Hiroki Muta. Here the output characteristics of transistors with same channel width but various channel lengths are used. This approach showed good results in simulations and with processed self-aligned poly-silicon-gate MOSFETs.

We present an investigation of the application of this method on metal-gate transistors, where the gate stack is aligned by lithography. This results in an asymmetric underdiffusion of the gate. For the investigation n-channel MOSFETs were produced using Spin-On-Dopant (SOD) technology for Source/Drain doping. The effective channel length and the channel resistance were determined using Terada Muta and compared to SIMS and contact resistant measurements.

HL 10.6 Mon 15:15 H13

Electrical characterization of doped semiconductor nanostructures with Scanning Microwave Microscopy — •Matthias A. Fenner[1], Hassan Tanbakuchi[1], Stephan Streit[2], Christine Baumgart[2], Manfred Helm[2], and Heidemarie Schmidt[2] — [1]Agilent Technologies, Campus Kronberg, 61476 Kronberg, Germany — [2]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf e.V., P.O. Box 510119, 01314 Dresden, Germany

Highly sensitive scanning microwave microscopy (SMM) with a capacitance resolution in the aF range [1] has been used to investigate the electrical properties of doped semiconductor nanostructures in the microwave frequency range from 1.5 GHz to 6 GHz at different dc offset biases. The microwave signal S11 reflected by the sample is related to the impedance of the sample. Superimposing an ac voltage in the kHz range one also gains information about the derivative of the S11 signal (dC/dV), which is dependent on the doping density in the semiconductor, circuit resistance, and reactance. We investigated a static random access memory (SRAM) cell and one cross-sectionally prepared Si epilayer structured sample [2]. The derivative of S11 strongly depends on the dc offset bias. The Si epilayer sample reveals the strongest dependence on f_{ac} and also on the biasing history during the SMM measurements.

[1] F. Michael Serry, Agilent Application Note 5989-8818EN, http://cp.literature.agilent.com/litweb/pdf/5989-8818EN.pdf, 2008.

[2] C. Baumgart, M. Helm, H. Schmidt, Phys. Rev. B 80, 085305 (2009).

HL 10.7 Mon 15:30 H13

VLS-grown Vertical Silicon Nanowire FETs — •Hesham Ghoneim, Mikael Bjoerk, Heinz Schmid, Kirsten Moselund, Siegfried Karg, Walter Riess, and Heike Riel — IBM Research GmbH, IBM Research Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland

Owing to their potential compatibility with existing CMOS technology, silicon (Si) nanowires (NWs) are considered to be one of the most promising candidates for future logic and memory elements. A major advantage is the significantly improved gate control using a Gate-All-Around (GAA) structure offered by the NW geometry allowing further downscaling beyond the 22nm node.[1] We report on the fabrication and characterization of vertical Field Effect Transistors (FETs) and vertical impact-ionization FETs based on Vapor-Liquid-Solid (VLS) grown Si NWs. Taking advantage of the vertical epitaxial VLS growth of Si NWs we fabricate GAA devices in a vertical geometry. For source and drain doping we investigated several approaches: in-situ doping during VLS-growth, ion implantation and solid source diffusion doping for both n- and p-type doping. With these methods n-i-n, p-i-p and n-i-p vertical nanowire structures are fabricated and used as basis for p-FETs, n-FETs and impact-ionization FETs. Electrical characteristics of the devices are investigated and a comparison between the different approaches and structures will be discussed.

[1]J.-P. Colinge, Multiple-gate SOI MOSFETs, Solid-State Electronics, 2004, Vol. 48, pp. 897-905.

HL 11: Transport

Time: Monday 14:00–17:45 Location: H14

HL 11.1 Mon 14:00 H14

Quantized magnetic confinement in quantum wires — •Mihai Cerchez[1], Alexey Tarasov[1], Stefan Hugger[1], Hengyi Xu[1], Thomas Heinzel[1], Igor Zozoulenko[2], Urszula Gasser-Szerer[3], Dirk Reuter[4], and Andreas Wieck[4] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Linköping University, Norrköping, Sweden — [3]ETH, Zürich, Switzerland — [4]Ruhr-Universität Bochum, Germany

We report the experimental observation of magnetically bound electronic states in a quantum wire (QWR), built by AFM lithography in a GaAs/AlxGa1-xAs heterostructure with a two-dimensional electron gas (2DEG) at 45 nm below the surface. A strong, inhomogeneous magnetic field is produced in the central region of the wire under the edge of a Dy ferromagnetic film evaporated on top and magnetized along the wire. Electronic transport measurements on the QWR are performed as a function of a superimposed, homogeneous perpendicular magnetic field. When the homogeneous field is applied in the opposite direction to the field produced by the ferromagnetic film, such that the magnetic field changes sign twice inside the QWR, we observe resonances in the conductance, which we interpret as bound electronic states induced by the inhomogeneous diamagnetic shift of the wire modes. Supported by simulations using a recursive Green function technique, we identify in the LDOS two types of bound states, one bonding state (ring-like) associated to a maximum in the transmission probability and therefore in conductance, and an anti-bonding state associated to reflection resonances.

HL 11.2 Mon 14:15 H14

The effect of gate control on the electrical conductivity of InAs nanowires — •Karl Weis[1,2], Christian Volk[1,2], Stephan Wirths[1,2], Sergio Estévez Hernández[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Andreas Penz[1,2], Stefan Trellenkamp[1,2], Jürgen Schubert[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

Semiconductor nanowires are an interesting step on the road to zero-dimensional systems. InAs is an especially suitable material because ohmic contacts can be prepared straightforwardly. Provided sufficient gate control, quantum dots can be formed.

Here, the electronic transport properties of nominally undoped InAs nanowires grown by metal-organic vapour phase epitaxy are examined. Their typical length and diameter are 5 μm and 100 nm, respectively. The gate control is studied for different gate geometries, e. g. fingers, back- and top-gates. Furthermore, we compare the performance of high-k dielectrics, e. g. $GdScO_3$ or $LaLuO_3$, with standard dielectrics like SiO_2 or Si_3N_4. Four-terminal transport measurements are performed both at room temperature as well as at low temperatures down to 30 mK.

Field effect transistor measurements performed at room temperature show that by using high-k dielectrics, the I_{on}/I_{off} ratio can be improved by at least one order of magnitude.

HL 11.3 Mon 14:30 H14

The influence of doping on the electronic transport properties of InAs nanowires — •Stephan Wirths[1,2], Karl Weis[1,2], Christian Volk[1,2], Shima Alagha[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Stefan Trellenkamp[1,2], Hans Lüth[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

The investigation of the electrical conductivity of semiconductor nanowires is a crucial step on the road to zero-dimensional electronic systems. Especially the effect of Si-doping on the resistivity plays an important role and has not been investigated, yet.

We study the electronic transport properties of n-doped InAs:Si nanowires grown by metal organic vapor phase epitaxy. Nominally undoped wires and Si-doped wires with four different dopant concentrations are examined. Two- and four-terminal transport measurements are performed both at room temperature and at low temperatures down to 4 K. In addition, by using a SiO_2 back gate, we yield field effect transistor characteristics. Hence, the depending of conductivity on the gate voltage is determined. Moreover, we investigate the temperature dependency of transport properties.

For the lowest dopant concentration we quantify $\rho = (3.8 \pm 0.8) \times 10^{-4}\,\Omega$m and $\rho = (1.8 \pm 0.4) \times 10^{-5}\,\Omega$m for the highest dopant concentration. The values of ρ were averaged over approximately 10 to 30 wires. We can conclude, that Si-doping decreases the resistivity.

HL 11.4 Mon 14:45 H14

Universal and reconfigurable logic gates in a compact three-terminal resonant tunneling diode — •Fabian Hartmann, Lukas Worschech, Tae Yang Kim, and Alfred Forchel — Universität Würzburg, Physikalisches Institut, Lehrstuhl für Technische Physik, Am Hubland, 97074 Würzburg

Submicron-sized mesas of resonant tunneling diodes (RTDs) with split drain contacts have been realized and the current-voltage characteristics have been studied in the bistable regime at room temperature. Dynamically biased, the RTDs show noise-triggered firing of spike-like signals and can act as reconfigurable universal logic gates for small voltage changes of a few mV at the input branches. These observations are interpreted in terms of a stochastic nonlinear processes. The logic gate operation shows gain for the fired-signal bursts with transconductance slopes exceeding the thermal limit. The RTD junction can be easily integrated to arrays of multiple inputs and have thus the potential to mimic neurons in nanoelectronic circuits.

HL 11.5 Mon 15:00 H14

Fast initialization of dynamic quantum dots — •Philipp Mirovsky, Bernd Kaestner, Christoph Leicht, Klaus Pierz, Thomas Weimann, and Hans Werner Schumacher — PTB, 38116 Braunschweig, Germany

We present experimental studies on dynamic quantum dots, formed within non adiabatic single electron pumps. We employ etched AlGaAs/GaAs nanowires crossed by three metal top gates, set to negative voltages to define a dot. By applying radio frequency signals of frequency f to the outermost gate, electrons are pumped through the dot. Directly after the loading electrons from source into the dot it is decoupled from the environment. The electron number is controlled by a plunger gate. During the second half of the cycle the pump transports the electrons previously loaded inside the dot to drain. Measuring the produced pumping current divided by e*f we obtain the population of the dot averaged over many cycles. In this way we are able to study the initialization conditions without the need for other single-charge detector system. This pumping mechanism also represents an alternative path to the realization of a high current high accuracy quantum standard for electrical current.

HL 11.6 Mon 15:15 H14

Electromigration in Ag-Nanowires with a Single Grain Boundary — •Simon Sindermann, Christian Witt, Michael Horn-von Hoegen, Günther Dumpich, and Frank-J. Meyer zu Heringdorf — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE) University Duisburg-Essen

Electromigration is the dominating cause of interconnect failure. For the electromigration transport of material, it is known that grain boundaries play a significant role as an important diffusion path in addition to surface diffusion. In former experiments, we avoided grain boundaries and examined electromigration effects in single-crystalline Ag nanowires. Here, we present a new approach of controlled fabrication of nanowires with isolated grain boundaries. On Si(111), Ag islands are known to form areas of different crystallographic orientations, Ag(111) and Ag(001), which can be distinguished by Photoemission Electron Microscopy (PEEM). Using a focused ion beam (FIB) we erode Ag from the islands such that a wire-like area in the vicinity of the grain boundary remains. After contacting the wires by ion beam induced Pt deposition, we study the electromigration *in-situ* by scanning electron microscopy, combined with a four wire resistance measurement.

HL 11.7 Mon 15:30 H14

Boltzmann equation approach to ballistic rectification at a potential step — •Daniel Urban and Jürgen König — Universität Duisburg-Essen and CeNIDE, Duisburg, Germany

We consider the device studied experimentally in Ref. [1]. It consists of a two-dimensional electron gas patterned such that two regions are separated by a potential step. Application of a bias voltage parallel to the potential step results in a transverse voltage (proportional to the square of the bias voltage). This effect can be exploited for rectification, since – due to the symmetry of the device – the transverse voltage does not depend on the bias polarity.

We model the electrons by means of the Boltzmann equation. In doing so we allow for non-parabolic dispersion and energy dependent scattering times. In order to capture the rectification effect, the distribution function has to be calculated to second order in the applied electric field. Based on the calculated distribution function we determine the transverse voltage. While its magnitude does not agree with the measured values in Ref. [1], qualitative features are reproduced: It depends quadratically on the applied bias and increases with increased mobility.

[1] A. Ganczarczyk *et al.*, preprint: arXiv:0804.0689v3 (2009).

HL 11.8 Mon 15:45 H14

Negative bend resistance in a nanoscale epitaxial graphene cross junction — •Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Florian Speck[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Technische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg

We report on the observation of inertial-ballistic transport in nanoscale cross junctions fabricated from epitaxial graphene grown on SiC(0001). Ballistic transport is indicated by a negative bend resistance which vanishes with increasing temperature.

The advanced morphology of graphene films on SiC(0001) grown in an Ar atmosphere [1] yields improved transport properties [2] and an electron mean free path of $l_e = 58$ nm at $T = 4.2$ K. The mean free path exceeds the device dimensions for a 50 nm wide orthogonal cross junction, and a negative bend resistance of $R_{12,43} \approx -170\,\Omega$ observed at $T = 4.2$ K indicates ballistic transport. With increasing temperature a transition from the ballistic to the diffusive transport regime is indicated by a change of sign in $R_{12,43}$. For cross junctions with leads of width $b = 80$ nm no negative bend resistance is observed, which is in accordance with the estimated mean free path ($l_e < 80$ nm).

[1] K.V. Emtsev, *et al.*, Nature Mater. **8**, 203 (2009).
[2] S. Weingart, *et al.*, Physica E, *doi:*10.1016/j.physe.2009.11.006.

15 Min. Coffee Break

HL 11.9 Mon 16:15 H14

Ballistic quantum spin Hall state of HgTe quantum wells in a strong magnetic field — •Tkachov Grigory[1,2] and Hankiewicz Ewelina[2] — [1]Max Planck Institut PKS, Dresden — [2]Institut für Theoretische Physik, Universität Würzburg

Recently novel two-dimensional electronic state - quantum spin Hall (QSH) state - has been theoretically proposed and experimentally realized in HgTe quantum wells [1]. It is observed in a zero magnetic field and for this reason is distinct from quantum Hall states. We show theoretically [2] that the QSH state persists in strong quantizing fields, turning into a quantum Hall one if the Fermi level is driven out of the band gap. We find that near such a transition the longitudinal ballistic conductance of edge channels vanishes due to the combined effect of edge-spectrum nonlinearity and channel backscattering. This contrasts the usual behavior of the zero-field conductance which increases as the Fermi level is pushed from the band gap into the metallic-type

conduction (or valence) band [1]. The combined effect of the spectral nonlinearity and backscattering is found to cause power-law suppression of the edge conductance with magnetic field, accompanied by spatial redistribution of the QSH channels. Our findings can be used for the detection and characterization of the QSH state in the recently achieved ballistic regime [1], still remaining largely unexplored.

1. M. König et al., Science **318**, 766 (2007); A. Roth et al., Science **325**, 294 (2009).
2. G. Tkachov and E. M. Hankiewicz, arXiv: 0909.4428.

HL 11.10 Mon 16:30 H14

Transport Measurements on a GaAs/AlGaAs High Mobility Sample — •Lina Bockhorn[1], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]ETH Zürich, Schafmattstr. 16, 8093 Zürich, Switzerland

We study the fractional Quantum-Hall effect in very high mobility two-dimensional electron systems (2DES). Hall bars are created by photolithography on a GaAs/AlGaAs quantum well containing a 2DES. The 2DES have an electron density of $n_e \approx 2.95 \cdot 10^{11}\mathrm{cm}^{-2}$ and a mobility of $\mu \approx 14.9 \cdot 10^6\mathrm{cm}^2/\mathrm{Vs}$ at 1.5 K. Similar parameters were obtained after cooling the sample slowly to the cryostat's base temperature (40 mK). For a given density of electrons we study the longitudinal resistance R_{xx} over a short range around zero magnetic field. The measurements carried out for several temperatures and different currents were applied to the Hall bar. A peak was observed at zero magnetic field for the temperature dependent measurements, as well as for the current dependent measurements. The maximum value of R_{xx}(B=0 T) is independent of the temperature and the applied current. The behavior of the longitudinal resistance for the temperature and the current dependent measurements is astonishing. Not only the fixed peak at the zero point is unusual, but also the distribution of the longitudinal resistance next to the peak. This region shows a different behavior for temperature variation than for different currents applied to the Hall bar. This clearly shows that the behavior for different currents is not a temperature dependent effect.

HL 11.11 Mon 16:45 H14

Transport in dually-gated suspended bilayer graphene devices in electric and magnetic fields — •R. Thomas Weitz, Monica T. Allen, Ben E. Feldman, Jens Martin, and Amir Yacoby — Department of Physics, Harvard University, Cambridge, MA, USA

The layer pseudospin of bilayer graphene can be controlled by applying an electric field E across the flake. We demonstrate control over this pseudospin in suspended bilayer graphene devices with suspended top gates. At zero magnetic field B, we observe a significantly larger increase in resistance at the charge neutrality point with growing E than had been reported before, indicative of the high sample quality. At finite B, the 8-fold degeneracy of the lowest Landau level is lifted due to electron-electron interactions [1]. The strength and nature of these symmetry broken filling factors are found to be depended on E. The nu=1 and 2 states can be enhanced with E. In the nu=0 state phase transitions between two insulating phases are observed. The position of this transition in the E-B plane is marked by an increased conductance and depends on the relative strengths of B and E. [1] B. E. Feldman et al. Nature Physics

HL 11.12 Mon 17:00 H14

On the self-consistent calculation of the electric Hall potential — •Tobias Kramer, Christoph Kreisbeck, and Viktor Krueckl — Institute for Theoretical Physics, Uni Regensburg

Using a first-principles many-body simulation of a Hall bar, we study the necessary conditions for the formation of the Hall potential: (i) Ohmic contacts with metallic reservoirs, (ii) electron-electron interactions, and (iii) confinement to a finite system. By propagating thousands of interacting electrons over million time-steps we capture the build-up of the self-consistent potential, which resembles results obtained by conformal-mapping methods. As shown by a microscopic model of the current injection, the Hall effect is linked to specific boundary conditions at the particle reservoirs.

HL 11.13 Mon 17:15 H14

Activation of acceptor levels in Mn implanted Si by pulsed laser annealing — •Lin Li[1,2], Shengqiang Zhou[2], Danilo Bürger[2], Peter Oesterlin[3], Jürgen Fassbender[2], Manfred Helm[2], Shude Yao[1], and Heidemarie Schmidt[2] — [1]State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China — [2]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden- Rossendorf e.V., Bautzner Landstraße 128, 01328 Dresden, Germany — [3]INNOVAVENT GmbH, Bertha-von-Suttner-Str. 5, 37085 Göttingen, Germany

Nearly intrinsic Si wafers were implanted with Mn ions. The implanted Si films were annealed by pulsed laser annealing (PLA) or rapid thermal annealing (RTA). Activation of acceptors was only realized in the PLA films with a free hole concentration of 4*1017 cm-3, compared to the activation of donors in RTA films with a free electron concentration of 6*1015 cm-3. The PLA films reveal negative magnetoresistance with MR= 0.5% at 20 K and 30 K and at 7 T, hinting towards spin polarization of holes. Ferromagnetism was probed for both RTA and PLA films by a SQUID magnetometer at low temperatures. The formation of ferromagnetic MnSi1.7 nanoparticles has been proven in RTA films by synchrotron radiation X-ray (SR-XRD) measurements [1] and could be excluded in Mn implanted Si annealed by PLA.

HL 11.14 Mon 17:30 H14

Interaction between quantum dots and a two-dimensional system — •Florian Lau[1], Gerold Kiesslich[1], Andreas Marent[2], Tobias Nowozin[2], Tobias Brandes[1], and Dieter Bimberg[2] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Novel types of memories will combine the advantage of non-volatility of the Flash-memory and the performance and endurance of the DRAM. One of the most promising options for charge-based memories is the use on self-organized quantum dots (QDs) as memory units. Recently, a QD-based memory concept was introduced with the potential to fulfill all requirements concerning storage/access time, endurance and scalability [1].
We investigated the read-out in such a QD-based memory by studying the coupling between InAs/GaAs QDs and an adjacent two-dimensional hole gas (2DHG). Self-consistent solutions of Poisson- and drift-diffusion equations yield the dependence of the charge carrier concentration on a variety of parameters such as the number of charge carriers stored in the QDs or the distance between the QDs and the 2DHG. Furthermore, the effect of charged QDs on the mobility of the 2DHG is discussed in terms of a memory-function approach. The simulation results are compared with measurements performed on a memory structure based on InAs/GaAs QDs.
[1] M.Geller, A. Marent, T. Nowozin, D. Bimberg, N. Akcay, and N. Öncan, Appl. Phys. Lett. **92**, 092108 (2008).

HL 12: Group-III-Nitrides: Optical Properties I

Time: Monday 14:00–15:30 Location: H15

HL 12.1 Mon 14:00 H15

Cathodoluminescence hyper-spectral imaging of InGaN/GaN quantum wells — •Jochen Bruckbauer[1], Paul R. Edwards[1], Tao Wang[2], and Robert W. Martin[1] — [1]Dept. of Physics, SUPA, University of Strathclyde, Glasgow, G4 0NG, UK — [2]Dept. of EEE, University of Sheffield, Sheffield, S1 3JD, UK

Cathodoluminescence (CL) spectroscopy is a powerful tool for investigation of light-emitting semiconductors [1, 2]. A field-emission gun SEM has been used to study the CL of InGaN/GaN quantum wells (QWs) with high spatial resolution approaching 10 nm. Forming a hyper-spectral image by collecting CL spectra at each pixel within a 2D map allows observable surface features to be correlated to observed changes in CL spectra. Comparison is made to photoluminescence measurements as a function of temperature down to 16 K. InGaN/GaN QWs were grown on c-plane sapphire substrates by MOCVD, emitting in the blue and green. To improve crystal quality a high-temperature AlN buffer layer technology was applied [3]. SEM imaging revealed the

well-known V-shaped pits in addition to trench-like features. CL spectral mapping showed shifts of the emission energy as well as changes in the line shape of spectra from those features. The non-uniformity of the emission of the QW is strongly influenced by the surface morphology and is related to local variations in dislocations, composition or strain. High spatial resolution CL provides useful information on the material properties and performance on a sub-micron scale. [1] Christen et al., J. Vac. Sci. Technol. B 9, 2358 (1991), [2] Martin et al., phys. stat. sol. (a) 201, 665 (2004), [3] Bai et al., JAP 99, 023513 (2006).

HL 12.2 Mon 14:15 H15

Spinodal and binodal decomposition of a thin InGaN layer grown on GaN — •Christian Tessarek, Timo Aschenbrenner, Stephan Figge, and Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

Unstrained InGaN is known to have a large miscibility gap due to spinodal decomposition [1]. Considering strain of an InGaN layer grown on GaN, the spinodal and binodal phase diagram changes significantly [2]: the ciritcal temperature, i.e. the maximum of the spinodal and binodal graph, is reduced and moved to higher x of $In_xGa_{1-x}N$.

Strong phase separation of a thin uncapped InGaN layer grown on GaN occurs into both high and low In content phases when the growth parameters are set into the unstable region of this strain considering spinodal phase diagram. The different InGaN phases were determined by x-ray diffraction and photoluminescence measurements. Furthermore, surface analysis of the decomposed structures were performed via scanning electron and atomic force microscopy. The phase separation forms among others dot-like and/or meandering InGaN structures as predicted in [3]. These structures are used as active material in light emitting devices.

[1] Ho, Stringfellow, APL **69**, 2701 (1996)

[2] Karpov, MRS Internet J. Nitride Semicon. Res. **3**, 16-1 (1998)

[3] Okumura, Ishida, Kamikawa, Jpn. J. Appl. Phys. **39**, 1044 (2000)

HL 12.3 Mon 14:30 H15

Kathodolumineszenz-Untersuchungen an dicken rissfreien GaN-Schichten auf Si(111)-Substraten — •Anja Dempewolf, Frank Bertram, Thomas Hempel und Jürgen Christen — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Deutschland

Die Heteroepitaxie von GaN auf Siliziumsubstraten stellt eine geeignete und wirtschaftliche Alternative zum Wachstum auf anderen Substraten, wie Saphir oder SiC, dar. Um dicke rissfreie GaN-Schichten hoher kristalliner und optischer Qualität für effiziente LEDs zu erzielen, ist ein geeignetes Stressmanagement erforderlich, das z. B. durch den Einsatz von LT-AlN-Zwischenschichten erreicht wird. Mittels hoch orts- und spektral aufgelöster Kathodolumineszenzmikroskopie (KL) wurden die Lumineszenzeigenschaften dicker rissfreier GaN-Schichten auf Si(111)-Substraten bei Heliumtemperatur untersucht. Auf einem optimierten Template, bestehend aus einer AlN-Keimschicht, einem AlGaN-Puffer mit stufenweise reduzierter Al-Konzentration, abgeschlossen mit einer nominell undotierten GaN-Schicht, wurden mehrere Mikrometer Si-dotiertes GaN, unterbrochen von AlN-Zwischenschichten, aufgewachsen. Ortsaufgelöste Messungen an der Bruchkante zeigen den Einfluss der Zwischenschichten auf die Quantenausbeute. Die Analyse der spektralen Position der bandkantennahen GaN-Emission in spektral hoch aufgelösten Linescans entlang der Bruchkante erlaubt direkte Rückschlüsse auf den Verspannungszustand und die Veränderung der freien Ladungsträgerdichte vom Substrat zur Oberfläche.

HL 12.4 Mon 14:45 H15

Impact of the AlN seeding layer thickness on GaN orientation on high index Si-substrates — •Roghaiyeh Ravash, Jürgen Bläsing, Peter Veit, Thomas Hempel, Armin Dadgar, Jürgen Christen, and Alois Krost — Otto-von-Guericke-University Magdeburg, FNW/IEP/AHE, Postfach 4120, 39016 Magdeburg, Germany

Silicon is considered to be a reasonable alternative to substrates such as sapphire and SiC, because of its low price and availability in large diameters. Because of spontaneous and strain induced piezoelectric polarization field along the c-axis, leading to the separation of electrons and holes in quantum wells reducing the recombination efficiency, c-axis oriented GaN-based light emitters have a low efficiency, especially in the longer wavelength region. In order to reduce or eliminate these polarization effects, semi-polar or non-polar GaN-heterostructure is favored. In this work we investigated the growth of GaN applying a low temperature AlN seeding layer with various thicknesses. The impact of the AlN seeding layer on GaN orientation using different Si substrate orientations (e. g. (211), (711), (410), (100)+4.5° off) were investigated by x-ray diffraction measurements in Bragg-Brentano geometry and x-ray pole figure measurements. We found that the thickness of the AlN seeding layer plays a significant role in obtaining different GaN textures. Applying a about 4 nm AlN seeding layer we achieved a single crystalline GaN epilayer on Si (211) with a 18 ° tilted c-axis orientation. Some of the samples were characterized by scanning electron microscopy and transmission electron microscopy.

HL 12.5 Mon 15:00 H15

Ein Indium Defekt Komplexes und die Lumineszenzeigenschaften von GaInN und AlInN — •Patrick Kessler[1], Katharina Lorenz[2,3], Jens Niederhausen[6], Bettina Steitz[1], Joao G. Correia[2,3,4], Karl Johnston[4,5], Reiner Vainden[1] und ISOLDE Collaboration[4] — [1]Helmholtz Institut für Strahlen und Kernphysik, Universität Bonn — [2]Instituto Tecnólogico e Nuclear, P-2686-953 Sacavém, Portugal — [3]Centro de Fisica Nuclear da Universidade de Lisboa, Portugal — [4]PH dept, CERN, Schweiz — [5]Technische Physik, Universität des Saarlands, Saarbrücken — [6]Physikalisches Institut der Humboldt Universität, Berlin

LEDs aus GaN zeigen trotz hoher Versetzungsdichte eine hohe Lichtausbeute. Dabei werden meist in der Anwendung zusammengesetzte Systeme wie AlInN oder GaIN verwendet. Die Rolle des Indiums im Lumineszenzeprozess wird mit der Methode der gestörten Winkelkorrelation (PAC) untersucht. Frühere Messungen zeigen einen Defektkomplex der Sonde ^{111}In und einer möglichen Stickstofflehrstelle, der bis zu hohen Temperaturen stabil ist. Als Konkurrenz zum strahlungslosen Übergang an Versetzungen, könnte der Komplex eine konkurrierende Exzitonenfalle sein, die die Lichtausbeute positiv beeinflusst.

Um weitere Informationen über den Komplex zu erhalten, werden ^{111}In mit ^{111m}Cd Messungen verglichen, um den Einfluss eines möglichen äfter effect"des Zerfalls zu untersuchen. Dieser kann auftreten, wenn nach dem Elekroneneinfang ein Loch in der Atomhülle zurückbleibt und wieder aufgefüllt wird. Zusätzlich werden Ergebnisse von e^--γ-Korrelationsmessungen vorgestellt.

HL 12.6 Mon 15:15 H15

Cathodoluminescence microscopy analysis of structural and optical properties of HVPE ELO-AlN layers — •Martin von Kurnatowski[1], Barbara Bastek[1], Juergen Christen[1], Thomas Hempel[1], Frank Bertram[1], Hideto Miyake[2], Yusuke Katagiri[2], Kazuki Okuura[2], and Kazumasa Hiramatsu[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Department of Electrical and Electronical Engineering, Mie University, Japan Institute of Solid State

Aluminum nitride is a promising candidate for solid state electronic and optical applications in the deep UV due to its large direct bandgap. However, there is a mismatch between the lattice constants and thermal expansion coefficients of AlN and conventional substrates. Consequently, a high density of dislocations and micro-cracks occurs. The approach of "epitaxial lateral overgrowth" (ELO) has already lead to a drastic reduction of this problem in GaN and AlGaN.

We investigate the microscopic, optical, and structural properties of HVPE-ELO-AlN layers with thicknesses of up to 25 μm. The ELO pattern consists of 1.3 μm wide trenches which were etched into the Sapphire leaving ridges of 2 μm widths. Integral CL spectra show a dominant near band edge (NBE) emission at 6.105 eV at coalescence height. Towards the surface the NBE peak shifts about 18 meV to lower energies. Right at the surface the near band edge energy is modulated by only 5 meV with the periodicity of the underlying trench-pattern.

HL 13: Quantum Dots and Wires: Preparation and Characterization I

Time: Monday 14:00–17:45 Location: H17

HL 13.1 Mon 14:00 H17

In-assisted growth of InAs nanowires by molecular beam epitaxy — •Thomas Grap, Christian Blömers, Mihail Ion Lepsa, Steffi Lenk, Thomas Schäpers, Hans Lüth, and Detlev Grützmacher — Institute of Bio- and Nanosystems (IBN-1) and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich

Semiconductor nanowires are expected to play a key role in future nanotechnology as well as for understanding the optical, electrical and spin-related properties in systems with reduced dimensionality and size. In particular, InAs nanowires are of special interest in connection with the material properties: low effective mass, narrow gap, high electron mobility and strong electron accumulation layer on its surface. As a better alternative to the growth of InAs nanowires using Au particles, we have successfully developed a method using In droplets as seeds. The nanowires have been grown on both GaAs and InP (111)B substrates covered with a very thin hydrogen silsesquioxan (HSQ) film. We show systematic results obtained for different growth conditions related to substrate temperature and beam fluxes of In and As. Information about the crystallographic structure of the nanowires got from transmission electron microscopy investigations is also presented.

HL 13.2 Mon 14:15 H17

Enhancement of Young's modulus in InAs nanowires — •Vadim Migunov[1], Zi-An Li[1], Marina Spasova[1], Michael Farle[1], Andrey Lysov[2], Werner Prost[2], Ingo Regolin[2], and Franz-Josef Tegude[2] — [1]Fakultät für Physik and CeNIDE — [2]Fakultät für Ingenieurwissenschaften and CeNIDE, Universität Duisburg-Essen, Duisburg, Deutschland

Semiconducting nanowires are of great interest due to their potential in electrical and electromechanical applications. In our study Young's modulus of InAs nanowires (NWs) with a diameter of approximately 50 nm was determined by electromechanical resonance measurements.

The NWs were grown by MOCVD on the (100) InAs substrate. Three types of NWs with different crystalline structures were identified by HR-TEM: Zinc-Blende (ZB) structure, Wurtzite (WZ) structure, mixed WZ and ZB structure. The electromechanical resonance was studied in-situ in TEM to correlate mechanical and structural properties of the NWs. The resonance frequency was determined by tuning the AC voltage frequency applied between STM tip and NW until the maximum amplitude of mechanical vibrations of the NW was achieved and directly observed in TEM. The measurements were performed on NWs with different lengths, diameters and structures. Young's modulus for two types of structures (pure WZ and mixed structure) was calculated using TEM tomography data for the NWs cross-section. An enhancement of about a factor of two of Young's modulus in comparison to the bulk value was observed for both NWs types.

The work is supported by SFB 445.

HL 13.3 Mon 14:30 H17

Improvement of the optical quality of site-controlled InAs quantum dots by a double stack growth technique in wet-chemically etched holes — •Tino Johannes Pfau[1], Aleksander Gushterov[1], Johann-Peter Reithmaier[1], Isabelle Cestier[2], Gadi Eisenstein[2], Evgany Linder[3], and David Gershoni[3] — [1]Technische Physik, INA, Universität Kassel, 34132 Kassel — [2]Electrical Engineering Dep., Technion, Haifa 32000, Israel — [3]Solid State Institute and Physics Dep., Technion, Haifa 32000, Israel

The optimization of the wet-chemically etching of holes and a special MBE growth stack technique allows enlarging the site-control of low density InAs QDs on GaAs substrates up to a buffer layer thickness of 55 nm [1]. The strain of InAs QDs, grown in the etched holes, reduces the hole closing, so that a pre-patterned surface is conserved for the second QD layer. The distance of 50 nm GaAs between the two QD layers exceeds drastically the maximum vertical alignment based on pure strain coupling (20 nm). Compared to stacks with several QD layers, this method avoids electronic coupling between the different QD layers and reduces the problems to distinguish the dots of different layers optically. Confocal microphotoluminecence reveals a significant diminution of the low temperature photoluminescence linewidth of the second InAs QD layer to an average value of 505 ± 53 μeV and a minimum width of 460 μeV compared to 2 to 4 meV for QDs grown on thin buffer layers. The increase of the buffer layer thickness decreases the influence of the surface defects caused by prepatterning.

[1] T. J. Pfau, *et al.,* Appl. Phys. Lett. 95 (2009)

HL 13.4 Mon 14:45 H17

Influence of arsenic species on InAs island formation on InAlGaAs/InP (100) **surfaces** — •Christian Gilfert[1], Emil-Mihai Pavelescu[2], and Johann Peter Reithmaier[1] — [1]Technische Physik, Institut für Nanostrukturtechnologie und Analytik, Universität Kassel, 34132 Kassel, Germany — [2]National Institute for Research and Development in Microtechnologies, 077190 Bucharest, Romania

The nucleation of $InAs$ on InP (100) is far more complex than in the $In(Ga)As/GaAs$ system and a variety of different structures has been reported. However, optoelectronic devices such as semiconductor lasers and amplifiers for $1.3\mu m$ and $1.55\mu m$ require a well established electronic confinement of the charge carriers for improved device performance in terms of, e.g., threshold current and temperature stability. Therefore, homogenously grown round-shaped quantum dots are the structures of choice, since they present a zero-dimensional system for the carriers. Round-shaped quantum dots on InP were accomplished by several growth methods. To the best of the authors' knowledge a study of the influence of the arsenic species on the nucleation of $InAs$ has not been reported yet. We demonstrate that the arsenic species has quite a dramatic impact. When supplying As_2 the deposited $InAs$ preferentially forms round-shaped quantum dots, which exhibit an improved photoluminescence over the As_4 counterparts. FWHM values as low as 22meV at 10K were achieved. This linewidth is smaller than state-of-the-art linewidth reported yet for $InAs$ quantum dots grown on $InAlGaAs/InP$ (100) based compounds.

HL 13.5 Mon 15:00 H17

Herstellung und Charakterisierung von InAs/GaAs-Quantenpunktstrukturen mittels Droplet-Epitaxie — •Verena Zürbig, Aleksandar Gushterov und Johann Peter Reithmaier — Technische Physik, Institut für Nanostrukturtechnologie und Analytik, Universtät Kassel, 34132 Kassel, Germany

Die Droplet-Epitaxie bietet neben der konventionellen Stranski-Krastanov-Methode die Möglichkeit, Quantenpunkte durch selbstorganisiertes Wachstum herzustellen. Dabei werden zuerst In-Metalltropfen auf der GaAs-Oberfläche gebildet, bevor diese durch Zugabe von As-Molekülen zu InAs-Quantenpunkten auskristallisieren. Der Vorteil der Droplet-Epitaxie liegt in der Herstellung von dreidimensionalen Nanostrukturen aus gitterangepassten und gitterfehlangepassten Materialkombinationen und der Herstellung von Quantenpunktstrukturen ohne Benetzungsschicht. Auf einem nicht dotierten [100] GaAs-Substrat wurden InAs-Quantenpunkte mittels Droplet-Epitaxie bei hohen Substrattemperaturen (450 °C und 500 °C) realisiert. Die Proben wurden in einer Molekularstrahlepitaxie-Anlage hergestellt und topographisch mit dem Rasterkraftmikroskop und optisch mit der Photolumineszenzspektroskopie untersucht. Durch die Variation verschiedener Wachstumsparameter (Öffnungszeit der As-Zelle, Mengenzugabe von Indium, Wachstumsrate von Indium, As-Druck, Substrattemperatur) konnten optimierte Parameter für die Herstellung von InAs/GaAs-Quantenpunktstrukturen mit geringer Größe (Höhe: 5-7 nm), großer Homogenität und guten optischen Eigenschaften (FWHM: 65 meV, Messtemperatur: 10-300 K) ermittelt werden.

HL 13.6 Mon 15:15 H17

Site Controlled InAs Quantum Dots with ultra low densities and improved spectral uniformity — •Carmen Drescher, Christian Schneider, Kousha Talebian, Martin Kamp, Sven Höfling, Stefan Reitzenstein, Lukas Worschech, and Alfred Forchel — Technische Physik,Physikalisches Institut, Universität Würzburg and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg,Am Hubland, 97074 Würzburg, Germany

In order to exploit InAs Quantum Dots (QDs) coupled to microcavities as single photon sources in a scalable manner one needs to know the exact position of the QD for device alignment. To improve the yield of spectrally resonant devices without adjusting the resonator geometry to the individual QD emission wavelength it is necessary to reduce

spectral inhomgeneities in the ensemble emission of the QD array. The position control of our site controlled QDs (SCQDs) is maintained by directing the QD nucleation to shallow etched nanoholes on a (1,0,0) GaAs surface. To achieve a reasonably low single QD linewidth and ensemble broadening, growth parameters during the molecular beam epitaxy (MBE) deposition step of the QDs have been optimized and investigated. We have monitored the influence of the substrate temperature during SCQD growth as an important parameter for spectral homogeneity and achieved accurate QD nucleation of single SCQDs on pitches up to 4 μm on both uncapped and buried SCQDs.

HL 13.7 Mon 15:30 H17

High quality single-photon photoluminescence emission of MOVPE grown InGaAs quantum dots — •Daniel Richter, Robert Hafenbrak, Klaus Jöns, Wolfgang-Michael Schulz, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

In recent years, investigations on semiconductor quantum dots (QDs) have been motivated by their potential application in the field of quantum information processing. Therefore, optically or electrically addressable single quantum dots are needed on a mass production scale using metal-organic vapor-phase epitaxy (MOVPE). A narrow linewidth of QD emission makes them suitable for e.g. two photon interference and single-photon emitters at high repetition rates. By applying special annealing techniques the growth of low density (10^7 cm^{-2}), small sized quantum dots grown on misoriented GaAs substrates by MOVPE was realized. The influence of the growth conditions on the QD structural properties was investigated by atomic force microscopy measurements. To enhance the photoluminescence extraction efficiency a DBR structure is used. With a high resolution PL setup, using a Fabry-Perrot Etalon, QD PL emission linewidths of 12 μeV were found. Furthermore the fine structure splitting is investigated. We prove the zero-dimensionality of the QD structures by performing 2nd order intensity autocorrelation measurements.

15 Min. Coffee Break

HL 13.8 Mon 16:00 H17

Structural and optical characterization of high areal density $Ga_xIn_{1-x}P$ quantum dots on GaP — •Vasilij Baumann, Sven Gerhard, Sven Höfling, and Alfred Forchel — Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We present a study of growth, morphology and optical properties of $Ga_xIn_{1-x}P$ quantum dots (QDs) for various Ga concentrations x.

All samples were grown on GaP substrates using a gas source molecular beam epitaxy system with thermally cracked PH_3 gas and Ga and In from solid source effusion cells.

QD areal densities up to 10^{11} cm^{-2} have been achieved showing strong dependence on the amount of gallium supplied. QD sizes and areal densities are evaluated using scanning electron microscopy and atomic force microscopy and are related to photoluminescence (PL) properties of the QDs.

Low temperature PL spectra are also presented showing emission in the visible red spectral range and emission intensities that are strongly dependent on Ga content.

Both structural and optical properties are promising for future applications of the herein reported QDs in visible wavelength optoelectronic devices.

HL 13.9 Mon 16:15 H17

GaAs/GaMnAs core-shell nanowires grown by MBE — •Andreas Rudolph[1], Marcello Soda[1], Matthias Kiessling[1], Dieter Schuh[1], Christian Back[1], Josef Zweck[1], Tomasz Wojtowicz[2], Werner Wegscheider[3], and Elisabeth Reiger[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93053 Regensburg, Germany — [2]Institute of Physics, PAS, Al. Lotnikow 32/46, 02-668 Warsaw, Poland — [3]Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland

Our research interest is focused on combining the diluted magnetic semiconductor GaMnAs with the growth of GaAs nanowires. We use a core shell nanowire approach were the core GaAs nanowire is grown at typical nanowire growth conditions using Au or Ga as catalysts [1,2]. The GaMnAs shell is deposited at low temperatures, known to be crucial for high quality GaMnAs. The nanowires are characterized by SEM, TEM, SQUID and transport measurements. Parameters like growth temperature, shell thickness and Mn content were varied to investigate their influence on Curie temperature and magnetic anisotropy [3]. Currently we work on improving the core nanowire growth to obtain more uniform nanowire samples with respect to size, shape and in particular side facets. With this samples the GaMnAs shell could be optimized on the specific crystal orientation of the side facets.

[1] M. Tchernycheva et al., Nanotechnology 17, (2006). [2] C. Colombo et al., PRB 77, (2008) [3] A. Rudolph et al., Nano Letters, (unpublished)

HL 13.10 Mon 16:30 H17

Single photon emission from positioned GaAs/AlGaAs axial heterostructure nanowires grown on pre-patterned substrate — •Jan Heinrich, Alexander Huggenberger, Tobias Heindel, Stephan Reitzenstein, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Nanowires (NWs) with axial heterostructure quantum dots (QDs) are predicted to be very efficient single photon sources (SPSs). In literature, besides the growth of positioned NW on pre-patterned substrates, also single photon emission from NW with embedded QD has been demonstrated. Here, the as-grown NWs are usually removed from the growth substrate for measurements, which has the drawback of a possible damage of the NW during the transfer. Moreover, there is an arbitrary orientation of the NW after the transfer. In contrast, we have grown AlGaAs NW with an embedded axial heterostructure GaAs QD, which allows us to probe single free standing and precisely positioned NW directly on the growth substrate. Single NW were examined by μPL and showed narrow PL emission around 740 nm with linewidths as small as 95 μeV. Morover, photon autocorrelation measurements were performed to examine the potential of the positioned NW to act as an SPS. The positioned NW with embedded QD showed clear photon anti-bunching, proving the non-classical light emission by emitting only one photon at a particular time.

HL 13.11 Mon 16:45 H17

Position control of self-catalyzed MBE-grown GaAs nanowires — •Benedikt Bauer[1], Andreas Rudolph[1], Anna Fontcuberta i Morral[2], Dieter Weiss[1], Dieter Schuh[1], Marcello Soda[1], Josef Zweck[1], and Elisabeth Reiger[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Institut des Materiaux, EPFL Lausanne, Switzerland

Nanowires grown in bottom-up processes are regarded as possible building blocks of future electronic devices. For integrating them into conventional electronic circuits controlling the position and diameter of the nanowires is inevitable [1]. We report on position controlled GaAs nanowires grown via self-catalyzed growth using MBE [2]. Starting with a GaAs (111)B substrate covered by a thin SiO_2 layer we use E-beam lithography in combination with wet chemical etching to define arrays of holes with diameters of 100 nm and varying interhole distances between 200 and 2000 nm. These holes in the SiO_2 layer act as nucleation sites for nanowire growth. The nanowires are oriented in the [111] direction and are restricted to the patterned areas.

SEM/TEM characterizations show that the nanowires have a hexagonal shape with {110} side facets and zinc blende as dominant crystal structure.

[1] Thelander et al., Mater. Today **9** (2006) 28.
[2] Colombo et al., Phys. Rev. B **77** (2008) 15532.

HL 13.12 Mon 17:00 H17

Conversion of rare earth doped ZnS to ZnO nanowires — •Sebastian Geburt, Gabriele Bulgarini, Christian Borschel, and Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

The ideal properties for nanoscaled photonic devices (light emission, wave guiding and light amplification) are combined in semiconductor nanowires (NWs). Doping with optical active elements offers new possibilities, but doping during nanowire growth is still an unsolved problem. Ion implantation overcomes the limitations, but the ion induced lattice damage can not completely be avoided and leads to suboptimal optical properties.

In a new approach, ZnS nanowires were implanted with rare earth elements (RE = Nd, Sm; 0.02 - 2 at%) and annealed in vacuum. Spa-

tial resolved cathodoluminescence (CL) shows the optical activation of the RE in the ZnS matrix. Upon further annealing at higher temperatures, the ZnS nanowires were converted to ZnO by oxidation. The conversion process eliminates lattice defects and enhances the integration of the optical active dopants into their surrounding. SEM, TEM and EDX give insights to the conversion process from ZnS to ZnO. Highly enhanced luminescence from the impurities can be detected by CL. The influence of annealing conditions, dopant concentration and temperature are subject of investigation. The results are compared with RE implanted ZnO nanowires yielding into much lower intensities.

HL 13.13 Mon 17:15 H17

Epitaxial silicon nanowire growth catalyzed by gold dot arrays from electron beam lithography patterning using silane precursors — •Björn Hoffmann, Gerald Brönstrup, Uwe Hübner, and Silke Christiansen — Institut für Photonische Technologien e.V., Abt. Halbleiter Nanostrukturen, 07745 Jena

Ordered arrays of silicon nanowires (SiNWs) are promising building blocks for a variety of photonic, photovoltaic and sensor applications. In our approach to create SiNWs we use electron beam lithography (EBL) and thermal metal evaporation to create nano-patterned arrays of gold nanodots on a Si(111) wafer. These Au dots are subsequently used to catalyze the bottom-up growth of SiNWs that follow the vapor-liquid-solid (VLS) growth mechanism using silane in a CVD reactor.

The grown nanowires are characterized structurally using SEM, TEM and electron backscatter diffraction (EBSD).

We observe epitaxial growth of the SiNWs on the Si(111) wafer and we are able to control the growth direction to be either dominated by <111> or <112> directions by just changing the silane partial pressure. The lengths as well as the diameters of the wires are precisely controlled by the EBL Au dot patterning and CVD parameters. To predict wire diameters modelling is carried out that takes into account the EBL- and CVD-parameters and describes the observed experimental results very well.

Furthermore we were able to create single crystalline Au-dot arrays which are very promising structures for surface enhanced raman spectroscopy (SERS) substrates.

HL 13.14 Mon 17:30 H17

Scaled nanowire field effect transistors and dopant free logic — •Andre Heinzig[1], Walter M. Weber[1], Daniel Grimm[2], Thorsten Roessler[3], Monika Emmerling[4], Martin Kamp[4], and Thomas Mikolajick[1] — [1]Namlab gGmbH, D-01187 Dresden — [2]IFW-Dresden — [3]IHM, TU-Dresden — [4]Universität Würzburg

Most digital electronic applications are based on complementary logic where symmetric pairs of p- and n-type transistors are combined to significantly reduce the power consumption. As downscaling proceeds the accurate and reproducible adjustment of doping profiles has proven to be a difficult task. Intrinsic silicon nanowire (NW) FETs were fabricated with intruded, abrupt Schottky junctions. The carrier injection over the metal ($NiSi_2$) to Si NW-hetero-junctions can be controlled accurately by locally adjusting the electric field. Successful gate control and saturation of the devices has been achieved for gate lengths down to 32 nm for a NW diameter of 17 nm. The integration of high-k dielectrics (HfO_2, Al_2O_3) was implemented to improve the gate coupling. A novel approach with a double top gate architecture was used to independently control the carrier injection through each junction. By blocking the undesired type of carriers at one junction, the intrinsic ambipolar behavior of the NW-FET can be tuned to p- or n-type without the use of doping. The first dopant free complementary inverter has been fabricated by combining two NW-FETs with inverse programmed polarity. The transfer characteristics show a clear inversion behavior with stable states over several periods. These results imply that all types of digital functions can be realized with undoped Si-NWs.

HL 14: Nanophotonics - Devices II (Focused Session with DS)

Time: Monday 14:00–17:45 Location: H2

Topical Talk HL 14.1 Mon 14:00 H2

High performance lasers realised by advanced nanofabrication technologies — •Johann Peter Reithmaier — Institute of Nanostructure Technologies and Analytics, Kassel, Germany

With advanced nanofabrication techniques beyond conventional semiconductor fabrication technologies, one has access to more independent parameters for the optimization of the device performance or the fabrication process itself. Two major nanostructure technologies will be addressed in this talk. One is based on self-organized growth of quantum dot materials with new formation techniques and structure designs, which are used for the realization of temperature stable high power lasers. Recent device results, e.g. based on tunnel-injection structures, and the realization of coolerless pump modules will be discussed. The second technique is based on nanolithography and high aspect ratio dry-etching, which allows the fabrication of surface defined gratings for high-speed multi-section DFB and DBR lasers. Recent results of such devices fabricated with this low-cost nanoimprint compatible fabrication technology will be presented. The work was mainly performed in the frame of two European projects (Brighter, DeLight).

Topical Talk HL 14.2 Mon 14:30 H2

High-brightness edge-emitting semiconductor lasers based on concepts of photonic band crystal and titled wave lasers — •Vladimir Kalosha, Thorsten Kettler, Kristian Posilovic, Daniel Seidlitz, Vitaly Shchukin, Nikolay Ledentsov, and Dieter Bimberg — Institute for Solid-State Physics, Technical University Berlin, Berlin, Germany

We will report on current status of the design, fabrication and performance of edge-emitting waveguide lasers and their arrays which are based on concepts of photonic band crystal (PBC) lasers and tilted wave lasers (TWL). Such lasers provide high radiation power and low beam divergence and present potentially a new elementary basis for high-brightness laser systems. Following to PBC concept, the laser is formed by multiple quasi-periodic AlGaAs layers and varying height and width of multiple stripes. As compared to typical lasers, they are characterized by an extremely large mode area and provide discrimination of high-order modes. Experimentally we have obtained a brightness of 8.7×10^7 W/cm^2/sr in pulsed regime and vertical and lateral beam quality factor $M^2 < 2$ for large range of the pump current in pulsed and cw regimes at 980 nm. Maximum power of 3.5, 10.5 and 27 W was achieved for one, three-and nine-stripe lasers, scalable with the number of stripes. Following to the TWL concept, the laser is formed by coupled narrow and broad waveguides and give rise in ultra-narrow tilted beam from the broad waveguide at proper phase-matching. Experiments have demonstrated far-field divergence of TWLs well below 1° and improved wavelength stability in wide pumping ranges.

Topical Talk HL 14.3 Mon 15:00 H2

Semiconductor optical amplifiers (SOA) for linear and nonlinear applications — •Wolfgang Freude[1], René Bonk[1], Thomas Vallaitis[1], Andrej Marculescu[1], Amita Kapoor[2], Christian Meuer[3], Dieter Bimberg[3], Romain Brenot[4], François Lelarge[4], Guang-hua Duan[4], and Juerg Leuthold[1] — [1]Inst. of Photonics and Quantum Electronics, Karlsruhe Institute of Technology, Germany — [2]On leave from Shaheed Rajguru College of Appl. Sciences for Women, Delhi, India — [3]Inst. of Solid State Physics, TU Berlin, Germany — [4]Alcatel-Thalès III-V Lab, Palaiseau, France

SOA characteristics for two selected applications are discussed, namely linear in-line amplification in gigabit passive optical networks (GPON), and fast nonlinear all-optical signal processing. As linear amplifiers, SOA feature moderate cost, low energy needs, 10 ... 25 dB gain in a bandwidth of 60 ... 120 nm, and a peak-gain range of 1.25 ... 1.60 μm.

In all-optical fast signal processing, SOA serve as regenerative wavelength converters, as nonlinear elements for four-wave mixing, and as switches. The respective application areas are determined by the SOA parameters gain, saturation power, recovery time, α-factor and noise figure.

Quantum-dot (QD) SOA are known for pattern-free amplification and fast cross-gain modulation. We demonstrate that QD SOA are also well suited as linear in-line amplifiers because of their large saturation power, wide dynamic range, large burst mode tolerance and small cross-phase modulation (XPM) due to a low α-factor. On the other hand, bulk SOA can be engineered for low saturation power and

large α-factor, which enables nonlinear signal processing via XPM.

Topical Talk HL 14.4 Mon 15:30 H2
Controlling light on the Nanoscale — •Nikolay Zheludev — University of Southampton, UK

We overview recent results on ultrafast active plasmonics, nanoscale phase change photonics, nonlinear and switchable metamaterials and tuneable free-electron light source on a chip.

15 min Coffee Break

Topical Talk HL 14.5 Mon 16:15 H2
New developments of high power LEDs and challenges in lighting applications — •Christian Fricke — Neophos Development Pte. Ltd, Jocherstr.7, 85221 Dachau

Improvement of PowerLED structures is still at a tremendous improvement rate per year. Epitaxy, chip design, phosphor efficiency and package design see large improvements - The brightness of LED devices increased by a factor of 4 over the last 4 years and will certainly continue over the next years. Light quality and device cost for LEDs that are to be marketed for home and office lighting are key to successfully replace conventional lighting by LED solutions. Only when standardized modular systems are available to the market consumers will switch at an accelerated rate. Key performance indicators will be presented as well as an outlook to individual tunable light sources fitting to existing home / office installations.

Topical Talk HL 14.6 Mon 16:45 H2
High speed VCSELs for short reach DATACOM applications — •Alex Mutig[1], James Lott[2], Sergey Blokhin[1], Gerrit Fiol[1], Alexey Nadtochiy[1], Vitaly Shchukin[3], Nikolai Ledentsov[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik und Zentrum für Nanophotonik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Federal Republic of Germany — [2]VI Systems GmbH, Hardenbergstrasse 7, 10623 Berlin, Federal Republic of Germany — [3]PBC Laser GmbH, Hardenbergstrasse 36, 10623 Berlin, Federal Republic of Germany

Around the year 2001 VCSELs emerged as the key component for up to 10 Gbit/s, aggregated high speed local-area and storage-area network data communication systems and soon thereafter for optical cable links for computer and consumer applications as well. The rapid increase in serial transmission speed and the limitations of copper wire-based links at bit rates >10 Gbit/s and distances >1 m greatly expanded the possible application areas of fiber-optic interconnects. Here we present our work on oxide-confined VCSELs operating at bit rates up to 40 Gbit/s and at low current densities of ∼10 kA/cm^2, sufficient for reliable operation. The small signal modulation bandwidths and resonant frequencies up to ∼22 GHz are measured, and the relaxation resonance frequency, damping factor, and electrical parasitic cut-off frequency are evaluated. According to our results with further improvement in the device design to reduce parasitics optical modulation bandwidths exceeding 30 GHz can be realized, leading toward reliable VCSEL serial operation at rates up to 50 Gbit/s.

Topical Talk HL 14.7 Mon 17:15 H2
Long-Wavelength Vertical-Cavity Surface-Emitting Lasers with a High-Contrast Grating — •Werner Hofmann — Technische Universität Berlin

Long-wavelength Vertical-Cavity Surface-Emitting Lasers (VCSELs) based on a subwavelength high-contrast gratings (HCGs) as output mirrors have been realized for the first time. By design, these devices are highly polarization stable, single-mode at large apertures and solve the VCSEL-mirror problem at long wavelengths in an elegant way. The device is grown on an InP substrate, incorporating a BTJ for a low electrical and optical losses and avoiding p-material. A hybrid reflector is used as bottom-mirror and the light is coupled out via the HCG reflector. With cost effective mass-fabrication in mind, the top HCG reflector consists of amorphous silicon on isolator. The single-mode laser emission is tailored to be around 1320 nm wavelength targeting applications in high-speed optical data transmission, especially for passive optical networks. The device is manufactured in a low parasitics, high-speed design, good for bandwidths well above 10 GHz. We report single-mode emission for devices with apertures as large as 11 μm operating continuous wave with output-powers in excess of 0.4 mW. Pulsed operation with output powers up to 4 mW at room temperature is demonstrated as well. This is the first electrically pumped VCSEL structure realized in this wavelength regime utilizing an HCG mirror.

HL 15: Organic Electronics and Photovoltaics II (Joint Session with DS/CPP/O)

Time: Monday 14:00–15:30 Location: H8

HL 15.1 Mon 14:00 H8
Influence of the substrate-lattice-geometry on the island shape of organic thin films — •M. Benedetta Casu[1], Britt-E. Schuster[1], Indro Biswas[1], Christoph Raisch[1], Helder Marchetto[2], Thomas Schmidt[2], T. Onur Menteş[3], Miguel A. Nino[3], Andrea Locatelli[3], and Thomas Chassé[1] — [1]IPTC, University of Tübingen, Tübingen, Germany — [2]Fritz-Haber-Institut, Berlin, Germany — [3]Sincrotrone Trieste S.C.p.A., Trieste, Italy

By using a combination of microscopic imaging and diffraction techniques with structural and chemical sensitivity, we studied the growth of diindenoperylene (DIP) on Au(100), and Au(111). Growth and structure of DIP films of different thickness were monitored in situ including real time PEEM and LEEM performed at the beamlines Nanospectroscopy at Elettra, and UE49-PGM-b-SMART at BESSY. A layer-by-layer mechanism characterizes the initial growth in both cases followed by island nucleation, i.e., the growth follows the Stranski-Krastanov mode. The islands surprisingly show a fractal-like shape when the DIP thin films are deposited on a Au(111) single crystal. DIP thin films deposited on various substrates at RT have been investigated, revealing the tendency to Stranski-Krastanov growth but the observed islands were always compact (i.e. non-fractal). In particular, real time LEEM investigations on Au(100), under the same preparation conditions as on Au(111), show compact islands. We interpret the fractal growth of DIP for these kinetic growth conditions as a consequence of the triangular symmetry of the substrate, as seen in homoepitaxial and heteroepitaxial metal on metal growth.

HL 15.2 Mon 14:15 H8
Can X-ray microspectroscopy probe inhomogeneities in the electron structure of organic devices? — •Christian Hub, Martin Burkhardt, Marcus Halik, and Rainer Fink — Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen, Egerlandstraße 3, 91058 Erlangen, Germany

The degree of homogeneity in the morphology of organic thin film devices has a major impact on the charge transport properties. Real devices usually strongly deviate from the ideal device structure since epitaxial growth with low defect concentrations cannot be achieved. We have recently started to investigate pentacene-based OFETs, which were prepared using commercial silicon nitride membranes as dielectric showing excellent transport characteristics. The overall device thickness is sufficiently small to perform scanning transmission X-ray microspectroscopy (SXTM) experiments at the PolLux microspectroscope. Grains with varying preferential orientation in the polycrystalline pentacene films are detected using the significant local NEXAFS dichroism. The local NEXAFS contrast is utilized to investigate differences in the electronic structure within these films while the devices are operated. Using the standard photomultiplier tube of the PolLux as detector no pronounced changes were observed when current is driven through the organic films. Therefore electron detection was implemented to further enhance the sensitivity of the microscope to ultrathin films. We will discuss the related problems and opportunities to use local NEXAFS with lateral resolution below 30 nm. The work is funded by the BMBF under contract 05 KS7WE1.

HL 15.3 Mon 14:30 H8
Morphology and electronic properties of an electron acceptor adsorbed on organic insulator pre-covered metal surfaces — •P. Amsalem[1], J. Frisch[1], A. Wilke[1], A. Vollmer[2], R. Rieger[3], K. Müllen[3], J.-P. Rabe[1], and N. Koch[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Brook-Taylor-Str. 6, 12489 Berlin, Germany — [2]HZB-BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany — [3]Max Planck Institut für Polymerforschung, Ackermannweg

10, 55128 Mainz, Germany

In this work, we explore the possibility of tuning the interface energetics at a pi-conjugated (electron acceptor) molecule-metal interface by modifying the adsorbate-substrate distance through pre-adsorption of insulating organic monolayers. We report a photoemission study of the growth of hexaazatriphenylene-hexacarbonitrale (HATCN) deposited on N,N-bis-(1-naphthyl)-N,N-diphenyl1-1,1-biphenyl1-4,4-diamine(α-NPD) or tris(8-hydroxyquinoline)aluminum (Alq_3) precovered Ag(111) surfaces. α-NPD and Alq_3 are known to be weakly adsorbed on Ag(111) and have both been used as thin organic spacer. The choice of HATCN has been motivated by its high electronic affinity ($\sim$3.5 eV). HATCN molecules deposited on α-NPD/Ag(111) are found to diffuse below the α-NPD molecules pre-adsorbed on Ag(111). In the case of HATCN on Alq_3/Ag(111), an interface state close to the Fermi-level is observed. This interface state differs markedly from the one measured for HATCN in direct contact with Ag(111). The results are discussed in terms of the formation of polaronic states and charge transfer across insulating layers.

HL 15.4 Mon 14:45 H8

Energy levels and work function of ultra-thin polythiophene films on conductive polymer electrodes — •Johannes Frisch[1], Antje Vollmer[2], Jürgen P. Rabe[1], and Norbert Koch[1] — [1]Humboldt-Universität zu Berlin, Institut f. Physik, Brook-Taylor-Straße 6, D-12489 Berlin — [2]Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, D-12489 Berlin

In modern organic photovoltaic cells (OPVCs), poly(ethylenedioxythiophene):poly(styrenesulfonate) (PEDT:PSS) and poly(3-hexylthiophene) (P3HT) are prototypical materials used as transparent anode and as donor polymer, respectively. In this context, it is essential to clarify how the efficiency of OPVCs based on these materials depends on the position of the energy level at the interface. In the present work, the morphology, work function, and energy level alignment of ultra-thin films of P3HT on PEDT:PSS were investigated using photoelectron spectroscopy (XPS, UPS). Ultra-thin films (down to sub-monolayer coverages) were produced by spin coating P3HT films on PEDT:PSS followed by a subsequent washing process. It has been found that the deposition of ultra-thin P3HT films on PEDT:PSS lowers the sample work function (Φ) by 0.4 eV due to doping of P3HT film with positive charges from the PEDT:PSS layer. The valence band edge (VBE) is located only 0.1 eV below the Fermi-level. For thicker P3HT films (ca. 10 nm), Φ further decreases by 0.2 eV and the VBE is observed 0.2 eV below the Fermi-level. These results are discussed within existing concepts of local work function fluctuations and energy level bending at the P3HT/PEDT:PSS interface.

HL 15.5 Mon 15:00 H8

Electronic properties of Cu-phthalocyanine-fullerene planar and bulk heterojunctions on PEDOT:PSS — •Andreas Wilke, Toshiko Mizokuro, Ralf Peter Blum, Jürgen P Rabe, and Norbert Koch — Institut für Physik, Humboldt-Universität zu Berlin, Brook-Taylor-Str. 6, D-12489 Berlin

In organic photovoltaic cells (OPVCs) typically two organic materials with electron-acceptor and electron-donor properties are placed between anode and cathode, forming either a layered planar or mixed bulk heterojunction where charge separation should occur. To improve the efficiency of this central process it is important to know and understand the energy levels at such heterojunctions, and how they may depend on heterojunction morphology. We report ultraviolet and X-ray photoelectron spectroscopy studies on layered planar and mixed bulk heterojunctions of Cu-phthalocyanine (CuPc) and C_{60}, a prototypical material pair for OPVCs. The respective heterojunctions were formed on poly(ethylene-dioxythiophene):poly(styrenesulfonate) substrates, in order to achieve morphologies comparable to those in actual OPVCs. The energy offset between the highest occupied levels of CuPc and C_{60} was determined to 1.3 eV for both the layered and mixed bulk heterojunction. Our results demonstrate that the energy levels that determined the efficiency of charge separation in OPVCs made of CuPC and C_{60} are independent of particular interface morphology, and that differences in device efficiency are due to other effects.

HL 15.6 Mon 15:15 H8

A high molecular weight donor for electron injection interlayers on metal electrodes — •Benjamin Bröker[1], Ralf-Peter Blum[1], Luca Beverina[2], Oliver T. Hofmann[3], Georg Heimel[1], Antje Vollmer[4], Johannes Frisch[1], Jürgen P. Rabe[1], Egbert Zojer[3], and Norbert Koch[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, D-12389 Berlin, Germany — [2]Department of Materials Science and INSTM, State University of Milano-Bicocca, Via Cozzi 53,I-20125 Milano, Italy — [3]Institute of Solid State Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria — [4]Helmholtz-Zentrum Berlin, Bessy II, Albert-Einstein-Str. 15, D-12489 Berlin, Germany

The molecular donor 9,9-ethane-1,2-diylidene-bis(N-methyl-9,10-dihydroacridine) (NMA) has been synthesized, and its electronic properties were characterized at interfaces to metals with photoelectron spectroscopy. Here a decrease of the sample work function is observed that becomes larger with increasing molecular coverage and clearly exceeds values that would be expected for metal surface electron "push back" alone, confirming the electron donating nature of NMA. For tris(8-hydroxyquinoline)aluminum (Alq_3) deposited on top of a NMA-modified Au(111) surface, the electron injection barrier (EIB) is reduced by 0.25 eV compared to that on pristine Au(111). Furthermore, the EIB reduction depends linearly on Θ of the donor-modified Au(111) surface, adjustable by NMA pre-coverage. Comparisons will also be given to the stronger donor MV0.
This work was supported by the EC project ICONTROL.

HL 16: Diamond

Time: Monday 16:00–17:30 Location: H13

HL 16.1 Mon 16:00 H13

Improved generation of single nitrogen-vacancy centers in diamond by ion implantation — •Boris Naydenov[1], Vladimir Richter[2], Johannes Beck[1], Matthias Steiner[1], Gopalakrishnan Balasubramanian[1], Jocelyn Achard[3], Fedor Jelezko[1], Jörg Wrachtrup[1], and Rafi Kalish[2] — [1]3 Institute of Physics, University of Stuttgart, Stuttgart Germany — [2]Solid State Institute, Technion City, Haifa Israel — [3]Laboratoire d'Ingénieurie des Matériaux et des Hautes Pressions, CNRS, F-93430 Villetaneuse, France

Nitrogen-vacancy (NV) centers in diamond have recently attracted the attention of many research groups due to their possible application as quantum bits (qubits), ultra low magnetic field sensors and single photon sources. These color centers can be produced by nitrogen ion implantation, although the yield is usually below 5 % at low ion energies. Here we report an increase of the NV production efficiency by subsequently implanting carbon ions in the area of implanted nitrogen ions. This method improves the production yield by more than 50 %. We also show that very low nitrogen concentration (below 0.1 ppb) in diamond can be determined by converting the intrinsic nitrogen atoms to single NV centers and detecting the latter using a confocal microscope.

HL 16.2 Mon 16:15 H13

Creation of nitrogen-vacancy centres in diamond with high resolution — •Sébastien Pezzagna[1], Dominik Wildanger[2], Stefan W Hell[2], Paul Mazarov[3], Andreas D Wieck[3], Boris Naydenov[4], Fedor Jelezko[4], Jörg Wrachtrup[4], and Jan Meijer[1] — [1]Rubion, Ruhr-Universität Bochum, Bochum, Germany — [2]Department of NanoBiophotonics, Max Planck Institute for Biophysical Chemistry, Göttingen, Germany — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Bochum, Germany — [4]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany

Nowadays, diamond and the nitrogen-vacancy (NV) colour centres constitute the best solid-state system in view of quantum-computing applications [1]. It has also been shown recently that single NV centres could be used as nanoscale magnetic sensors [2]. Such applications require the creation of single NV centres with very high resolution and with a high efficiency. The nano-implanter at the university of Bochum provides low energy nitrogen ions which can be implanted through a hole pierced in the tip of an atomic force microscope [3]. Ultrapure diamond samples have been implanted with spot sizes of 50nm and

less. Stimulated Emission Depletion (STED) microscopy [4] has been used to characterise and resolve the implanted spots.

[1] M. V. Gurudev Dutt et al., Science 316, 1312 (2007).
[2] G. Balasubramanian et al., Nature 455, 648 (2008).
[3] J. Meijer et al., Appl. Phys. A 91, 567 (2008).
[4] E. Rittweger et al., Nature Photonics 3, 144 (2009).

HL 16.3 Mon 16:30 H13

Nanoscale electric field sensing with a single spin in diamond — •Florian Dolde[1], Tobias Nöbauer[2], Boris Naydenov[1], Helmut Rathgen[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalische Institut Universität Stuttgart,Stuttgart,Deutschland — [2]Atominstitut österreichischer Universitäten TU Wien, Wien, Austria

We study the linear stark effect of a single nitrogen vacancy center in diamond (NV). The unique properties of the NV allow optical detection of magnetic resonance (ODMR). We use the spin of a single NV as a nano scale electric field sensor. Using pulsed experiments long coherence times are reached, such that the phase difference induced by an alternating electric field can be detected. We reached shot noise limited detection of the electric field. The nano scale sensing of electric fields has a wide range of applications in biology and material sciences.

HL 16.4 Mon 16:45 H13

Oberflächenwachstumskinetik ultrananokristallener Diamantschichten — •Hadwig Sternschulte[1], Claudia Baier[2], Slimane Ghodbane[3], Martin Fischer[4], Doris Steinmüller-Nethl[3], Matthias Schreck[4] und Ulrich Stimming[1] — [1]nanoTUM, TU München, James-Franck-Str. 1, D-85748 Garching — [2]Physik Department E19, TU München, D-85748 Garching — [3]rho-Best coating GmbH, Exlgasse 20a, A-6020 Innsbruck — [4]Institut für Physik, Universität Augsburg, D-86135 Augsburg

Ultrananokristalline Diamantschichten (UNCD) zeichnen sich durch ihre kleine, von der Schichtdicke unabhängige Korngröße von 10 nm und weniger sowie von Rauhigkeitswerten von 10-15 nm aus. Die runden, kristallinen Diamantkörner sind in einer sp^2/sp^3-Matrix ohne Vorzugsorientierung eingebettet. Proben mit solchen Eigenschaften stellen ideale Systeme dar, um dasWachstum und die Oberflächenentwicklung mit bestehenden Modellen zu vergleichen. Die ultrananokristallinen Diamantschichten wurden mit Hilfe eines hot-filament-Verfahrens in einem H_2/CH_4-Gasgemisch auf Siliziumsubstraten abgeschieden. Durch eine Variation der Bekeimungsparameter wurde die Primärnukleationsdichte zwischen $10^8/cm^2$ - $10^{10}/cm^2$ eingestellt. Die Wachstumsdauer betrug zwischen 5 und 80 min. Zur Bestimmung der Oberflächenwachstumskinetik wurden diese UNCD-Schichten mit Rasterelektronen- und Rasterkraftmikroskopie charakterisiert. Die zeitliche Entwicklung der Größe einzelner Diamantinseln, die Wachstumsrate und der Rauhigkeit in Abhängigkeit der Primärnukleationsdichte wird diskutiert und mit Simulationsrechnungen verglichen.

HL 16.5 Mon 17:00 H13

Noise characterization of diamond solution gate field effect transistors for biosensing applications — •Moritz Hauf, Lucas Hess, Martin Stutzmann, and José A. Garrido — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

Diamond, when terminated with hydrogen at the surface, shows the intriguing property of a p-type surface conductivity with a two-dimensional hole gas forming beneath the surface. If brought into electrolyte solutions, this surface conductivity can be effectively modulated by an electrode controlling the electrolyte potential. This allows for the fabrication of FETs with the electrolyte solution functioning as the gate, therefore called solution gate FETs. SGFETs show great potential for biosensing and biomedical applications due to the operation in aqueous environment. In particular, diamond is considered a suitable material due to its good biocompatibility and electrochemical inertness.

We have shown that such diamond SGFETs are capable of extracellular recording of action potentials from different cell types. For future applications, it will be highly important to have a low noise level of the SGFET for the chemical detection of single neurotransmitter vesicles. For comparison of device performance we report on the noise of SGFETs realized with different substrate materials such as diamond, graphene, Si, and GaN. For diamond, we compare different surface properties such as surface roughness or dislocation density of the diamond crystal that can contribute to the noise level.

HL 16.6 Mon 17:15 H13

Spatially resolved photoconductance of oxygen barriers on hydrogenated single crystalline diamond — •Max Seifert, Markus Stallhofer, Moritz Hauf, Gerhard Abstreiter, José A. Garrido, and Alexander W. Holleitner — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

Undoped single crystalline hydrogen-terminated diamond exhibits a p-type surface conductivity. This surface conductivity originates from a two dimensional hole gas formed due to a band bending beneath the surface. An oxygen-terminated diamond surface, however, shows no surface conductivity and therefore, thin lines with oxygen-termination can be used to form tunneling barriers within the two dimensional hole gas. We create such barriers with a lithographic width down to 50 nm by electron-beam lithography. In spatially resolved photocurrent measurements, we demonstrate that the devices can be exploited for photodetector applications at room temperature.

HL 17: Organic Semiconductors: Solar Cells I (Joint Session with DS/CPP/O)

Time: Monday 16:00–17:45 Location: H15

HL 17.1 Mon 16:00 H15

Pulsed Photocurrent Measurements in Bulk Heterojunction Solar Cells — •Markus Mingebach[1], Moritz Limpinsel[1], Alexander Wagenpfahl[1], Alexander Goldmann[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Centre of Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg

The performance of organic bulk heterojunction solar cells greatly improved during the last years up to 6% power conversion efficiency. Nevertheless very important properties such as the voltage dependent photocurrent are not fully understood yet. We investigate the photocurrent in poly(3-hexyl thiophene) (P3HT) : [6,6]-phenyl-C_{61} butyric acid methyl ester (PCBM) solar cells by applying a pulsed measurement technique (proposed by Ooi et al.) and also find a point of optimal symmetry (POS) at 0.52-0.64 V. In contrast to Ooi we identify this voltage not as the built-in voltage, but as the case of flat bands in the bulk of the cell (confirmed by macroscopic simulations). [1] To explain the voltage dependent photocurrent, we apply a combination of Onsager–Braun (polaron pair dissociation) and Sokel–Hughes (charge carrier extraction) theory in conjunction with the POS. In addition we observe and investigate a voltage-independent offset of the photocurrent, which is crucial for optimizing the device performance.

[1] M. Limpinsel, A. Wagenpfahl, M. Mingebach, C. Deibel and V. Dyakonov, Investigation of the Photocurrent in Bulk Heterojunction Solar Cells, submitted (2009).

HL 17.2 Mon 16:15 H15

Analytical analysis of the CELIV theory — •Jens Lorrmann[1], Bekele Homa Badada[2], Carsten Deibel[1], Olle Inganäs[2], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians University of Würzburg — [2]Biomolecular and Organic Electronics, IFM, Linköping University, Sweden — [3]ZAE Bayern, Div. Functional Materials for Energy Technology, Würzburg

Charge extraction by linearly increasing voltage (CELIV) has attracted much interest in organic semiconductor research, due to its feature of measuring charge carrier mobility and density directly and simultaneously. Up to now the theoretical description of this method has been solved for a low mobility approximation only, because the general solution was impeded by a Ricatti type first order differential equation. In this contribution we present the analytical solution for this Ricatti equation, thus completing the analytical framework of the CELIV method. We compare it with the approximated theory and show that especially for standard organic solar cell materials the low mobility approach is hardly valid. The evaluation of photo-CELIV mea-

surements on poly(3-hexyl thiophene-2,5-diyl):[6,6]-phenyl-C_{61} butyric acid methyl ester solar cells can then be done by fitting the current transients. Surprisingly the fit results are only in a good agreement with the experimental currents, if two extraction currents are taken into account – the origin of which we will discuss. Furthermore we present a new equation for mobility evaluation from numerical analysis within our framework, which can be applied over the entire experimental range.

HL 17.3 Mon 16:30 H15

Oxygen Induced Degradation of P3HT:PCBM Solar Cells — •Julia Schafferhans, Stefan Neugebauer, Andreas Baumann, Alexander Wagenpfahl, Carsten Deibel, and Vladimir Dyakonov — Experimental Physics VI, Faculty of Physics and Astronomy, Julius-Maximilians-University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Power conversion efficiencies of 6% for organic solar cells have already been achieved, with growing tendency. A critical issue yet to be addressed are the factors influencing the device lifetime. To gain a detailed understanding of the device stability, the underlying degradation mechanisms and their impact on the solar cell performance is an important prerequisite for lifetime enhancement. We investigated the oxygen induced degradation of state of the art (PCE > 3%) P3HT:PCBM (poly(3-hexylthiophene):[6,6]-phenyl C61 butyric acid methyl ester) solar cells in the dark as well as under simultaneous illumination. Current–Voltage measurements are supplemented by Thermally Stimulated Current (TSC) and Charge Extraction by Linearly Increasing Voltage (CELIV) measurements. In the case of dark degradation the influence of oxygen results in a decrease of the short circuit current (Isc), whereas degradation under bias light leads to a decrease of all solar cell parameters. With the aid of a macroscopic simulation we demonstrate that the origin of the loss in Isc is oxygen doping, which we confirmed by CELIV measurements. In addition, TSC and CELIV measurements revealed an increase of deeper traps and a slight decrease of the mobility due to oxygen.

HL 17.4 Mon 16:45 H15

Polaron Recombination Dynamics in Bulk Heterojunction Solar Cells — •Andreas Baumann[1], Alexander Wagenpfahl[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Centre of Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg

Organic solar cells with more than 6% power conversion efficiency were recently shown, coming closer to commercialization. For further improvements, a better understanding of the loss mechanisms inside the solar cell are needed, such as the recombination of photo-generated charge carriers. We applied the experimental technique of charge extraction by linearly increasing voltage (Photo-CELIV) to investigate the recombination dynamics in poly(3-hexylthiophene) (P3HT) : [6,6]-phenyl-C_{61} butyric acid methyl ester (PCBM) bulk heterojunction solar cells. It was found experimentally, that the dominating polaron loss mechanism in P3HT:PCBM solar cells is of Langevin type, but reduced by a factor in the range of 0.1 in pristine samples to 0.01 in annealed ones [1]. We propose a model taking the charge carriers profile inside the active layer into account, which describes the origin of the observed reduced Langevin recombination [2].

[1] C. Deibel, A. Baumann, V. Dyakonov, APL 93, 252104 (2008)
[2] C. Deibel, A. Wagenpfahl, V. Dyakonov, PRB 80, 075203 (2009)

HL 17.5 Mon 17:00 H15

Relation of open circuit voltage to charge carrier concentration in organic bulk heterojunction solar cells — •Daniel Rauh[1], Alexander Wagenpfahl[2], Carsten Deibel[2], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg — [2]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg

A deeper understanding of the open circuit voltage V_{oc} in bulk heterojunction solar cells is crucial for further performance enhancements. In order to investigate V_{oc}, we measured temperature dependent current–voltage characteristics of poly(3-hexylthiophene):[6,6]-phenyl C61 butyric acid methyl ester (P3HT:PCBM) solar cells (pristine and annealed) at various light intensities. With charge extraction measurements under the same conditions we could determine the corresponding charge carrier densities n in the operating device. Extrapolating V_{oc} to T=0K gives a constant value for all intensities indicating the effective bandgap of the donor–acceptor system. Fitting the data with V_{oc} models [1,2] showed excellent agreement with only one free parameter, the effective density of states. From our analysis, we gain insights into the recombination meachanisms limiting V_{oc}.

[1] Koster et al., Appl. Phys. Lett. 86, 123509 (2005)
[2] Cheyns et al., Phys. Rev. B 77, 165332 (2008)

HL 17.6 Mon 17:15 H15

Charge Carrier Concentration and Temperature Dependent Recombination in Polymer-Fullerene Solar Cells — •Alexander Foertig[1], Andreas Baumann[1], Daniel Rauh[2], Thiemo Gerbich[1], Vladimir Dyakonov[1,2], and Carsten Deibel[1] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Centre for Applied Energy Research (ZAE Bayern e.V.), Am Hubland, D-97074 Würzburg, Germany

We performed temperature dependent transient photovoltage and photocurrent measurements on poly(3-hexyl thiophene):[6,6]-phenyl-C_{61} butyric acid methyl ester bulk heterojunction solar cells. Thus we determined small perturbation carrier lifetime and charge carrier densities under operating conditions. We found a strongly charge carrier concentration and temperature dependent Langevin recombination prefactor. The observed recombination mechanism is discussed in terms of a bimolecular loss and compared with charge carrier extraction by linearly increasing voltage (photo-CELIV) measurements done on the same blend system. The observed charge carrier dynamics, following an apparent order larger than two, are explained by dynamic trapping of charges in the tail states of the Gaussian density of states.

HL 17.7 Mon 17:30 H15

Charge Carrier Generation Yield in Organic Solar Cells using a C80 Derivative as Acceptor — •Moritz Liedtke[1,2], Andreas Sperlich[2], Hannes Kraus[2], Andreas Baumann[2], Carsten Deibel[2], Vladimir Dyakonov[1,2], and Claudia Cardona[3] — [1]Centre for Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg, Germany — [2]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [3]Luna Innovations Incorporated, 521 Bridge Street, Danville, VA 24541 (USA)

Organic solar cells (OSC) with C_{70} and C_{80} fullerenes show a higher open circuit voltage (Voc) than the standard [6,6]-phenyl-C[61]-butyric acid methyl ester (PCBM):poly-3-hexylthiophene (P3HT) bulkheterojunction cells. Devices containing the trimetallic nitride endohedral fullerene Lu_3:N@C_{80} showed a Voc of 910mV compared to 600mV with C_{60}-PCBM. Still the overall efficiency of these cells remain below the performance of our C_{60}-PCBM:P3HT reference cells. We address the origin of the lower efficiency by means of optical, magnetic and current measurement techniques. In samples containing Lu_3:N@C_{80} we found photoluminescence quenching 3.2 times weaker, triplet yield higher and short-cut current about 2mA/cm^2 lower than in cells with C_{60}-PCBM as acceptor. We conclude that less efficient charge carrier generation in the Lu_3:N@C_{80}:P3HT bulkheterojunction system is the reason for the lower photocurrent.

HL 18: Focussed Session: Strong Light Matter Coupling I

Time: Tuesday 9:30–13:00 Location: H13

Invited Talk HL 18.1 Tue 9:30 H13

Strong light-matter interaction in quantum dot micropillar cavities — •Stephan Reizenstein, Caroline Kistner, Steffen Münch, Christian Schneider, Micha Strauss, Philipp Franeck, Arash Rahimi-Iman, Tobias Heindel, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Würzburg, Germany

Following the first demonstration of strongly coupled quantum dot

(QD)-microcavity systems enormous effort has been devoted to this field of cavity quantum electrodynamics (cQED). For applications and for fundamental cQED studies it is crucial to control the light-matter coupling strength by external parameters. To date most experimental studies involving strong coupling in QD-microcavity systems have relied on temperature tuning while electric and magnetic fields are required to fully explore their potential in terms of switching speed, local tuning and in-situ control of the interaction strength.

In this contribution, we will address recent progress in the field of strongly coupled QD-micropillar systems controlled by external parameters. For instance, it will be demonstrated that electrically contacted high-Q micropillars with large, high oscillator strength $In_{0.3}Ga_{0.7}As$ QDs in the active layer allow for electro-optical resonance tuning in the strong coupling regime. Besides, we will show that external magnetic fields can induce a transition from the strong to the weak coupling regime and provide a means to access the spin degree of freedom in magneto-optical studies.

Invited Talk HL 18.2 Tue 10:00 H13

Strong light-matter coupling in GaN based semiconductors — •Nicolas Grandjean — EPFL, Switzerland

III-V nitride semiconductors are well suited for short-wavelength optoelectronic devices such as blue light emitting diodes and laser diodes. On the other hand, III-V nitrides are quite promising for the physics of cavity-polaritons. Indeed, GaN possesses intrinsic properties like oscillator strength 10x larger than that of GaAs and exciton binding energy as large as 50 meV in ultra-thin quantum wells (QWs). As a consequence, the light matter-interaction is enhanced allowing the strong coupling regime (SCR) to be sustained at room-temperature (RT). Such characteristics have led to the first demonstration of polariton lasing at 300K.

Optical pumping experiments performed on GaN bulk MCs have already shown the potential of III-V nitride semiconductors for polariton condensation. Recent results obtained on QW-MC indicate polariton condensation at 300K with a very low threshold. As expected, the threshold is dependent on both the temperature and the detuning of the cavity mode with respect to the exciton mode.

Another interesting feature is concerned with the polarization behaviour with increasing the pump power above threshold. A depinning of the polarization is observed resulting in a progressive decrease of the polarization degree of the emitted light.

Finally, we will discuss the perspectives of GaN cavity-polaritons for device applications.

HL 18.3 Tue 10:30 H13

Higher Order Photon Bunching in a Semiconductor Microcavity — •Franziska Veit[1], Marc Assmann[1], Manfred Bayer[1], Mike van der Poel[2], and Jorn M. Hvam[2] — [1]Experimentelle Physik II , TU Dortmund , D-44221 Dortmund, Germany — [2]DTU Fotonik, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

We were able to show the statistical behaviour of photons in the single mode emission of a semiconductor microcavity by determining the correlation function $g^{(n)}$ (τ, t) of the emitted light up to fourth order. We studied the photon correlation in the weak as well as in the strong coupling regime. Our setup using a modified streak camera allowed us to directly record the photon counting statistics with picosecond time resolution. Therefore, we had the possibility to perform measurements of the photon bunching with a time resolution comparable to the coherence time of the light, allowing us to address $g^{(n)}$ (τ, t) inside the light pulses instead of just between them.
We can illustrate bunching behaviour in the strong coupling regime whereas in the weak coupling regime the cavity starts lasing and therefore the photon bunching vanishes leading to statistically independent photon emission. For the first time the n! prediction for the zero delay correlation function $g^{(n)}(\tau = 0)$ of n thermal light photons could be verified.

HL 18.4 Tue 10:45 H13

Multi-Quantum-Well Microcavity Structures for electrical excitation of Exciton-Polaritons — •Matthias Lermer[1], Arash Rahimi-Iman[1], Christian Schneider[1], Sven Höfling[1], Stephan Reitzenstein[1], Lukas Worschech[1], Alfred Forchel[1], Na Young Kim[2], and Yoshihisa Yamamoto[2] — [1]Technische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [2]E. L. Ginzton Laboratory, Stanford University, Stanford, CA 94305, USA

In semiconductor microcavities strong coupling between quantum-well (QW) excitons and cavity-photons can be realized. In low excitation regime, bosonic quasiparticles, the so called exciton-polaritons, are formed, consisting of half-light/half-matter and exhibit unique properties like stimulated scattering, Bose-Einstein-Condensation and lasing, which have been intensively investigated so far by optical excitation.

We have studied planar AlGaAs/AlAs microcavities featuring 1, 4 and 12 GaAs/AlAs QWs and investigated the strong coupling in photoluminescence and reflection for varying temperatures. To amplify the process of stimulated scattering, it is important to enhance the density of polaritons, thus in the presented work we carefully increased the number of QWs in the device. At the same time homogenous pumping of the QWs has to be ensured as it is critical for the purpose of realization of an electrically driven polariton structure. In that way we could achieve a light emitting diode operation in the strong coupling regime, namely a polariton diode. Our results show that the number of GaAs/AlAs QWs in combination with a sophisticated cavity design is of key importance for studies in the field of polaritronics.

15 Min. Coffee Break

Invited Talk HL 18.5 Tue 11:15 H13

Spectroscopy and Thermodynamics of Ultracold Excitons in a Potential Trap — •Heinrich Stolz — Institut für Physik, Universität Rostock,18051 Rostock, Germany

The condensation of Bosons into the system ground state at sufficiently low temperature in thermal equilibrium is one of the most spectacular manifestations of the quantum nature of matter and was first realized for atoms in a potential trap. Due to the general nature of the arguments, this Bose-Einstein condensation should occur in any system of quasi-particles with integer spin, the most prominent example being excitons, bound electron-hole-pair excitations in semiconductors. Especially promising have been the yellow 1S exciton states in cuprous oxide, but, despite several experimental studies of dense exciton states in this material, none of these resulted in a clear demonstration of the existence of a Bose condensed state of excitons. Recently, we have developed a theory of the spatio-spectral luminescence of excitons in a confining potential that takes both the polariton nature of the excitons and the exciton-exciton interaction into account [1]. Experimental results from a new strategy for creating a dense exciton system at low temperatures in a potential trap will be discussed with respect to these predictions. [2] H. Stolz and D. Semkat, submitted to Phys. Rev. B, cond-mat. ArXiv:0912.2010(2009).

HL 18.6 Tue 11:45 H13

Resonantly probing micropillar cavity modes by photocurrent spectroscopy — •Caroline Kistner, Stephan Reitzenstein, Kai Morgener, Christian Schneider, Sven Höfling, Lukas Worschech, and Alfred Forchel — Universität Würzburg, Technische Physik, Am Hubland, 97074 Würzburg

Compared to simple optically excited structures electrically contacted high-quality (high-Q) quantum dot-micropillar cavities provide an additional degree of freedom to either control the emission properties of the system via the quantum confined Stark-effect or to read out its optical properties by means of photocurrent (PC) spectroscopy [1,2]. This has particular implications when probing the system under strict resonant optical excitation where stray light from the excitation laser is a critical issue in resonance fluorescence studies. Here, we demonstrate the feasibility of detecting the cavity mode patterns of high-Q micropillars via PC spectroscopy. In particular, we resonantly probe the cavity resonances of electrically contacted micropillars by scanning the wavelength of the light incident on the top facet of the device and simultaneously measure the PC through the p-i-n structure using lock-in technique. At the cavity mode resonances of the micropillar the incident photons can efficiently enter the stop-band of the distributed Bragg reflectors, thus leading to an enhanced absorption of the light in the quantum dot layer which is reflected in pronounced resonances in the PC. The PC spectrum is in very good agreement with the mode spectrum obtained from micro-photoluminescence measurements.

HL 18.7 Tue 12:00 H13

Growth and characterization of II-VI-based Bragg reflectors for the blue-violet spectral region — •Sebastian Klembt, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, Semiconductor Epitaxy, University of Bremen, Otto-Hahn-Allee NW1, 28359 Bremen, Germany

The objective is to realize surface emitters for the blue to violet spec-

tral range from 400 to 460 nm using II-VI materials. For this purpose, highly reflective distributed Bragg reflectors (DBRs) are necessary. Since the standard high index material ZnSSe is absorbing at 460 nm, it has to be alloyed to achieve a higher bandgap. The investigated structures consist of ZnMgSSe layers for the high refractive index material and MgS/ZnCdSe superlattices for the low index material. One main challenge is to achieve sharp DBR interfaces when the Mg content of the quaternary ZnMgSSe layers is higher than 20%. Furthermore, the requirement of lattice matching to the GaAs substrate needs precise control of deposition parameters during the DBR growth run. High-resolution X-ray diffraction (HRXRD) measurements were performed for calibration of the composition. In order to determine the exact quarterwave thickness of each layer, the use of in-situ reflectometry turned out to be crucial.

A 16 pairs DBR with a stopband centered at 460 nm reaches a reflectivity exceeding 98%, while the stopband width is about 35 nm. Vertical resonators formed by two DBR mirrors and a cavity containing binary ZnSe quantum wells will also be discussed.

HL 18.8 Tue 12:15 H13

Influence of growth imperfections on optical properties of nitride pillar VCSEL microcavities — •Matthias Florian[1], Frank Jahnke[1], Angelika Pretorius[2], Andreas Rosenauer[2], Heiko Dartsch[2], Carsten Kruse[2], and Detlef Hommel[2] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]Institute for Solid State Physics, University of Bremen, Germany

The combination of distributed Bragg mirrors and pillar fabrication leads to photonic devices with efficient three-dimensional photon confinement for applications as low-threshold lasers and single-photon sources[1]. However, the quality of the optical mode confinement is reduced by fabrication imperfections of the underlying structure. For a Al(Ga)N/GaN micropillar system high resolution TEM investigations reveal layer-thickness gradients and fluctuations. The experimentally determined true layer profile as well as dispersion measurements for the low and high-index material are used as input for numerical calculations of the three-dimensional mode structure based on a vectorial transfer matrix approach[2]. We determine the influence of various types of structural imperfections on the reduction of the mode confinement in terms of the cavity quality factor. Furthermore, theoretical and experimental mode spectra are compared, that exhibit various confined transverse modes.

[1] H. Lohmeyer et al., Eur. Phys. J. B 48, 291–294 (2005)
[2] D. Burak and R. Binder, IEEE JQE 33, 1205–1215 (1997)

Invited Talk HL 18.9 Tue 12:30 H13

Novel polariton-based devices: Room temperature polariton laser and electrically controlled polariton parametric amplifier — •Gabriel Christmann, Stavros Christopoulos, Christopher Coulson, and Jeremy J. Baumberg — NanoPhotonics Centre, Department of Physics, University of Cambridge, CB3 0HE, UK

Semiconductor microcavities (MCs) offer a unique system for producing novel types of non linear devices. In such systems polariton parametric amplification as well as polariton lasers can be obtained. These properties combined with the recent demonstration of electrical injection of polaritons offer a great potential for device realization.

Room temperature polariton lasers will be first presented. Here such systems are fabricated from lattice-matched monolithic GaN-based multilayers, including both bulk and QW microcavities. Coherent emission with a threshold below exciton saturation density is demonstrated in both types of structures. These devices offer a new route to robust long-lived GaN lasers and also provide a new prototype system for the study of macroscopic coherent states.

Then, recent results on a biased GaAs polariton light emitting diode structure will be presented. Pump probe experiments in the parametric amplifier geometry have been performed exhibiting up to 100 fold gains. By varying the electric field across the cavity, a very strong (>90%) quenching of the optical gain is observed for a sharp resonance. This effect is ascribed to competition between the rate of Rabi-coupling and of electronic tunnelling between adjacent quantum wells and is of high potential for the realization of novel light modulators.

HL 19: Spin-controlled Transport I

Time: Tuesday 9:30–13:00 Location: H14

HL 19.1 Tue 9:30 H14

Sub-ns electrical spin control in a diluted magnetic semiconductor quantum well — •Yuansen Chen[1], Maciej Wiater[2], Grzegorz Karczewski[2], Tomasz Wojtowicz[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik and CeNIDE, Universität Duisburg-Essen, Bismarkstr.81,47057, Duisburg, Germany — [2]nstitute of Physics, Polish Academy of Science, Al. Lotnikow 32/46 02-668 Warsaw, Poland

To gain control over the spin degree of freedom is a key issue in semiconductor spintronics. We present an approach to electrically control spins on a sub-ns time scale and on a micrometer length scale in a diluted magnetic semiconductor quantum well (DMS QW). Microscale Au coils are defined atop a CdMnTe/CdMgTe DMS QW and by introducing a short current pulse through the coil, a local magnetic field can be generated enabling an electrical control of Mn2+ spin dynamics in the DMS QW. Due to the strong sp-d exchange interaction, the Mn2+ spin dynamics can be effectively probed by means of time- and polarization- resolved micro-photoluminescence measurements. Thanks to our high time-resolution, we are able to clearly separate the field induced spin alignment and the Mn2+ spin heating process . At zero external field the Mn2+ spin polarization can be switched on a time-scale of several hundred picoseconds, i.e. clearly below typical time scales expected for spin-lattice relaxation . Applying an external field of 100 mT, an additional slow component appears with typical time constants in the few 100 ns regime.

HL 19.2 Tue 9:45 H14

Time-resolved studies of current-induced spin polarization in strained InGaAs/GaAs structures — •Markus Hagedorn[1,2,3], Sebastian Kuhlen[1,3], Marten Patt[1,3], Paul Schlammes[1,3], Frederik Klein[1,3], Stefan Göbbels[1,3], Gernot Güntherodt[1,3], Mihail Lepsa[2,3], Thomas Schäpers[2,3], and Bernd Beschoten[1,3] — [1]II. Phys. Institut A, RWTH Aachen University — [2]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich — [3]JARA - Fundamentals of Future Information Technology

Understanding the mechanisms of electron spin interactions and dephasing in nonmagnetic semiconductor heterostructures are crucial for building novel spintronic devices. Conventional all-optical pump/probe methods for the creation and detection of coherent spins are nowadays supplemented by means of electrical techniques.

The underlying mechanisms which enable the so-called current induced spin polarization (CISP) are internal effective magnetic fields evoked by the broken inversion symmetry of the zinc blende structure in III-V semiconductor materials (Dresselhaus term) and, additionally, by strain in, e.g., InGaAs/GaAs heterostructures.

Applying ultrafast current pulses (time-resolved CISP) to lateral transport devices without ferromagnetic contacts, we are able to create and manipulate phase coherent spin ensembles, which are probed by Faraday rotation.

Work supported by DFG through FOR912.

HL 19.3 Tue 10:00 H14

Selective Optical Excitation of In-Plane and Out-of-Plane Spin Polarizations with Linearly Polarized Light in InGaAs — •Stefan Göbbels[1,2], Frederik Klein[1,2], Philipp Schäfers[1,2], Markus Hagedorn[1,2], Klaus Schmalbuch[1,2], Gernot Güntherodt[1,2], Thomas Schäpers[3,2], Mihail Lepsa[3,2], and Bernd Beschoten[1,2] — [1]II. Physikalisches Institut A, RWTH Aachen University, 52056 Aachen — [2]Jülich-Aachen Research Alliance, JARA - Fundamentals of Future Information Technology — [3]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich

Excitation with circularly polarized light is a standard technique for optical spin orientation in semiconductors. This method is based on the transfer of angular momentum from the photons to the electrons and yields a polar spin polarization directed along the propagation direction of the exciting laser beam.

Here we present linearly polarized all-optical pump-probe experiments to excite and detect coherent electron spins in InGaAs. We find the magnitude and the orientation of the spin polarization strongly de-

pendent on the polarization axes of the exciting light. While in general the excited spin ensemble is composed of both polar and transverse spin components, the polarization axis of the exciting light can be chosen such that polar and transverse spin components can be excited separately. Thus, selective excitation of in-plane and out-of-plane spin polarizations is feasible with linearly polarized light.

This work has been supported by DFG through FOR 912.

HL 19.4 Tue 10:15 H14

Spin-flip tunneling in quantum dots — •Lars Schreiber[1], Floris Braakman[1], Tristan Meunier[1], Victor Calado[1], Werner Wegscheider[2], and Lieven Vandersypen[1] — [1]Kavli Institute of NanoScience, Delft, The Netherlands — [2]Institute for Experimental and Applied Physics, University of Regensburg, Germany

Electron spins in a gate-defined double quantum dot formed in a GaAs/(Al,Ga)As 2DEG are promising candidates for quantum information processing as coherent single spin rotation and spin swap has been demonstrated recently. In this system we investigate the two-electron spin dynamics in the presence of microwaves (5..20 GHz) applied to one side gate. During microwave excitation we observe characteristic photon assisted tunneling (PAT) peaks at the (1,1) to (0,2) charge transition. Some of the PAT peaks are attributed to photon tunneling events between the singlet S(0,2) and the singlet S(1,1) states, a spin-conserving transition. Surprisingly, other PAT peaks stand out by their different external magnetic field dependence. They correspond to tunneling involving a spin-flip, from the (0,2) singlet to a (1,1) triplet. The full spectrum of the observed PAT lines is captured by simulations. This process offers novel possibilities for 2-electron spin manipulation and read-out.

HL 19.5 Tue 10:30 H14

Nonlinear transport effects in ferromagnetic multiple quantum well structures — •Christian Ertler[1,2] and Jaroslav Fabian[1] — [1]Institut für Theoretische Physik, Universität Regensburg, Universitätsstrasse 31, 93040 Regensburg, Germany — [2]Institut für Theoretische Physik, Karl-Franzens Universität Graz, Universitätsplatz 5, 8010 Graz, Austria

Heterostructures made of both magnetic and nonmagnetic semiconductors provide rich opportunities for controlling and tuning their spin-dependent transport properties [1]. In the case that the ferromagnetic order in the quantum wells (e.g., made of GaMnAs) is mediated by the itinerant carriers, the resonant tunneling transport and the magnetic properties become strongly interconnected [2]. Here, we show that in coupled multiple quantum well structures this can lead to interesting dynamical effects, such as self-sustained current oscillations or moving magnetoelectric domain walls. The requirements for the occurrence of these effects and for their possible experimental observation are discussed. This work has been supported by the DFG, SFB 689.

[1] J. Fabian, A. Matos-Abiague, C. Ertler, P. Stano and I. Zutic, Acta Phys. Slov. 57, 565 (2007).

[2] C. Ertler and J. Fabian, Phys. Rev. Lett. 101, 077202 (2008).

HL 19.6 Tue 10:45 H14

DC measurements on InAs two-stage spin-filter cascades — •Jan Jacob, Hauke Lehmann, Marc-Antonio Bisotti, Toru Matsuyama, Guido Meier, and Ulrich Merkt — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

For spintronics it is a prerequisite to create devices capable of generating and detecting spin-polarized currents. We present an all-semiconductor nanostructure based on an InAs heterostructure, which can be used to generate spin-polarized currents all-electrically utilizing the intrinsic spin Hall effect in a Y-shaped junction. By cascading two spin filters the first acts as a generator of spin-polarized currents while the second acts as an all-electrical detector [1]. Measurements applying an AC voltage to the two-stage spin-filter cascade have proven the feasibility of these devices as efficient generators and detectors for spin-polarized currents [2]. For the investigation of the influence of magnetic and electric fields in different directions it is essential to use DC voltages to direct the electron flow in constant direction instead of alternating directions in the AC case and thereby keeping the geometric relation between the current flow and the applied field constant. To enable lock-in technique we apply a DC voltage with AC modulation to the spin-filter cascade.

[1] A. Cummings, R. Akis, D. Ferry, J. Jacob, T. Matsuyama, U. Merkt, and G. Meier. J. Appl. Phys., **104**, 066106 (2008).

[2] J. Jacob, G. Meier, S. Peters, T. Matsuyama, U. Merkt, A. Cummings, R. Akis, and D. Ferry. J. Appl. Phys., **105** 093714 (2009).

15 Min. Coffee Break

HL 19.7 Tue 11:15 H14

The Rashba Effect in the Magnetization of an Asymmetric InGaAs/InP Quantum Well — •Benedikt Rupprecht[1], Christian Heyn[2], Hilde Hardtdegen[3], Thomas Schäpers[3], Marc A. Wilde[1], and Dirk Grundler[1] — [1]Lehrstuhl für Physik funktionaler Schichtsysteme, Physik Department, Technische Universität München, James-Franck-Strasse 1, D-85747 Garching b. München — [2]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, D-20355 Hamburg — [3]Institute for Bio- and Nanosystems (IBN-1) and JARA Jülich-Aachen Research Alliance, Research Centre Jülich GmbH, D-52425 Jülich

The measurement of the magnetic susceptibility was proposed by Bychkov and Rashba in 1984 to observe the spin splitting induced by the spin-orbit interaction (SOI) in a two-dimensional electron system (2DES). The detection of the corresponding beatings in the magnetization M is experimentally challenging. Magnetization data obtained on a high mobility 2DES in an AlGaAs/GaAs heterostructure revealed these beatings in M only at high tilt angles δ between the sample normal and the external field B. By using micromechanical cantilever magnetometry we were able recently to measure the magnetization of an asymmetric InGaAs/InP quantum well showing SOI induced beating patterns in M at small δ. From the data we extract the bandstructure parameters effective mass m^*, Landé g-factor g^* and Rashba parameter α_R. The work was supported via SPP 1285 "Halbleiter-Spintronik" (GR1640/3) and the German Excellence Cluster "Nanosystems Initiative Munich" (NIM).

HL 19.8 Tue 11:30 H14

Interplay of Intrinsic and Extrinsic Mechanisms to the Spin Hall Effect in a Two-Dimensional Electron Gas — •Peter Schwab[1] and Roberto Raimondi[2] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]CNISM and Dipartimento di Fisica, Università Roma Tre, Via della Vasca Navale 84, 00146 Roma, Italy

In recent years spin-orbit interaction in semiconductors has attracted considerable attention due to its potential for controlling the spin degrees of freedom by electric fields. The spin Hall effect due to the structure inversion asymmetry (Rashba term) has been intensively studied, and it has been established that the spin Hall current vanishes in the static limit. The situation is different when both extrinsic and intrinsic effects are present. We provide a theory for this situation.

We derive drift-diffusion equations for the spin density in the presence of intrinsic spin-orbit coupling as well as skew scattering and side-jump contributions (extrinsic effects). We calculate the electric-field induced spin polarization and the spin Hall conductivity. First, the result by Edelstein for the spin polarization is strongly modified by the presence of the extrinsic spin-orbit interaction. Second, our expression for the spin Hall conductivity correctly reproduces the known limits. For realistic parameters the spin Hall conductivity is mainly due to the side-jump contribution.

[1] R. Raimondi, P. Schwab, EPL **87**, 37008 (2009).

HL 19.9 Tue 11:45 H14

Spin Hall drag in electronic bilayers — •Samvel M. Badalyan[1,2] and Giovanni Vignale[3] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Radiophysics, Yerevan State University, 1 A. Manoukian Street, Yerevan, 375025 Armenia — [3]Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA

In electronic bilayers an electric current, driven in one of the layers, induces via inter-layer Coulomb scattering a charge accumulation in the other layer. This phenomenon known as Coulomb drag is of fundamental interest as a probe of electron correlations. Another effect of great interest is the Spin Hall Effect, i.e. the generation of spin accumulation by an electric current. This is due to spin-orbit interactions and has recently received great attention for its usefulness as a source of spin-polarized currents. Here we predict a new effect in electronic bilayers: spin Hall drag. The effect consists of the generation of spin accumulation across one layer by an electric current along the other layer. It arises from the combined action of spin-orbit and Coulomb interactions. Our theoretical analysis identifies two main contributions

to the spin Hall drag resistivity: the side-jump contribution, going as T^2, and the skew-scattering contribution, as T^3. The induced spin accumulation, while generally quite small, should be observable in optical rotation experiments.

Work is supported by EU Grant PIIF-GA-2009-235394, SFB Grant 689, and NSF Grant No. DMR-0705460.

HL 19.10 Tue 12:00 H14

The spin-dependent recombination between phosphorus donors in silicon and Si/SiO_2 interface states — •Felix Hoehne[1], Hans Huebl[2], Bastian Galler[1], Christian Huck[1], Christoph Pellinger[1], Martin Stutzmann[1], and Martin Brandt[1] — [1]Walter Schottky Institut, München — [2]Walther-Meissner-Institut, München

Electrically detected magnetic resonance (EDMR) is a well known tool to detect small numbers of spins. In this approach to spin resonance, the spin state is transferred to a charge state via a spin-dependent process governed by the Pauli principle involving two paramagnetic states. So far, the identification of such correlated states has only been achieved indirectly in EDMR. Here, we investigate the spin species relevant for the spin-dependent recombination used for the electrical readout of coherent spin manipulation in phosphorus-doped silicon. Via a multi-frequency pump-probe experiment in pulsed electrically detected magnetic resonance, we demonstrate that the dominant spin-dependent recombination transition occurs between phosphorus donors and Si/SiO_2 interface states. Combining pulses at different microwave frequencies allows us to selectively address the two spin subsystems participating in the recombination process and to coherently manipulate and detect the relative spin orientation of the two recombination partners.

Financial support by SFB 631 is gratefully acknowledged.

HL 19.11 Tue 12:15 H14

Anisotropic electron spin relaxation in bulk GaN — •Jan Heye Buss, Jörg Rudolph, and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr Universität Bochum, Germany

The wide-gap semiconductor GaN has attracted growing interest during the last years. Besides its potential for short-wavelength optoelectronics, the spin related properties make GaN a promising material for spintronics.[1] Above room-temperature ferromagnetism is predicted for rare-earth or transition-metal doping,[2] and due to the weak spin-orbit coupling long spin relaxation times are expected. We investigate the electron spin dynamics in n-type c-oriented wurtzite GaN epilayers by time-resolved Kerr-rotation measurements at $T = 80$ K. The electron spin lifetime shows a sudden increase if an external magnetic field is applied in the sample plane. This enhancement is explained by anisotropic Dyakonov-Perel spin relaxation in bulk GaN as a direct consequence of the special anisotropy of spin-orbit coupling in semiconductors with wurtzite structure.[3]

[1] I. Zutic et al., Rev, Mod. Phys. **76**, 323 (2004)
[2] T. Dietl et al., Science **287**, 1019 (2000)
[3] J. H. Buss et al., Appl. Phys. Lett. **95**, 192107 (2009)

HL 19.12 Tue 12:30 H14

Spin correlations due to Dyakonov-Perel and spin noise spectroscopy in semicoductor quantum wells — •Tobias Hartenstein, Michael Krauss, and Hans Christian Schneider — Department of Physics and Research Center OPTIMAS Kaiserslautern University of Technology,PO Box 3049, 67653 Kaiserslautern, Germany

We present a theoretical investigation of dynamical electronic spin-spin correlations in quantum wells resulting from the Dyakonov-Perel mechanism due to electron-impurity interactions in the presence of external magnetic fields. We set up the coupled equations of motion for the different spin-spin correlation functions, and solve them numerically. Since spin-noise measurements are sensitive to the spin-spin correlation functions, our results provide a microcscopic basis for this measurement technique [1], but also allow us to study how the Dyakonov-Perel relaxation mechanism affects non-trivial electronic spin correlations and correlation waves that can be induced by the absorption of non-classical polarization-squeezed light [2].

[1] G. M. Müller, M. Römer, D. Schuh, W. Wegscheider, J. Hübner, and M. Oestreich, Phys. Rev. Lett **101**, 206601 (2008).
[2] E. Ginossar, Y. Levinson, and S. Levit, Phys. Rev. B **78**, 205204 (2008)

HL 19.13 Tue 12:45 H14

Fourth-order frequency correlation spectroscopy at radio-frequencies — •Sebastian Starosielec, Rachel Fainblat, Jörg Rudolph, and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany

The study of fluctuations, like e.g. Spin Noise Spectroscopy has proved to be a valuable tool for determining intrinsic properties of dynamical systems even in thermal equilibrium. The measurement of higher order correlations, like the "noise of the noise", promises the access to additional hidden dynamics in the fluctuating signals. We find that higher order correlations are useful for characterizing e.g. the dynamics of a noise-driven nonlinear system or the critical dynamics of systems around a phase transition. The measurement of the covariance of noise intensity at different frequencies is especially appealing, since recent developments in parallel computing on commercially available graphics hardware allow the calculation of two-dimensional correlation spectra of fourth order. Depending on frequency range and resolution, high coverage rates up to real-time processing may be achieved at sample rates up to 180 MHz. As a demonstration, we find strong correlations in frequency modulated radio signals and investigate thermal resistor noise. We envision application to the study of magnetic phase transitions, incoherent spin waves, spin noise in semiconductors, and $1/f$ noise in various devices. The latter is of high interest since the origin of $1/f$ noise is still debated, and higher order correlations might distinguish between proposed mechanisms.

HL 20: Organic Semiconductors: Transistors and OLEDs

Time: Tuesday 9:30–12:45 Location: H15

HL 20.1 Tue 9:30 H15

Ionic liquid gated polymer transistor — •Johannes Schöck, Daniel Secker, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7/A3, D-91058 Erlangen, Germany

We fabricate field-effect transistors with a polymer semiconductor using an ionic liquid top-gate, replacing the gate insulator. The geometry is bottom contact, liquid top gate. Electrical characterization yields a low conductance threshold of the device (~ -2.5 V), and a steep increase of the source-drain current. An analysis points towards unusually high charge carrier mobility of the semi-conducting channel, with very favorable leakage currents through the gate. Strong hysteretic effects are observed.

HL 20.2 Tue 9:45 H15

Electrolyte-gated organic thin film transistors — •Felix Buth[1], Marin Steenackers[2], Deepu Kumar[1], Martin Stutzmann[1], and Jose Antonio Garrido[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Institute for Advanced Study, Technische Universität München, Arcisstr. 21, 80333 München, Germany

Organic semiconductors are today widely used as the active material in several applications based on thin film transistors. For most of these devices large operational voltages are required. One approach to reduce the gate voltage is increasing the capacitance of the gate dielectric. Several materials, including high-k dielectrics, ultra-thin cross-linked polymers or polyelectrolytes have been tested for this purpose. Among those, polyelectrolytes offer extraordinarily high capacitances with a relatively low technology cost. The high capacitance results from the electrical double layer formed at the polyelectrolyte/semiconductor interface, opening the possibility of using organic thin film transistors for biological and chemical sensors, in which in-electrolyte operation is required. Since, however, water stable organic semiconductors are generally deposited by evaporation in

UHV, the surface of the polyelectrolyte needs to be smooth to enable the growth of high quality films. In this contribution the properties of different polyelectrolyte dielectrics are investigated. We show how polyelectrolytes can be directly prepared on conductive substrates, resulting in homogeneous films with high interfacial capacitances. Furthermore, we show the preparation of high quality pentacene thin films onto the polyelectrolyte films.

HL 20.3 Tue 10:00 H15

Molecular weight dependent short channel effect in MDMO-PPV — •Ali Veysel Tunc, Elizabeth von Hauff, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

In this study, organic field effect transistors (OFETs) based on poly [2-methoxy,5-(3',7'-dimethyl-octyloxy)]-p-phenylene vinylene (MDMO-PPV) with two different weight-average molecular weights (Mw) were fabricated and the effect of the molecular weight on the device properties was investigated. It was observed that the operation performance of the OFET depends on the molecular weight and channel length. The short channel effect was observed, i.e. a lack of saturation in the output characteristic with a fixed gate voltage. We found that the saturation behavior and hole mobility of a given material strongly depend on molecular weight. Short channel effects were observed in higher molecular weight for MDMO-PPV. The hole mobility around 10 times better for higher molecular weight that has been shown in literature.

HL 20.4 Tue 10:15 H15

Electron Mobility in Methanofullerens — •Maria S Hammer[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 W\"urzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg

Methanofullerenes are the state of the art acceptor-type semiconductors applied in flexible and printed electronic devices, e.g. they are used together with a donor-type polymer in (i) solar cells or (ii) complementary circuits. While the hole transport in polymers has been intensely investigated within the last years, less attention has been drawn to the fundamentals of the transport within methanofullerenes. In the present study, the electron mobility, which strongly depends on the electron density, is investigated.

We utilize the organic field effect transistor (OFET) as it provides a way of probing the mobility within a wide range of electron densities via gate voltage. Nevertheless, the performance of an OFET sensitively depends on electron injection from the contacts and trapping at the dielectric interface. Therefore, in order to assess the transport parameters of methanofullerenes, it is indispensable to vary the work function of the electrodes as well as the insulator. We will investigate and discuss the ambipolar charge transport in dependence of the charge carrier density in [6,6]-phenyl-C61-butyric acid methyl ester and other derivatives, employing a variation of dielectric surfaces and injecting metals.

HL 20.5 Tue 10:30 H15

Correlation between the effective contact resistance and the charge carrier transport in organic semiconductors of different mobility — R. Winter[1], F. Wörner[1], M.S. Hammer[1], C. Deibel[1], and •J. Pflaum[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University, 97074 Würzburg — [2]Bavarian Center For Applied Energy Research, 97074 Würzburg

In this presentation we address questions on the impact of the charge carrier mobility on the injection behavior in organic thin film transistors (OTFTs). Though many theoretical models treat the contact resistance, R, and the mobility, μ, independently, we demonstrate a significant correlation between these two quantities for P3HT and pentacene. Corresponding TFT measurements have been performed between 40 - 300K. To modify the effective contact resistance, monolayers of different oligoacenes were deposited between the Au bottom contacts and the active organic transport layer. Despite significant differences in the room temperature mobilities, 10^{-4}cm^2/Vs for P3HT and 10^{-2}cm^2/Vs for pentacene, the temperature dependent variations of the mobility as well as of the effective contact resistance prove to be similar. For both materials a change in the slope of the R(T) and μ(T)-slope can be detected. However, the cross-over temperature for pentacene amounts to 80K whereas that for P3HT is shifted to 185K. We will discuss this observation in the context of a balanced transport, i.e. that the injection at the metal contact interfaces is strongly related to the charge carrier transport in the semiconducting layer.
Financial support by BMBF (project GREKOS) is acknowledged.

HL 20.6 Tue 10:45 H15

Thickness dependence of contact and sheet resistance of thiophene and pentacene based organic field effect transistors — •Torsten Balster, Steve Pittner, Dagmawi Belaineh, Arne Hoppe, and Veit Wagner — School of Engineering and Science, Campus Ring 1, Jacobs University Bremen, 28759 Bremen, Germany

The electrical properties of evaporated organic semiconductors in dependence on the film thickness are affected by the growth mode of the thin film. While dihexyl-substituted oligothiophenes (DHnT) show a typical layer-by-layer growth mode on hexamethyldisilazane(HMDS)-treated silicon oxide, pentacene exhibits 3-dimensional growth. The growth mode as determined by AFM investigations is also reflected in the integral in-situ IV-measurements during growth. DHnT shows oscillatory behaviour in the mobility and the contact resistance within the first two monolayers, whereas the pentacene saturates without oscillations for 10nm. The total contact resistance with gold electrodes has been evaluated by the transfer line method. Furthermore the potential barriers at source and drain contact are determined separately by a four probe setup. For this purpose, additional sense fingers are prepared within the channel allowing the direct access to the channel potential. Major contact effects are identified for channel length smaller than 10 microns.

HL 20.7 Tue 11:00 H15

Semiconducting Thin Films of Fluorinated and Unsubstituted Phthalocyanines for Applications in Organic Field Effect Transistors — •Harry Brinkmann[1], Christopher Keil[1], Olga Tsaryova[2], Dieter Wöhrle[2], and Derck Schlettwein[1] — [1]Institute of Applied Physics, Justus-Liebig-University Giessen, Germany. email:schlettwein@uni-giessen.de — [2]Institute of Organic and Macromolecular Chemistry, University of Bremen, Germany.

Perfluorinated phthalocyanines ($F_{16}Pc$) show n-type characteristics as active layers in organic field transistors while organic field transistors with unsubstituted phthalocyanines (Pc) exhibit p-type characteristics. The growth of $F_{16}Pc$ and Pc films has been studied in OFETs on organic (polyimide, $PMMA$) and inorganic insulating layers (SiO_2) with different surface modifications ($HMDS$ treatments). We report here about the dependence of the growth mode of the films and the field effect mobility on the used substrate for the copper complexes. The development of the electrical conduction was studied in-situ during film growth and the field effect mobility was determined for various film thicknesses in different regimes of the Stranski-Krastanov growth mechanism that led to the formation of ultrathin conductive layers in the monolayer range followed by reorganization towards island growth. Optical absorbance was measured in reflection or transmission in dependence of the used substrate to investigate details of the intermolecular coupling.

15 Min. Coffee Break

HL 20.8 Tue 11:30 H15

Carrier density in a Gaussian density of states: Approximation for the Gauss- Fermi integral — •Gernot Paasch[1] and Susanne Scheinert[2] — [1]IFW Dresden — [2]TU Ilmenau

The density of hopping transport states in organics can be approximated by a Gaussian DOS. As a consequence, the mobility becomes a function of carrier density, field and of course temperature. Such dependencies can now be implemented easily in advanced device simulation programs as Sentaurus Device. However, the carrier density as function of the Fermi energy is not taken into account until now. For inorganic semiconductors with a square root DOS the situation was similar with the carrier density expressed by the Fermi- Dirac integral F1/2. Further Fermi-Dirac integrals are needed for the electronic energy density and for Einstein's relation. For these cases analytical approximations have been developed early allowing for fast simulation. For the Gaussian DOS the carrier density is given by the integral over the product of Gaussian DOS and Fermi-Dirac distribution, the Gauss-Fermi integral. Related integrals describe the electronic energy density and occur in Einstein's relation. Here we present an extremely simple and accurate approximation for the Gauss-Fermi integral and discuss its potential applicability in simulation of organic devices.

HL 20.9 Tue 11:45 H15

Comparative transport studies in Bridgman and sublimation grown 9,10-Diphenylanthracene single crystals. — •Andreas Steindamm[1], Ashutosh K. Tripathi[2], Rainer Stöhr[3], Jörg Wrachtrup[3], and Jens Pflaum[1] — [1]Institute of Experimental Physics VI, Julius-Maximilians-University, 97074 Würzburg, Germany — [2]Holst Centre/TNO, 5656 AE Eindhoven, NL — [3]Physikalisches Institut, University of Stuttgart, 70550 Stuttgart, Germany

To improve organic electronic applications, knowledge about microscopic mechanisms determining the charge carrier mobilities is pivotal. 9,10-Diphenylanthracene (DPA) has been identified as model system to study those correlations due to its high electron and hole mobilities at room temperature [1] and its complex structural phase behaviour. We will demonstrate our temperature dependent Time-Of-Flight data on single crystals grown by vapor phase transport (VPT) and by Bridgman growth technique. Both preparation techniques revealed crystals of different morphologies resulting in significant variations of the related bipolar mobilities. As a key result, the charge carrier mobility of $\sim 1 cm^2/Vs$ at room temperature along the (111)-direction of Bridgman crystals exceeds that along the (001)-direction of VPT grown crystals by about one order of magnitude. The observed differences in the mobility data will be discussed in the context of the microscopic molecular arrangement within the respective crystal structure. Financial support by BMBF (project GREKOS) is acknowledged.

[1] Tripathi A. K. et al., Adv. Mater. 19 (2007) 2097

HL 20.10 Tue 12:00 H15

Probing charge carrier dynamics in conducting polymers using single molecules as sensors — •Maximilian Nothaft[1], Steffen Höhla[2], Aurélien Nicolet[3], Jens Pflaum[4], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Phys. Ins., Univ. Stuttgart — [2]Chair of Display Technology, Univ. Stuttgart — [3]MoNOS, Huygens Laboratory Leiden — [4]Exp. Phys. VI, Univ. Wuerzburg and ZAE Bayern

Doping of conducting polymers by guest molecules is widely applied in organic light emitting devices to improve their efficiency. By reducing the concentration of suited guest molecules it becomes possible to study the dynamics of single molecule emitters using confocal microscopy.

In our contribution we discuss the optical properties of single Dibenzoterrylene dye molecules dispersed in an OLED consisting of PPV as host material. It will be shown how to prepare devices of photostable single molecules in PPV emitting a constant flux of single photons at room temperature by excitation from a Ti:sapphire laser.

By simultaneous laser excitation and electrical operation it is possible to detect the effect of injected charge carriers on the dynamics of single quantum emitters. Since the ratio of singlet to triplet exciton formation in the device is 1:3, this leads to an effective pumping to the triplet state of the single molecule thereby reducing its fluorescence intensity. Modeling this process it becomes possible to associate the reduced fluorescence intensity with the local current density at the position of the molecule. This correlation enables us to optically probe the current density in an OLED with nm spatial resolution.

HL 20.11 Tue 12:15 H15

Energy band alignment at the oxide-organic interface ITO/ZnPC determined by photoelectron spectroscopy — •Jürgen Gassmann and Andreas Klein — Surface Science Department, Istitute of Materials Science, TU Darmstadt, Germany

The possibility to generate light on the front- and backside of an organic light-emitting diode (OLED) is given for inverted top-emitting OLEDs. For them the transparency of the back contact is crucial. Here transparent conductive oxides (TCO) like indium tin oxide (ITO) or zinc oxide are of special interest, because these films can be deposited with magnetron sputtering at room temperature. In this work the energy band alignment between the organic material zinc phthanalocyanine (ZnPC) and the transparent oxide ITO is evaluated. For this the X-ray photoelectron spectroscopy technique (XPS) is used and combined with an in-situ preparation of the films. The energy band alignments of the deposition sequences ITO on ZnPC and vice versa are compared. Here valence band offsets up to 1.3eV can be detected. The energy band alignment shows a strong dependence on the deposition sequence. Additionally the electrical and optical properties of ITO films sputtered at room temperature are investigated.

HL 20.12 Tue 12:30 H15

Highly efficient white top-emitting organic light-emitting diodes with forward directed light emission — •Patricia Freitag, Sebastian Reineke, Mauro Furno, Björn Lüssem, and Karl Leo — Institut für Angewandte Photophysik, TU Dresden, George-Bähr-Straße 1, 01069 Dresden, Germany

The demand for highly efficient and energy saving illumination has increased considerably during the last decades. Organic light emitting diodes (OLEDs) are promising candidates for future lighting technologies. They offer high efficiency along with excellent color quality, allowing substantially lower power consumption than traditional illuminants. Recently, especially top-emitting devices have attracted high interest due to their compatibility with opaque substrates like metal sheets. In this contribution, we demonstrate top-emitting OLEDs with white emission spectra employing a multilayer hybrid cavity structure with two highly efficient phosphorescent emitter materials for orange-red (Ir(MDQ)2(acac)) and green (Ir(ppy)3) emission as well as the stable fluorescent blue emitter TBPe. To improve the OLED performance and modify the color quality, two different electron blocking layers and anode material combinations are tested. Compared to Lambertian emission, our devices show considerably enhanced forward emission, which is preferred for most lighting applications. Besides broadband emission and angle independent emission maxima, power efficiencies of 13.3 lm/W at 3 V and external quantum efficiencies of 5.3% are achieved. The emission shows excellent CIE coordinates of (0.420, 0.407) at approx. 1000 cd/m2 and color rendering indices up to 77.

HL 21: Quantum Dots and Wires, Optical Properties I: Nitrides

Time: Tuesday 9:30–11:15 Location: H17

HL 21.1 Tue 9:30 H17

Theory for Optical Properties of Nitride-based Quantum Dot Systems — •Kolja Schuh, Michael Lorke, Jan Seebeck, Stefan Schulz, Paul Gartner, Gerd Czycholl, and Frank Jahnke — Institute for Theoretical Physics, University of Bremen, Germany

The influence of structural properties and interaction-induced effects on optical spectra of self-assembled Nitride-based quantum-dot (QD) systems is analyzed within a microscopic theory. Beside the QDs, the wetting-layer (WL) plays an important role for laser applications since it is involved in the carrier generation and scattering processes, which modify the optical properties of the QDs. The single-particle properties are determined on an atomistic level from tight-binding calculations [1]. Coulomb interaction effects and carrier-phonon interaction are considered in a second step to study excitation-induced effects for elevated carrier densities at room temperature.

Numerical results are presented for InN/GaN QD-WL systems. Nearly degenerate top valence-subbands lead to strong subband mixing [1, 2]. We also find modified dipole selection rules with a dark ground state exciton and rather strong excitation-induced line shifts of the QD transitions in addition to the excitation-induced line-broadening [3]. While these results are masked in conventional lasers due to strong inhomogeneous broadening, they are directly relevant for the application of QDs in microcavity lasers.

[1] S. Schulz et al., Phys. Rev. B 73, 245327(2006)
[2] S.L. Chuang et al., Phys. Rev. B 54, 2491(1996)
[3] M. Lorke et al., APL 95, 081108 (2009)

HL 21.2 Tue 9:45 H17

Polarization-induced charge carrier separation in GaN quantum dots on polar and nonpolar surfaces — •Oliver Marquardt, Tilmann Hickel, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Düsseldorf

Wurtzite III-nitride quantum dots (QDs) show a strongly reduced light emission efficiency when grown in the polar direction, due to strong built-in potentials which spatially separate electrons and holes, leading to weak recombination rates. To overcome this problem, QDs grown

on nonpolar substrates have received much research interest, recently. We have compared GaN QDs grown on polar and nonpolar surfaces using an eight-band $\mathbf{k}\cdot\mathbf{p}$ model, employing geometries observed in recent experimental studies. Our studies indicate that the spatial separation of electrons and holes is even larger in QDs on nonpolar surfaces than in polar ones of comparable size, leading to even weaker recombination rates. A systematic investigation of various modifications on the above reference systems allowed us to identify the size of nonpolar QDs as the key parameter to achieve a higher efficiency in light emission processes. In particular, it has been found that this effect is stronger in nonpolar than in polar QDs by several orders of magnitude, making nonpolar QDs a promising research object for future light emission devices.

HL 21.3 Tue 10:00 H17

Microphotoluminescence Investigations of Single Group-III-Nitride Quantum Dots — •Stefan Werner, Christian Kindel, Thomas Switaiski, and Axel Hoffmann — Institut für Festkörperphysik, Technische Universität Berlin

The optical research of single InGaN quantum dots is difficult due to the fact that their emission lines are significantly broadened. The emission energies of wurtzite InGaN QDs are strongly influenced by fluctuating electric fields, resulting in line-width broadening. We present spatially- and time-resolved photoluminescence measurements of single InGaN/GaN quantum dots. Therefore, a new microphotoluminescence setup was built. In order to investigate the behavior of different excitonic complexes and their recombination dynamics, power, polarization and time-dependent measurements were performed. Some lines saturate at high-power excitation, giving an indication for exciton-like behavior. Others have a super-linear intensity increase. Those lines might be biexcitionic. Most emission lines showed a strong linear polarization but with different polarization angels. That fact helps to assign the lines to different quantum dots. The presented time-resolved PL measurements might give addional informations about the origin of the observed emission lines. For some lines, the decay time is increased by a factor of 2 in respect to other lines, indicating biexcitionic behavior.

HL 21.4 Tue 10:15 H17

Electroluminescence from an isolated single InGaN QD up to 150 K in the green spectral region — •Joachim Kalden, Christian Tessarek, Kathrin Sebald, Stephan Figge, Carsten Kruse, Detlef Hommel, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

Semiconductor quantum dots (QDs) are known to be favourable for solid state single photon sources. As state-of-the-art detectors have their efficiency maximum in the green spectral region, InGaN QDs are particularly suitable to realize such devices, providing emission in the visible spectral range. However, only few reports exist on the electroluminescence (EL) of nitride QDs. We present EL from a p-i-n diode containing InGaN QDs as active layer. The onset bias is 3.15 V at room temperature (RT), which is raised to 8.8 V at 4 K mainly due to carrier freeze-out effects. The intensity at RT remains at 28% of the intensity at 4 K. Further, slope variation or shift of the ensemble EL are shown to be negligible at RT for driving currents from 10 mA to 150 mA. This demonstrates the excellent stability of the EL. At 4 K and for a constant driving current of 19 mA, sharp emission lines are detectable nearly background-free at the lower energy tail of the emission band. EL from an isolated single InGaN QD emitting at 527 nm is obtained from 4 – 90 K. From 100 K onwards, the distinct QD emission is still visible may be traced up to 150 K as a shoulder on a raising background. These results hold much promise for future electrically driven single photon emission at room temperature.

HL 21.5 Tue 10:30 H17

Electronic and optical properties of nitride semiconductor quantum dots with wurtzite structure — •Stefan Barthel, Daniel Mourad, and Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen, 28359 Bremen

A multiband empirical tight-binding model for group-III-nitride semiconductors with a wurtzite structure has been developed and applied to the calculation of the electronic and optical properties of (embedded) InN/GaN quantum dots. As a minimal basis set we assume one s-orbital and three p-orbitals localized in the unit cell of the hexagonal Bravais lattice, from which one (s-like) conduction band and three (p-like) valence bands are formed. Non-vanishing matrix elements up to second nearest neighbors are taken into account. These matrix elements are determined so that the resulting tight-binding band-structure reproduces the known Γ-point parameters. Furthermore, the tight-binding band-structure is also fitted to the band energies at other special symmetry (boundary) points of the Brillouin zone (known, in particular, from recent first-principles GW-calculations). These matrix elements allow for supercell calculations of the electronic properties of single and coupled quantum dots and for a separate wetting layer (quantum well) treatment. Crystal-field-splitting, spin-orbit coupling and the influence of intrinsic fields (spontaneous polarization, etc.) can be taken into account. The calculation of dipole and Coulomb matrix elements allows for the determination of excitonic spectra and selection rules within the configuration interaction (CI) scheme.

HL 21.6 Tue 10:45 H17

Complete Study of Excitonic Fine-Structure Splitting in GaN/AlN Quantum Dots — •Gerald Hönig[1], Momme Winkelnkemper[1], Andrei Schliwa[1], Axel Hoffmann[1], Dieter Bimberg[1], Christian Kindel[1,2], Satoshi Kako[3], Takeshi Kawano[2], Hiroaki Oishi[2], and Yasuhiko Arakawa[2,3,4] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany — [2]Research Center for Advanced Science and Technology, University of Tokyo, Japan — [3]Institute for Nano Quantum Information Electronics, University of Tokyo, Japan — [4]Institute of Industrial Science, University of Tokyo, 4-6-1 Komaba, Meguro, Tokyo 153-8505, Japan

A detailed understanding of the excitonic fine structure in quantum dots (QDs) is indispensable for their use in quantum cryptography devices. While the fine structure in As-based QDs has been studied extensively, there is a lack of such investigations for N-based QDs, which might operate at room temperature. We present the first complete study of excitonic fine-structure splitting (FSS) in GaN/AlN QDs. Our experimental studies reveal a huge FSS of up to 7meV with a strong dependence on the emission energy inverse to that in As-based QDs. Our theoretical studies, performed with a configuration-interaction method based on realistic 8-band-$k\cdot p$ Hartree-Fock states, confirm the experimental results and identify the origin of FSS as lattice strain induced. Based on our results it is possible to induce a strain gradient (by micro mechanic techniques or structuring methods), which will reduce the FSS to zero for the emission of entangled photon pairs.

HL 21.7 Tue 11:00 H17

Optical properties of GaN/AlGaN heterostructures embedded in GaN nanowires — Florian Furtmayr[2], •Jörg Teubert[1], Pascal Becker[1], Martin Stutzmann[2], and Martin Eickhoff[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, 34392 Gießen, Germany — [2]Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

A fascinating property of self-assembled III-N nanowires grown by molecular beam epitaxy (MBE) is their high crystal quality as it provides the possibility to perform fundamental studies of the material properties without the perturbing influence of structural defects. In this context, heterostructures such as quantum wells embedded in nanowires are of special interest. We report on structural and optical properties of $GaN/Al_xGa_{1-x}N$ nanowires with embedded GaN nanodisks grown by plasma assisted MBE on Si(111) substrates. Lateral overgrowth with the AlGaN barrier material during the synthesis of multi quantum-disk structures leads to the formation of a core-shell system that influences the mechanical strain in the quantum well regions. The effect on the optical properties of multi quantum-disk structures was investigated by temperature dependent photoluminescence measurements on samples with different structural parameters. The results will be discussed in terms of carrier confinement, strain and piezoelectric effects and will be compared to theoretical simulations.

HL 22: Graphene 2 (Joint Session with TT)

Time: Tuesday 9:30–12:45 Location: H21

HL 22.1 Tue 9:30 H21

Relativistic quantum Corbino effect in graphene — •Adam Rycerz — Institut für Theoretische Physik, Universität Regensburg, D–93040, Germany — Marian Smoluchowski Institute of Physics, Jagiellonian University, Reymonta 4, PL–30059 Kraków, Poland

Electron transport through the Corbino disk in graphene is studied in the presence of uniform magnetic fields. At the Dirac point, we observe conductance oscillations with the flux piercing the disk area Φ_d, characterized by the period $\Phi_0 = (2h/e)\ln(R_o/R_i)$, where R_o (R_i) is the outer (inner) disk radius. The oscillations magnitude increase with the radii ratio and exceed 10% of the average conductance for $R_o/R_i \geqslant 5$ in the case of the normal Corbino setup, or for $R_o/R_i \geqslant 2.2$ in the case of the Andreev-Corbino setup. At a finite but weak doping, the oscillations still appear in a limited range of $|\Phi_d| \leqslant \Phi_d^{max}$, away from which the conductance is strongly suppressed. At large dopings and weak fields we identify the crossover to a ballistic transport regime.

[1] A. Rycerz, arXiv:0909.3018 (unpublished).

HL 22.2 Tue 9:45 H21

Electrical transport and low-temperature scanning tunneling microscopy of microsoldered graphene — •Viktor Geringer[1], Dinesh Subramaniam[1], Ann-Kathrin Michel[1], Bart Szafranek[2], Daniel Schall[2], Alexander Georgi[1], Torge Mashoff[1], Daniel Neumaier[2], Marcus Liebmann[1], and Markus Morgenstern[1] — [1]II. Physikalisches Institut, RWTH Aachen and JARA-FIT, Otto-Blumenthal-Straße, 52074 Aachen — [2]Advanced Microelectronic Center Aachen (AMICA), Otto-Blumenthal-Straße 25, 52074 Aachen

Using the recently developed technique of microsoldering [1], we perform a systematic transport study of the influence of PMMA on graphene flakes revealing a doping effect of up to $\Delta n = 3.8\times10^{12}\,cm^{-2}$, but a negligible influence on mobility and gate voltage induced hysteresis. Moreover, we show that the microsoldered graphene is free of contamination and exhibits a very similar intrinsic rippling as has been found for lithographically contacted flakes. Finally, we demonstrate a current induced closing of the previously found phonon gap appearing in scanning tunneling spectroscopy experiments, strongly non-linear features at higher bias probably caused by vibrations of the flake and a B-field induced double peak attributed to the 0. Landau level of graphene.

[1] Ç. Ö. Girit and A. Zettl, Appl. Phys. Lett. 91, 193512 (2007).

HL 22.3 Tue 10:00 H21

Spin injection in graphene spin valve devices via thin MgO barriers — •Tsung-Yeh Yang[1], Julia Samm[1], Marc Drögeler[1], Sebastian Blaeser[1], Frank Volmer[1], Mihaita Popinciuc[1], Jayakumar Balakrishnan[2], Ahmet Avsar[2], Manu Jaiswal[2], Mingang Zheng[2], Bernd Beschoten[1], Barbaros Oezyilmaz[2], and Gernot Güntherodt[1] — [1]II. Physikalisches Institut, RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany — [2]Department of Physics, National University of Singapore, 2 Science Drive 3 Singapore 117542

We report all-electrical spin transport measurements in non-local spin valve structures on graphene at room temperature. The graphene flakes were deposited on Si/SiO_2 substrates by mechanical exfoliation. The application of a back gate voltage allows for continuous control of the charge carrier type and density. Using ferromagnetic Co electrodes, efficient spin injection/detection was realized via thin MgO layers introduced between Co and graphene. Spin valve and Hanle spin precession measurements were performed for various charge carrier densities. The measurements at room temperature reveal the charge carrier mobilities of 4-5x10^3 cm^2/Vs and spin relaxation lengths of about 3 micrometers in the metallic conduction regime. Temperature dependent measurements of the Co/MgO/graphene contacts resistances indicate that the thin MgO layers behave as tunnel barriers.

This work is supported by DFG through FOR 912.

HL 22.4 Tue 10:15 H21

Direct measurement of the electron mean free path in few layer graphene samples — •Srujana Dusari, Jose Barzola-Quiquia, and Pablo Esquinazi — Division of Superconductivity and magnetism, Institute for Experimental Physics II, University of Leipzig, 04103 Leipzig, Germany

The large coherence length of the electrons in graphite is expected to lead to a long electronic mean free path and to a large spin-diffusion length even at room temperature [1]. The aim of this work is the direct measurement of the electron mean free path, Fermi wavelength and mobility and their temperature dependence in multigraphene samples, i.e. micrometer large few layer graphene (FLG) samples with thickness below 100 nm. This is possible by studying the electronic transport through constrictions using specific design and nanostructuring of the sample. By measuring the resistance before and after making constrictions of different size it is possible to obtain the necessary parameters [1]. We developed a new method to avoid Ga+ ion contamination while making the constriction on the samples. First results on the temperature dependence of the mean free path in FLG samples obtained without free parameters will be presented.

[1]. N García, P. Esquinazi, J. Barzola-Quiquia, B. Ming, and D. Spoddig, Phys. Rev. B 78, 035413 (2008).

HL 22.5 Tue 10:30 H21

Electronic properties of graphene nanoribbons under gate electric fields — •Tobias Burnus[1], Daniel Wortmann[1], Yuriy Mokrousov[1], Gustav Bihlmayer[1], Stefan Blügel[1], and Klaus Michael Indlekofer[2] — [1]Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Hochschule RheinMain, Unter den Eichen 5, 65195 Wiesbaden, Germany

Graphene nanoribbons (GNR) hold great future promise for field-effect transistor and quantum dot (QD) devices. The gate electrodes and the electric field distribution play a crucial role. For a realistic description of a quantum dot, the many-body interaction of the few electrons in the quantum dot have to be described properly. The QD itself is formed by the vast number of electrons in a many nanometer long ribbon under the presence of a gate. As a first step, the GNR is calculated using density-functional theory (DFT), where the gate electrode is simulated by an inhomogeneous charge-sheet placed atop of the ribbon. Hereby, all electrons in the GNR are taken into account and one can directly calculate the dielectric constant ε and changes in the charge density due to the applied voltage on the gates. Using this technique, adatoms or different ribbon terminations can be taken into account. Based on the resulting matrix elements, the few electron problem of the GNR QD is treated within a relevant many-body subspace by means of configuration interaction (CI). In the presentation, the first result along this line will be shown. The work is supported by the DFG Research Unit 912 "Coherence and Relaxation Properties of Electron Spins".

HL 22.6 Tue 10:45 H21

How Graphene-like is Epitaxial Graphene? Quantum Oscillations and Quantum Hall Effect — •Johannes Jobst[1], Daniel Waldmann[1], Florian Speck[2], Roland Hirner[2], Duncan K. Maude[3], Thomas Seyller[2], and Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [3]Laboratoire des Champs Magnétiques Intenses, 25 Avenue des Martyrs, 38042 Grenoble, France

We report on the transport properties – in particular charge carrier density, mobility, conductivity and magnetoconductance – of high-quality single-layer graphene. Graphene was epitaxially grown on the silicon terminated face of a semi-insulating 6H silicon carbide substrate and then patterned into devices of different geometry and size. Large samples as well as submicrometer-sized Hall bars which are entirely lying on atomically flat substrate terraces yield similar transport properties confirming the uniformity of the epitaxial process. In high magnetic fields Shubnikov-de Haas oscillations with the distinct Landau level spectrum of single-layer graphene are clearly visible in samples with different charge carrier densities. When gated close to the Dirac point, the mobility increases substantially, and the graphene-like quantum Hall effect occurs. This proves that epitaxial graphene is ruled by the same pseudo-relativistic physics observed previously in exfoliated graphene.

15 min. break

HL 22.7 Tue 11:15 H21

Top and bottom gated field effect devices on epitaxial graphene — •Daniel Waldmann[1], Johannes Jobst[1], Florian Speck[2], Thomas Seyller[2] und Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, Universtität Erlangen-Nürnberg, Erlangen, Germany — [2]Lehrstuhl für Technische Physik, Universtität Erlangen-Nürnberg, Erlangen, Germany

We fabricate high-quality epitaxial graphene devices (Hall bars) for electrical transport measurements. In order to tune the charge density in the graphene layer, we developed different gating schemes (top gate and bottom gate). As a top gate we either used an electrochemical gate employing an ionic liquid or a solid state gate using aluminium oxide. A bottom gate has the advantage of leaving the graphene layer open. We have opted for an implanted conducting layer buried in the semi-insulating silicon carbide substrate. Hence, the SiC above the implanted gate serves both as substrate and gate dielectric. We present experimental data from low temperatures to room temperature which cover a broad range of charge densities including the electron hole transition at the Dirac point. Advantages and limitations of each method are discussed.

HL 22.8 Tue 11:30 H21

Giant Rashba splitting in Au-intercalated graphene — •Dmitry Marchenko[1], Andrei Varykhalov[1], Markus R. Scholz[1], Oliver Rader[1], Gustav Bihlmayer[2], and Emmanuel I. Rashba[3] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie — [2]Institut für Festkörperforschung, Forschungszentrum Jülich — [3]Department of Physics and Center for Nanoscale Systems, Harvard University

The use of graphene for spin transport [1] is generally connected to the small size of its intrinsic spin-orbit coupling leading to a splitting of the order of 0.01 to 0.1 meV [2]. This small value can be enhanced by a Rashba effect from a substrate [3] which couples graphene spin and pseudospin [4]. For the graphene-Au interface created by intercalation of a Au monolayer between graphene and Ni(111) a spin-orbit splitting of $\Delta_{so} \sim 13$ meV was measured [3]. By optimized sample preparation, we obtain now Δ_{so} values of the order of 100 meV near the Fermi energy by spin- and angle-resolved photoelectron spectroscopy, i. e., an enhancement by 3 to 4 orders of magnitude relative to the intrinsic values. We discuss the origin of this large splitting with the help of ab initio density functional calculations using the generalized gradient approximation.

[1] N. Tombros et al., Nature 448, 571 (2007)
[2] J. C. Boettger and S. B. Trickey, Phys. Rev. B 75, 121402(R) (2007); C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 226801 (2005)
[3] A. Varykhalov et al., Phys. Rev. Lett. 101, 157601 (2008)
[4] E. I. Rashba, Phys. Rev. B 79, 161409(R) (2009)

HL 22.9 Tue 11:45 H21

Spin relaxation of conduction electrons in Graphene induced by impurities — Martin Gradhand[1], •Dmitry Fedorov[2], Sergey Ostanin[1], Igor Maznichenko[2], Arthur Ernst[1], Peter Zahn[2], and Ingrid Mertig[2,1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Martin-Luther-Universität Halle, Institut für Physik, D-06099 Halle, Germany

Graphene is a very attractive system for future spintronics applications. Experiments [1,2] have shown unexpected fast spin relaxation of conduction electrons in Graphene. A probable explanation is based on the dominance of the Elliott-Yafet spin relaxation mechanism.
Recently, we have developed a fully relativistic ab initio approach, based on the Korringa-Kohn-Rostoker method, for a theoretical study of the Elliott-Yafet mechanism caused by impurities [3]. Here we present our calculations of the spin-flip scattering time in Graphene via the Elliott-Yafet mechanism and estimate the Dyakonov-Perel spin relaxation time.

[1] N. Tombros et al., Nature 448, 571 (2007)
[2] N. Tombros et al., Phys. Rev. Lett. 101, 046601 (2008)
[3] M. Gradhand et al., submitted to Phys. Rev. B (2009)

HL 22.10 Tue 12:00 H21

The x-ray edge problem in graphene — Georg Röder[1], Grigory Tkachov[2], and •Martina Hentschel[1] — [1]MPI für Physik komplexer Systeme, Dresden — [2]Julius-Maximilians-Universität Würzburg

The excitation of a core electron to the conduction band by an x ray leads to the sudden creation of a localized, attractive potential and triggers the many-body responses that contribute to the x-ray edge problem, namely Anderson orthogonality catastrophe and Mahan's exciton (Mahan-Nozieres-DeDominicis response). We study them in mesoscopic systems, in particular for graphene, where the discrete level structure, boundary effects, and the filling-dependent variations in the density of states cause characteristic deviations from the well-understood bulk (metallic) behavior. The vanishing of the density of states at the Dirac points suppresses the orthogonality catastrophe. In the photoabsorption cross section, and for fillings smaller than half-filling, an additional Fermi-edge singularity develops at the Dirac point, similar to the behavior that, in metals, is known as the opening of a second band. We furthermore discuss the role of edge states that occur on zig-zag edges and their influence on the photoabsorption cross section.

HL 22.11 Tue 12:15 H21

Analog of graphene using microwave photonic crystals — •Maksim Miski-Oglu[1], Stefan Bittner[1], Barbara Dietz[1], Pedro Oria Iriarte[1], Achim Richter[1,2], and Florian Schaefer[3] — [1]Institut für Kernphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]ECT*, Villa Tambosi, I-38100 Villazzano (Trento), Italy — [3]LENS, University of Florence, I-50019 Sesto-Fiorentino (Firenze), Italy

A Dirac spectrum has been measured in a microwave photonic crystal consisting of a triangular lattice of metallic cylinders placed between two metallic plates. Up to a certain excitation frequency the wave propagation in this structure is governed by the 2D Helmholz equation with Dirichlet conditions at the boundaries of the cylinders. Microwave power is coupled into the periodioc structure via one dipole antenna and the reflected power is measured. It is proportional to the local density of states at the position of the antenna. In a Dirac spectrum the local density of states tends to zero linearly with the frequency at the Dirac point where two bands approach each other as a pair of cones. This linear character of the dispersion relation is clearly seen in the measured reflection spectra. These and measured wave functions are presented in the talk. It is argued, that these experiments offer the possibility to study a variety of phenomena connected with graphene as well as with QED in the table top experiments in photonic crystals with well controlled parameters.

This work has been supported within the DFG grant SFB634.

HL 22.12 Tue 12:30 H21

Time-resolved spectroscopy of graphene — •Tim Botzem[1], Tobias Plötzing[1], Bart Szafranek[2], Daniel Schall[2], Daniel Neumaier[2], and Heinrich Kurz[1] — [1]Institut für Halbleitertechnik, RWTH Aachen, Gemany — [2]AMICA, AMO GmbH, Aachen, Gemany

In graphene the coupling of various quasi particles accounts for the ultrafast temporal evolution of nonequilibrium carrier distributions. Hence understanding of the relaxation processes is crucial for designing high speed electronic and photonic devices. For investigating the involved quasi particle interactions we apply femtosecond pump-probe spectroscopy (17 fs temporal resolution) on exfoliated graphene mono- and bilayer flakes prepared on transparent sapphire substrates. Relaxation of hot carriers takes place within the first few tens of femtoseconds after excitation, revealing the strong coupling between the different quasi particles involved. A detailed analysis of the dependence on excitation fluence, carrier concentration and fabrication method will be given.

HL 23: Plasmonics and Nanophotonics I (Joint Session with DS/O)

Time: Tuesday 10:30–13:00 Location: H2

HL 23.1 Tue 10:30 H2

Electrochemically tunable photonic metamaterial — •Lihua Shao, Stefan Linden, Matthias Ruther, Jörg Weissmüller, and Martin Wegener — Institut für Nanotechnologie and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We report experiments to combine two approaches for designing functional nanomaterials. Photonic metamaterials provide a strategy for obtaining unconventional optical response - in the extreme, negative refractive indices - by lithographically structured elements like arrays of split-ring resonators (SRR). Nanomaterials with tunable electronic structure exploit large specific surface area of metal nanostructures to tune the surface properties through the controlled space-charge regions for tuning macroscopic properties. The combination is a photonic metamaterial in which the space-charge at the surface of SRR is controlled via an applied potential, leading to a tunable optical resonance. We report first results support this concept. SRR structures with resonance frequencies in the near infrared are immersed into aqueous electrolytes as working electrode in an electrochemical experiment. Varying the electrode potential, E, induces a space-charge layer at the metal surface as part of the electrochemical double-layer. We find the resonance frequencies vary linearly, reversibly, and reproducibly with E, with a blue shift for negative potential. A tentative explanation is based on the effective thickening of the SRR by the excess electrons, which changes the SRR aspect ratio. The observation of larger frequency shift for thinner SRR's is compatible with this scenario.

HL 23.2 Tue 10:45 H2

Mixing colours like nature — •Mathias Kolle, Maik Scherer, Pedro Cunha, Fumin Huang, Jeremy Baumberg, and Ullrich Steiner — Cavendish Laboratories, University of Cambridge, UK

Biomimetic attempts to produce novel photonic structures have attracted increasing research interest in recent years. Nature offers us an enormous amount of multifunctional micro- and nanostructures, that provide outstanding, distinctive, dynamic and tailored colouration. A "brilliant" example is the indonesian butterfly *papilio blumei*, whose wing scales are covered with 5-10μm wide concavities, that are cladded with a perforated cuticle multilayer. The regularly shaped multilayer structure gives rise to very impressive colour mixing effects, accompanied by controlled change in light polarisation.

We have successfully replicated the intricate photonic structure of *papilio blumei* on the cm^2-scale in four simple steps involving colloidal templating, electrochemical growth and atomic layer deposition. A small conceptual modification of the original photonic structure leads to a completely different optical effect. Any freely chosen colour and its complementary hue can be separated and reflected into different directions while conserving a particular polarisation effect.

Since the procedures are easily up-scaleable, these biomimetic photonic structures have a huge potential for industrial applications in security printing, encoding of information, non-emissive display technology and other fields where distinct colours play an important role.

HL 23.3 Tue 11:00 H2

Optical properties of carpets of randomly grown silicon nanowires on glass — •Gerald Brönstrup and Silke Christiansen — Institut für Photonische Technologien e.V., Abt. Halbleiter-Nanostrukturen, 07745 Jena

Silicon Nanowires [SiNWs] have attracted much attention in the recent years as possible future building blocks for field effect transistors, sensors, photo detectors and solar cells. For the latter SiNWs grown on a cheap substrate like glass is of special interest. To build solar cells with high efficiencies a high absorption is mandatory. We present a study of the influence of the diameter on the reflection, transmission and absorption spectra of carpet like assembly of SiNWs grown on glass.

We grew SiNWs on glass using gold colloids of different fixed diameters to achieve a control over the diameter of the SiNWs. Then we measured the reflection R and transmission T using an integrating sphere. The absorption A was calculated using the simple formula A=1-T-R.

For a better understanding of the underlying physics of the absorption happening in SiNWs with diameters much smaller than the wavelength of the visible light we present a statistical model based on scattering cross sections calculated for single SiNWs using Mie-theory.

HL 23.4 Tue 11:15 H2

Suppressed transmission through ultrathin metal films by subwavelength hole arrays — •Julia Braun[1], Bruno Gompf[1], Uwe Huebner[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart — [2]IPHT Jena, Albert-Einstein-Straße 9, 07745 Jena

If an opaque metal film is periodically perforated by tiny subwavelength holes, extraordinary high transmission is observed [1]. We investigate the transmission through subwavelength hole arrays (SWHA) in ultrathin semitransparent Au films with various periodicities and hole diameters and observe the opposite behavior: less light is transmitted through the pierced metal compared to the closed film. The samples were fabricated by optical interference and electron beam lithography in 12 nm and 20 nm thick Au films with periodicities between 250 nm and 400 nm, and than characterized in the frequency range 4400 cm^{-1} to 37000 cm^{-1} (0.6 eV to 4.6 eV). The optical properties of SWHA cannot be explained by a pure dielectric function, but show a strong $\vec{k}$-dependent behavior. In ultrathin Au films it is marked by the excitation of strongly damped antisymmetric short range surface plasmons. The obtained dispersion curves perfectly agree with this explanation when the altered dielectric function of the ultrathin Au films is taken into account [2].

[1] T.W. Ebessen, H.J. Lezec, H.F. Ghaemi, T. Thio, and P.A. Wolff, *Nature* **391**, 667 (1998).

[2] J. Braun, B. Gompf, G. Kobiela, M. Dressel, *Physical Review Letters* **103**, 203901 (2009)

HL 23.5 Tue 11:30 H2

Manipulation of fluorescence resonance energy transfer in single plasmonic nanoresonators — •Valerie Faessler, Calin Hrelescu, Sergiy Mayilo, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and Center for Nano Science (CeNS), Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 München, Germany;

We show that fluorescence resonance energy transfer (FRET) between two organic chromophores can be manipulated in plasmonic nanoresonators consisting of two spherical gold nanoparticles.The nanoresonators can be tuned by varying the inter-particle distance or the nanoparticle size. This allows us to selectively modify the decay channels of the chromophores. FRET can be supressed if the molecules are placed in the nanoresonator at a certain distance from the nanoparticle surface. Furthemore we observe spectral shaping and intensity modulation of the fluorophore emision in the nanoresonators [1]. Correlated whitelight Rayleigh scattering and fluorescence microscopy data of the hybrid system are discussed in the framework of generalized Mie theory.

[1] M. Ringler, A. Schwemer, M. Wunderlich, A. Nichtl, K. Kürzinger, T. A. Klar, J. Feldmann Phys. Rev. Lett., 100, 203002 (2008)

HL 23.6 Tue 11:45 H2

Optical antenna thermal emitters — •Jon Schuller[1], Thomas Taubner[1,2], and Mark Brongersma[1] — [1]Stanford University, Stanford, CA, USA — [2]1. Physikalisches Institut, RWTH Aachen, Germany

Optical antennas are a critical component in nanophotonics research[1] and have been used to enhance nonlinear and Raman cross-sections and to make nanoscale optical probes [2]. In addition to their receiving properties, optical antennas can operate in broadcasting mode, and have been used to modify the emission rate[3] and direction [4] of individual molecules.

In these applications the antenna must operate at frequencies given by existing light emitters. Using thermal excitation of optical antennas, we bypass this limitation and realize emitters at infrared frequencies where sources are less readily available [5].

Specifically, we show that the thermal emission from a single SiC whisker antenna is attributable to well-defined, size- tunable Mie resonances. Furthermore, we derive a fundamental limit on the antenna emittance and argue theoretically that these structures are nearly ideal black-body antennas.

1. Schuck, P. J. et al., PRL 94, 017402 (2005).
2. Farahani, J. N., et al., PRL 95, 017402 (2005).
3. Kuhn, S., et al., PRL 97, 017402 (2006).
4. Taminiau, T. H., et al, Nature Photon. 2, 234-237 (2008).
5. Schuller, J.A. et al., Nature Photon. 3, 658-661 (2009).

HL 23.7 Tue 12:00 H2

Spatial Resolved Near Field Interference on Nanooptical Bowtie Antennas — •Pascal Melchior, Daniela Bayer, Christian Schneider, Martin Rohmer, Alexander Fischer, and Martin Aeschlimann — Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

The response of metallic nanostructures is responsible for interference effects of the electric near field in the vicinity of the structure surface. While the incoming electric field vectors are independent in the far field, spectral interference in the near field can occur since the resulting field vectors are not necessarily perpendicular. On the nanostructure configuration of a Bowtie antenna, we show how the superposition of different plasmonic excitation modes leads to a local enhancement of the effective near field depending on the phase relation between the incoming electric field vectors. Via an interferometric superposition of two laser pulses with cross polarized electric fields the near field interference can be directly observed by means of a photoemission electron microscope (PEEM). Spatial switching of the photoemission yield depending on the relative phase between the two superposed laser pulses will be demonstrated.

HL 23.8 Tue 12:15 H2

Interaction effects of gold nanoantenna arrays in the infrared — •Daniel Weber[1], Frank Neubrech[1], Dominik Enders[2], Tadaaki Nagao[2], and Annemarie Pucci[1] — [1]Kirchhoff Institute for Physics, University of Heidelberg, Germany — [2]National Institute for Materials Science, Tsukuba, Japan

Gold nanoantennas are of great interest for applied spectroscopy due to their tuneable plasmonic properties including local electromagnetic (EM) field enhancement (FE). Excited resonantly by EM radiation, they are able to strongly enhance the local EM field. In the past, we exploited this strong effect for surface-enhanced infrared spectroscopy (SEIRS) with gold nanoantennas. We want to further improve the sensitivity of SEIRS by making use of nanoantenna coupling. Coupling may increase local FE but also strongly modify the spectral distribution of the FE, which provides further options for optimum resonance tuning as necessary for specific sensor applications.

We report on the IR optical properties of gold-nanoantenna arrays with different gap sizes and show the relation between plasmonic resonances and geometrical arrangement on the substrate. Stripe-like, polycrystalline gold nanoantennas (nanorods) with rectangular cross-sections were produced by electron beam lithography on silicon wafers. IR measurements were performed by micro-spectroscopy in our laboratories and at the synchrotron light source ANKA (Karlsruhe Institute of Technology). Special focus is on the preparation of very small gaps between the tip ends of nanorods, where the highest local FE is expected.

HL 23.9 Tue 12:30 H2

Structural and Optical Properties of Gold and Iron Nanowires — •Piotr Patoka[1,2], Georgios Ctistis[3], Michael Hilgendorff[1], and Michael Giersig[1] — [1]Freie Universität Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH — [3]University of Twente, MESA+ Institute & Dept. of Science and Technology, Complex Photonic Systems (COPS), Enschede, The Netherlands

Plasmonic nanostructures gained a tremendous interest during the last decade due to their structural and optical properties, which make them promising materials for opto-electronic as well as bio-sensing-applications.

Here we will present results on gold and iron nanowires prepared by means of nanosphere lithography as a cheap method of preparation of large areas of such nanostructures. The 30nm thick lines with 440nm in periodicity have been characterized with atomic force microscopy and scanning electron microscopy. The investigation showed strong influences of the preparation steps to the final structure. For optical investigation UV-VIS-NIR spectrometry and scanning near field optical microscopy have been used showing extraordinary light transmission.

HL 23.10 Tue 12:45 H2

Surface Plasmon Resonance Coupling on Magnetically Capped Gold Nanorods — •Gillian Doyle and Dominic Zerulla — Plasmonic and Ultrafast Optics Group, School of Physics, University College Dublin, Belfield, Dublin 4, Ireland

Nanorods compared to their spherical counterparts exhibit enhanced sensitivity and are used for a wide variety of applications from biosensing to solar cells. The presence of two resonance peaks in their scattering spectra allows their two geometrical axes, the longitudinal and transverse axes to be separately distinguished. In this research we use iron capped gold nanorods with geometrical dimensions in the range of 60 x 700 nm. Coupling of the surface plasmons between the two axes is investigated both in multiple particle and single particle experiments and the effect of the proximity of particles to each other and their associated coupling is considered. In the single particle experiments a 532 nm laser beam is used to optically trap and manipulate a nanorod, while coupling white light to the setup allows Mie Scattering Spectroscopy (MSS) to be performed on a single particle. Large sample MSS experiments provide more intense signals for detection and give an insight into phenomena occurring at the surface of the nanoparticle [1]. In addition, the intensity of the scattering cross section by these nanorods is examined by magnetically manipulating the particles themselves and opening a novel method of optimum signal detection of SP resonances on nanorods.

[1] G Doyle, D. Zerulla, Applied Physics A, Vol 89, No. 2, 2007

HL 24: Quantum Dots and Wires, Optical Properties II: Single Photon Sources

Time: Tuesday 11:30–12:45 Location: H17

HL 24.1 Tue 11:30 H17

Electrically driven quantum dot-micropillar single photon source with 34% overall efficiency — •Tobias Heindel, Christian Schneider, Matthias Lermer, Soon-Hong Kwon, Tristan Braun, Stephan Reitzenstein, Sven Höfling, Martin Kamp, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The realization of efficient single photon sources (SPSs) is a driving force in the development of quantum dot - microcavity structures. In fact, the outcoupling efficiency of a quantum dot (QD) can be strongly enhanced in the presence of a high quality microcavity providing three dimensional photon confinement. In this context, QD-micropillar cavities are of special interest due to predicted photon extraction efficiencies of up to 70%. In light of possible applications of SPSs, e.g. in quantum key distribution systems, and the associated device integration it is crucial to establish an electrical pumping scheme capable for high frequency operation.

We report on triggered single photon emission from low mode volume electrically driven quantum dot-micropillar cavities at repetition rates of up to 220 MHz. Due to an optimized layout of the doped planar microcavity and an advanced lateral current injection scheme, highly efficient single photon sources are realized. While $g^{(2)}(0)$-values as low as 0.13±0.05 and a Purcell-factor of 4 are observed for a 2 μm diameter micropillar, single photon emission at a rate of (35±7) MHz and an overall efficiency of (34±7)% are demonstrated for a 3 μm device.

HL 24.2 Tue 11:45 H17

Quantum-dot-based, electrically-driven single-photon sources with 1 GHz excitation rate and with site-controlled quantum dot — •Jan A. Töfflinger[1], Erik Stock[1], Anatol Lochmann[1], Waldemar Unrau[1], Dieter Bimberg[1], Askhat K. Bakarov[2], Aleksandr I. Toropov[2], Aleksandr K. Kalagin[2], Vladimir A. Haisler[2], Paola Atkinson[3], and Oliver G. Schmidt[4] — [1]Institut für Festkörperphysik, TU-Berlin, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, 630090 Novosibirsk, Russia — [3]MPI für Festkörperforschung, 70569 Stuttgart, Germany — [4]IIN, IFW Dresden, 01069 Dresden, Germany

For future quantum cryptography systems the development of highly efficient, electrically pumped single-photon sources with high repetition rates is of utmost importance. We have developed InGaAs/GaAs-quantum dot (QD) based Resonant-Cavity LEDs (RC-LED). A built-in AlGaOx current aperture allows electrical excitation of a single QD. The resonant cavity leads to increased external quantum efficiency and due to the Purcell effect to an increase of the spontaneous emission rate allowing us to electrically pump the single QD at 1 GHz repetition rate. To further optimize our single photon sources and to increase the device yield we also demonstrate a new electrically pumped LED with a site-controlled MBE-grown InGaAs/GaAs-QD on pre-patterned GaAs substrate. Electroluminescence measurements show pure spectrum with only lines from a patterned QD and demonstrate single photon emission with a second order correlation function $g^2(0) \leq 0.4$. This work is partly funded by SfB 787 and NATO SfP 982735.

HL 24.3 Tue 12:00 H17

Triggered single–photon emission from electrically driven InP/(Al,Ga)InP quantum dots — •Christian Kessler, Matthias Reischle, Wolfgang-Michael Schulz, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Semiconductor quantum dots (QDs) are a promising approach to realize a single–photon source. To avoid bulky and expensive laser systems for future applications, electrical excitation is desirable. InP QDs are especially suited, as they emit in the red spectral range and therefore in the optimal range of commercial detectors. Additionally, they have been shown to be capable of emitting single photons up to 80 K [1]. Thus, we embedded InP QDs in the intrinsic region of a p–i–n diode. To form single devices, 100 μm mesas were etched and supplied with electrical contacts. We investigated the electroluminescence from single QDs and performed second-order auto correlation measurements to verify single–photon emission. To prevent expensive helium cooling and reach operation above 80 K, we investigated the influence of elevated temperature on the performance of our device. Since triggered single–photon emission is required for most applications, sub–nanosecond pulses were applied and pulsed single-photon ($g^{(2)}(0) = 0.24$) emission was observed up to 200 MHz.

[1] M. Reischle et al., Opt. Express 16, 12771 (2008)

HL 24.4 Tue 12:15 H17

Nanowire quantum dots as an ideal source of entangled photon pairs — •Ranber Singh and Gabriel Bester — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany

We predict that semiconductor nanostructures grown along the [111] direction such as self-assembled quantum dots or nanowire quantum dots have vanishing fine structure splitting on the grounds of their symmetry and therefore, are ideal candidates for the generation of entangled photon pairs. We confirm this predicton by million-atom empirical pseudopotential calculations on *realistic* InAsP/InP and InGaAs/GaAs structures. We further study how robust the results are against deformations. Through the control of size, shape and composition the InAsP/InP nanostructures would emit at the optical fiber communication wavelength (*conventional C band*) of 1.55 μm (0.8 eV) which should boost their attractiveness.

HL 24.5 Tue 12:30 H17

Coherent optoelectronic manipulation of single excitons — •Steffen Michaelis de Vasconcellos[1], Simon Gordon[1], Dirk Mantei[1], Max Bichler[2], Torsten Meier[1], and Artur Zrenner[1] — [1]CeOPP, Universität Paderborn, Paderborn, Germany — [2]WSI, TU München, Garching, Germany

The coherent state manipulation of single quantum systems is a fundamental requirement for the implementation of quantum information devices. As recently shown, excitons in semiconductor quantum dots are an interesting qubit implementation for coherent optoelectronic devices, especially due to their excellent control by ultrafast laser pulses.

In our contribution, we present the coherent manipulation of an exciton in a single QD by electric signals. The new scheme employs a fixed optical clock signal and a synchronous electric gate signal, which is applied to a single QD photodiode and controls the coherent manipulation of the exciton qubit. A first picosecond laser pulse turns the qubit in a coherent superposition state. Afterwards, the phase of the qubit is manipulated by applying a 2.4 GHz electric signal, which is phase locked to the laser pulses. A second laser pulse is used to analyze the quantum state after the coherent manipulation. We are able to achieve a quantum phase shift of π by varying the electric phase of the 2.4 GHz signal. To verify the experimental data, we performed theoretical calculations based on the optical Bloch equations. These show a very good agreement with the experimental data.

HL 25: Focussed Session: Strong Light Matter Coupling II

Time: Tuesday 14:00–15:45 Location: H13

Invited Talk HL 25.1 Tue 14:00 H13

Sub-cycle switching of ultrastrong light-matter interaction — A. A. Anappara[1,2], A. Sell[1], G. Günter[1], G. Biasiol[3], L. Sorba[2,3], S. DeLiberato[4], C. Ciuti[4], A. Tredicucci[2], A. Leitenstorfer[1], and •R. Huber[1] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]NEST CNR-INFM and Scuola Normale Superiore, Pisa, Italy — [3]Laboratorio Nazionale TASC CNR-INFM, Trieste, Italy — [4]CNRS and Universite Paris Diderot-Paris 7; Ecole Normale Superieure, Paris, France

While sophisticated light-matter coupling has been tailored in all three spatial dimensions, on a sub-wavlength scale, control in the fourth dimension - time - has been barely developed. Here, we exploit ultrabroadband terahertz technology and an intersubband cavity structure to demonstrate sub-cycle switching, for the first time: A 12-fs near-infrared laser pulse photoinjects electrons into the lowest conduction subband of the quantum wells, thereby activating mid-infrared transitions to the next higher subband. The system is found to morph from a bare microcavity to an ultrastrongly coupled cavity polariton system, within less than a cycle of light. We monitor directly in the time domain how a coherent photon population trapped inside a bare microcavity converts to light-matter mixed states when coupling is abruptly activated. This system forms a first promising laboratory for unprecedented sub-cycle QED phenomena reminiscent of Hawking radiation of black holes and represents an efficient room-temperature switching device at the ultimate speed.

HL 25.2 Tue 14:30 H13

Characterization of the strong coupling in ZnSe-based monolithic microcavities — •K. Sebald[1,2], A. Trichet[1], M. Richard[1], Le Si Dang[1], and C. Kruse[2] — [1]CEA-CNRS-UJF group Nanophysique et Semiconducteurs, Institut Néel, 25 Avenue des Martyrs, F38042 Grenoble, France — [2]Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

II-VI-based microcavities are particularly well suited for the investigation of the photon-exciton coupling behavior in semiconductors under high excitation thanks to the much stronger exciton-photon coupling and the larger exciton binding energy as compared to other compounds. In this contribution we will present results on the optical properties of monolithic microcavities containing 20 ZnSe quantum wells located at the antinode positions of a 5λ cavity surrounded by distributed Bragg reflectors grown by molecular beam epitaxy. To achieve spectral tuning the sample has been grown without rotation resulting in a thickness gradient along the wafer. The strong coupling regime between cavity photon modes and quantum well excitons is challenging to be measured in this system, because the Rabi splitting is larger than the exciton binding energy. Hence, the strong coupling was characterized by measuring the lower polariton dispersion for different exciton photon detuning and temperatures. Furthermore, the influence of a lateral optical confinement on the polariton dispersion will be discussed for airpost pillar microcavities with diameters between 1.5 and 2 μm.

HL 25.3 Tue 14:45 H13

Electrically-driven AlGaAs/AlAs Quantum Well-Microcavities for Exciton-Polariton Studies — •Arash Rahimi-Iman[1], Matthias Lermer[1], Christian Schneider[1], Sven

Hoefling[1], Stephan Reitzenstein[1], Lukas Worschech[1], Alfred Forchel[1], Na Young Kim[2], and Yoshihisa Yamamoto[2] — [1]Technische Physik, Universität Würzburg, D-97074 Wuerzburg, Germany — [2]Ginzton Laboratory, Stanford University, Stanford, CA-94305, USA

In a semiconductor microcavity with embedded quantum wells (QWs) new eigenmodes are formed called the polaritons when the confined cavity photon modes strongly couple to the QW excitons. Cavity polaritons and their ability to undergo Bose-Einstein condensation have been intensively studied in the last decade, mainly in the optical pumping regime. Very recently, also electrically driven polariton systems for further studies and future applications have been brought into focus.

Doped microcavity structures with p-i-n-diode type design have proven as appropriate systems for current injection into the active region of the cavity. We have realized and studied electrically contacted AlGaAs/AlAs microcavities containing 4 GaAs QWs in a $\lambda/2$ AlAs cavity sandwiched between an n-doped lower and an p-doped upper distributed Bragg reflector. For the planar sample structure, we observed strong coupling associated with a Rabi-splitting of ≈10 meV in photo- as well as electroluminescence. We report on angularly resolved studies on polariton emission under both optical and electrical excitation. The respective data will be compared with results obtained from polariton LEDs based on InGaAs QWs.

HL 25.4 Tue 15:00 H13

Non-resonant Quantum Dot-Cavity Coupling — •Ata Ulhaq[1], Sven Ulrich[1], Serkan Ates[1], Stephan Reitzenstein[2], Andreas Löffler[2], Sven Höffling[2], Alfred Forchel[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen (IHFG), Univ. Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg

The talk addresses recent results on the fascinating effect of "non-resonant emitter-cavity coupling" which is observed as an unexpected pronounced cavity resonance emission even in strongly detuned single quantum dot (QD)-microcavity systems. This phenomenon is an indication of strong, complex light-matter interactions in solid-state systems, going beyond the predictions by the general Jaynes-Cummings interaction picture of a discrete two-level emitter and cavity system. We have studied the effect of non-resonant QD-cavity coupling from individual QDs in micropillars under resonant excitation, revealing a pronounced effect over positive and negative QD-mode detunings. Our results suggest a dominant role of phonon-mediated dephasing in dot-cavity coupling, giving a new perspective to the controversial discussions ongoing in the literature. Furthermore, non-resonant coupling is demonstrated as a versatile "monitoring" tool to investigate relevant QD s-shell emission properties and background-free photon statistics from individual QDs under purely resonant excitation.

HL 25.5 Tue 15:15 H13

Strong light-matter coupling in ZnO Nano-Pillar Resonators — Annekatrin Meissner, •Rüdiger Schmidt-Grund, Helena Hilmer, Chris Sturm, Jesus Zúñiga-Pérez, Martin Lange, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

Strong light-matter coupling (formation of exciton-polaritons) in microcavity resonators is of great interest in current research towards polariton lasers. ZnO is a suitable material to be used as active medium due to its large exciton oscillator strength and binding energy. In 1D confined ZnO-based resonators, strong coupling was observed up to 410K with a coupling strength of V=55meV [1]. Further 2D or 3D confinement by means of Bragg-reflector (BR) coated nano-pillars is expected to enhance the coupling strength due to the reduced mode volume and to provide efficient relaxation channels for a strong population of the exciton-polariton ground state.

We present strong coupling in cylindrical resonators containing ZnO nano-pillar cavities (diameters 80...200nm, length ≈5μm). The pillars are coated with a concentric cylindrical shell and, for the 3D case, as well with a top dielectric BR. PL and reflectivity measurements are carried out on the lateral surface of the pillars in dependence on temperature, exit angle and polarization. We were able to investigate the exact same pillar before and after coating. The experimentally observed optical modes can be well described using the exciton-polariton concept involving 2D (V=80meV) and 3D Fabry-Pérot modes.

[1] C. Sturm *et al.*, New J. Phys. **11**, 073044 (2009).

HL 25.6 Tue 15:30 H13

Strong light matter coupling with free and localized donor bound excitons — •Chris Sturm, Helena Hilmer, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

The strong light-matter coupling in two, one and zero dimensional confined electronic systems is still of interest due to its fascinating properties such as non-linear optical effects and a formation of a Bose-Einstein-condensate. Of special interest are ZnO based resonators since here exciton-polaritons are stable well above room temperature [1]. In this work we present the simultaneously coupling of the cavity-photon with the donor bound excitons (D^0, X), which are strongly localized, and the free exciton in a ZnO-based Bragg reflector resonator. This allows to investigate the coupling behaviour of these two excitonic systems with the same photonic mode. The exciton polaritons were observed by PL measurements. Beside the lower polariton branch (LPB) a second mode is observable with an energy close to the (D^0, X) for low temperatures ($(10-70)$ K). The energy of this mode increases with increasing emission angle and the LPB converges at high emission angles to an energy close to the (D^0, X). This indicates that the (D^0, X) couple with the cavity-photon and the second mode can be attributed as a middle polariton branch. From the dispersion behaviour of the two polariton branches we obtain a coupling strength of about 4 meV, which is half of the (D^0, X) broadening. The coupling strength with the free exciton was determined to be about (D^0, X).

[1] C. Sturm *et al.*, New. J. Phys. **11**, 073044 (2009).

HL 26: Spin-controlled Transport II

Time: Tuesday 14:00–16:15 Location: H14

HL 26.1 Tue 14:00 H14

Graphene gets picky with the different formalisms for deriving spin-coherent Boltzmann equations — •Janik Kailasvuori — Max Planck Institut für Physik komplexer Systeme

Semiclassical spin-coherent kinetic equations can be derived from quantum theory with many different approaches. In graphene, where the pseudospin-orbit interaction constitutes the entire kinetic energy, the difference actually manifests itself and determines the precise value of electron-hole coherence authored quantum correction to the Drude conductivity $\sim \frac{e^2}{h}\ell k_F$. We derive this correction analytically for single and multilayer graphene with arbitrary impurities and find different results with different approaches. We also find that the often neglected principal value terms in the collision integral are very important. Neglecting them gives a leading correction only of order $(\ell k_F)^{-1}$, whereas including them can give a correction of order $(\ell k_F)^0$. In the latter scenario the correction could be accurately determined with simple linear regression of the conductivity in the Boltzmann regime. Thus graphene may offer an excellent setting for experimentally settling conflicts between different approaches.

HL 26.2 Tue 14:15 H14

Tight binding model of spin-orbit coupling in graphene — •Sergej Konschuh, Martin Gmitra, and Jaroslav Fabian — Universität Regensburg, Regensburg, Germany

We construct a tight-binding model to explain the spin-orbit coupling effects on the electronic band structure of graphene. We expand the wave functions into a combination of the atomic (s,p,d)-orbitals. We show that the usually neglected d-orbital states contribute to the spin-orbit splitting at the K(K') points in the first order; the s and p orbitals contribute in the second order, qualitatively explaining our recent first-principles results. In contrast, the d-orbitals play no role in the so called extrinsic SOC effect, which is the spin-orbit splitting in the presence of a transverse (to the plane) electric field. Analytical results are derived for the spin-orbit splitting in terms of the atomic energies, hopping and overlap integrals, as well as the atomic spin-orbit splittings.

This work is supported by the DFG SPP1285.

HL 26.3 Tue 14:30 H14

Beating of Friedel oscillations induced by spin-orbit interaction — •Samvel M. Badalyan[1,2], Alex Matos-Abiague[1], Giovanni Vignale[3], and Jaro Fabian[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Radiophysics, Yerevan State University, 1 A. Manoukian Street, Yerevan, 375025 Armenia — [3]Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA

By exploiting our recently derived exact formula for the Lindhard polarization function in the presence of Bychkov-Rashba (BR) and Dresselhaus (D) spin-orbit interaction (SOI), we show that the interplay of different SOI mechanisms induces highly anisotropic modifications of the static dielectric function. We find that under certain circumstances the polarization function exhibits doubly-singular behavior, which leads to an intriguing novel phenomenon, beating of Friedel oscillations. This effect is a general feature of systems with BR+D SOI and should be observed in structures with a sufficiently strong SOI.

The work is supported by the EU Grant PIIF-GA-2009-235394 (SMB), SFB Grant No. 689, and NSF Grant No. DMR-0705460 (GV).

HL 26.4 Tue 14:45 H14

Cu-doped Nitrides: Spinaligner at room-temperature — •Philipp R. Ganz[1,2], Christoph Sürgers[1,3], and Daniel M. Schaadt[1,2] — [1]DFG-Center for Functional Nanostructures, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany — [2]Institut für Angewandte Physik, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany — [3]Physikalisches Institut, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany

Nitride based spintronics is emerging as an interesting alternative to arsenide based spintronics. One reason for this strong interest is the long spin-lifetime in InN quantum dots which is shown to be temperature independent. For spin-injection into these quantum dots, a ferromagnetic spin-aligner which yields high spin-polarization at room-temperature is necessary. Copper doped nitrides are promising candidates as spin-aligners, because non-magnetic material is used, thereby avoiding confusing results due to magnetic clusters, as in the case of Maganese or Gadolinium doped nitrides. Theoretical predictions show the possibility of ferromagnetism and a high spin-polarization for Cu-doped GaN and AlN. A few experimental results have indicated ferromagnetism in both materials. We investigated and optimized the growth of Cu-doped GaN and AlN by plasma assisted molecular beam epitaxy on different substrates. Our Cu-doped films show ferromagnetic behaviour far above room temperature. The influence of growth parameters such as growth temperature, Cu to metal flux ratio and metal to nitrogen flux ratio on the magnetic properties was determined.

15 Min. Coffee Break

HL 26.5 Tue 15:15 H14

An exact solution to the problem of spin edge state — Vahram Grigoryan[1], Alex Matos-Abiague[2], and •Samvel Badalyan[1,2] — [1]Department of Radiophysics, Yerevan State University, 1 A. Manoukian Street, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany

We present an exact solution to the problem of spin edge state, which generalizes the bulk solution by Rashba to the important for spin transport case of the current carrying spin channels. The obtained spin edge states are induced by the combined effect of spin-orbit interaction and hard-wall confining potential in a two dimensional system, exposed to a perpendicular magnetic field. We are able to explain exactly how the spin resolved edge states are separated in space, to achieve a deeper intuitive understanding of the exact behavior of spin and spin current components, depending on the electron position with respect to the sample edges and as a function of the Fermi energy of the electron gas. These findings can serve as an effective tool for controlling the spin motion in spintronic devices. The presented exact solution can be a strong input in studying the spin transport through edge channels in semiconductor nanostructures.

Work is supported by the Volkswagen Foundation, EU Grant PIIF-GA-2009-235394, ANSEF Grant PS-1576, and SFB Grant 689.

HL 26.6 Tue 15:30 H14

$SU(2)$ symmetry and the Boltzmann equation for the Rashba model — •Cosimo Gorini[1], Peter Schwab[1], and Roberto Raimondi[2] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]CNISM and Dipartimento di Fisica, Università Roma Tre, Via della Vasca Navale 84, 00146 Roma, Italy

Spin-orbit coupling in low-dimensional systems leads to rich physics, interesting from both the fundamental point of view and for applications. Spin-charge coupled dynamics allows to manipulate the spin degrees of freedom by purely electrical means.

The Boltzmmann equation is very useful for the theoretical description of transport properties. However in its standard formulation for the Rashba model the scattering kernel is cumbersome and the physical origin of the electric field induced spin currents is not transparent. We exploit the $SU(2)$ gauge symmetry in the model which allows a symmetric treatment of spin and charge degrees of freedom.

We obtain a Boltzmann equation where the $SU(2)$ magnetic field due to spin-orbit coupling appears explicitly. This generates the spin Hall currents, just as standard Hall currents are generated by the real magnetic field. We derive the coupled spin-charge diffusion equations.

HL 26.7 Tue 15:45 H14

Interference of heavy holes in an Aharonov-Bohm ring — •Dimitrije Stepanenko[1], Minchul Lee[2], Guido Burkard[3], and Daniel Loss[1] — [1]University of Basel, Basel, Switzerland — [2]Kyung Hee University, Yongin, Korea — [3]University of Konstanz, Konstanz, Germany

We study the coherent transport of heavy holes through a one-dimensional ring in the presence of spin-orbit coupling. Spin-orbit interaction of holes, cubic in the in-plane components of momentum, gives rise to an angular momentum dependent spin texture of the eigenstates and influences transport. We analyze the dependence of the resulting differential conductance of the ring on hole polarization of the leads and the signature of the textures in the Aharonov-Bohm oscillations when the ring is in a perpendicular magnetic field. We find that the polarization-resolved conductance reveals whether the dominant spin-orbit coupling is of Dresselhaus or Rashba type, and that the cubic spin-orbit coupling can be distinguished from the conventional linear coupling by observing the four-peak structure in the Aharonov-Bohm oscillations.

HL 26.8 Tue 16:00 H14

Scanning tunneling spectroscopy of a dilute two-dimensional electron system exhibiting Rashba spin splitting — •Stefan Becker, Marcus Liebmann, and Markus Morgenstern — II. Physikalisches Institut B, RWTH Aachen and JARA-FIT, 52074 Aachen

Using scanning tunneling spectroscopy (STS) at 5 Kelvin in B-fields up to 7 Tesla, we investigate the local density of states of a two-dimensional electron system (2DES) created by Cs adsorption on p-type InSb(110). Cs induces a large band bending on the p-type InSb(110) surface creating a 2DES in the inversion layer, which in contrast to previous STS studies exhibits a 2D Fermi level. The 2DES shows standing waves with wave numbers in accordance with theory. In a perpendicular magnetic field the percolating drift states of the quantum hall transition are observed within the disorder broadened Landau levels. Using a highly doped sample we achieve a steep band bending potential showing Landau levels with a beating pattern attributed to Rashba spin splitting. Due to the high electric field of the potential, a large Rashba parameter in the order of $\alpha = 7 \times 10^{-11}$ eV·m can be estimated. A simulation of the density of states using this value reproduces the observed beating pattern very well.

HL 27: GaN Preparation and Characterization

Time: Tuesday 14:00–16:15 Location: H15

HL 27.1 Tue 14:00 H15

Defect distributions at III-nitride interfaces from ab-initio-based thermodynamic data — •Christoph Freysoldt, Björn Lange, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Düsseldorf

The electrical, optical, and other properties of III-nitrides for optoelectronic devices are critically determined by dopants, vacancies, and other point defects. These defects have been extensively studied in experiment and theory. However, real devices contain inhomogeneities such as interfaces or electric fields, which affect the point defect distribution. We employ a multiscale approach to treat the interplay of local composition and macroscopic fields. The formation energies and charge transition levels of individual defects are obtained from density functional theory. These thermodynamical parameters then determine the local concentration in a continuum model for the device scale. However, defect concentrations and electric fields sensitively depend on each other and may vary over several orders of magnitude. In addition, defects may react to form complexes with different charge-transition characteristics, which makes these reactions explicitly potential-dependent. Instead of resorting to a time-demanding simulation of the equilibration process, we have developed an efficient method to compute the thermodynamic equilibrium directly. We apply our approach to the hydrogen distribution around Mg-induced inversion domain boundaries in p-GaN. Our results show that the enhanced affinity of Mg_3N_2 towards H^+ produces significant space charge zones, even though the total amount of hydrogen in the boundary is very low.

HL 27.2 Tue 14:15 H15

Ab-initio based growth simulations of III-Nitride nanowires. — •Liverios Lymperakis and Jörg Neugebauer — Computational Materials Design department, Max-Planck-Institut für Eisenforschung, Max-Planck-Str. 1, 40237 Düsseldorf

III-Nitride based nanowires (NWs) have recently emerged as potential candidates for novel nanodevice applications. A prerequisite for improved device features is to achieve a better understanding of the atomic scale mechanisms that control the growth of these nanostructures. A key step is a quantitative description of the adatom kinetics taking place on the top and the side facets. In a recent *ab-intio* study we have investigated the thermodynamics and adatom kinetics on the non-polar GaN surfaces [1]. Computing the potential energy surfaces for Ga adatoms revealed a strong anisotropy for the diffusion barriers for both *a*- and *m*-plane non-polar surfaces. Based on this insight and using the *ab-intio* computed kinetic parameters we developed a mesoscale growth model. This model consistently incorporates temperature and realistic growth geometries and allows to numerically solve the surface diffusion problem. Based on these calculations we provide a detailed discussion on the dependence of the NW growth rate on temperature, geometry as well as on the substrate.

[1] L. Lymperakis and J. Neugebauer, PRB **79**, 241308(R) (2009).

HL 27.3 Tue 14:30 H15

Processing and contacting of free standing nanorod arrays — •Richard Neumann, Ünsal Sökmen, Stephan Merzsch, Sönke Fündling, Shunfeng Li, Gerhard Palm, Hergo-Heinrich Wehmann und Andreas Waag — Institut für Halbleitertechnik, Technische Universität Braunschweig, 38092 Braunschweig

Nanorods are a hot topic in today's research. Large surfaces are excellent preconditions for gas sensors. The decreased thermal conductivity with good electric conductivity gives a chance for high efficiency thermoelectric devices. Furthermore nanorods show less dislocations then bulk material, giving rise to applications like high quality LEDs with an enhanced light out-coupling due to a smoother refractive index transition or due to photonic crystal effects in which they could be arranged in.

All these possibilities have one thing in common - they need electrical contacts on free standing nanorods, and therefore, suitable processing techniques. The three dimensionality of the structure generates problems that can't be overcome with conventional two dimensional processing used in semiconductor techniques. The first approach we are presenting is planarization giving the possibility to use conventional techniques afterwards. We show different materials with the possibility to level structures with a height of up to 6 μm.

As a second approach we show a new way to contact every single nanorod simultaneously without the need of planarization and lithography. This approach gives the possibility to contact single nanorods without encapsulating the surface.

HL 27.4 Tue 14:45 H15

Elektrische Messungen selbstorganisierter GaN Nanosäulen — •G. Kunert, C. Kruse, T. Aschenbrenner, S. Figge, D. Hommel, J. Kalden, K. Sebald und J. Gutowski — Institute für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

In den letzten Jahren wurden die Eigenschaften von GaN-basierten Nanosäulen umfangreich untersucht. Die Herstellungsmethode des selbstorganisierten Wachstums ist wegen der daraus resultierenden sehr guten Kristallqualität (FWHM D_0X=1,2 meV) anderen Verfahren teilweise überlegen. Der Prozess verwendet in r-Richtung $(1\bar{1}02)$ geschnittenen Saphirsubstrate.
Zur Herstellung der Kristalle wird das Substrat in einem ersten Schritt mittels metallorganischer Dampfphasenepitaxie nitridiert. Dabei bilden sich AlN-Inseln auf der Substratoberfläche. In einem zweiten Schritt wird das Wachstum der Nanosäulen mittels Molekularstrahlepitaxie durchgeführt. Das Verfahren führt zu Nanosäulen welche um 28° zur Oberflächennormalen geneigt sind, sowie einer kompakten, zweidimensionalen Schicht, welche die Nanokristalle umschließt. Es wurden n-, p-Dotierungen, sowie p-n-Übergänge der Nanokristalle realisiert.
Eine Methode zur elektrischen Kontaktierung von Nanosäulen-Ensembles wird präsentiert. Elektrische Messungen zeigen ohmsche Kontaktcharakteristiken für beide Dotierungen. Bei 5V angelegter Spannung konnten Stromdichten von $10\,\mathrm{A\,cm^{-2}}$ (n-dotiert) bzw. $16\,\mathrm{mA\,cm^{-2}}$ (p-dotiert) erreicht werden. Diodenkennlinien von n-p-dotierten Nanosäulen werden diskutiert.

HL 27.5 Tue 15:00 H15

Elektrische Untersuchungen an AlN/AlGaN-Strukturen für LEDs auf Si(111) — K.-M. Günther, •H. Witte, A. Rohrbeck, P. Saengkaew, J. Bläsing, A. Dadgar und A. Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität-Magdeburg, Magdeburg, Germany

AlGaN ist aufgrund seiner variablen Bandlücke von 3,4 eV (GaN) bis 6,2 eV (AlN) ein sehr attraktives Material für optoelektronische Bauelemente für den UV-Bereich. Für diese Anwendung werden jedoch Schichten mit hoher Qualität benötigt. Um die strukturellen Eigenschaften einer AlGaN/GaN-LED auf Si(111) zu verbessern, wurde zur Defektreduktion eine Niedrigtemperatur (LT)/Hochtemperatur (HT)-AlN-Multilayer-Struktur als Anpassschicht zum Si-Substrat verwendet. Diese LED-Strukturen wurden mittels temperaturabhängiger IU- und CV-Messungen und mittels Admittanz- und Photoleitungsspektroskopie detailliert untersucht. Es wurden Hinweise auf Grenzflächendefekte in der LT-AlN/HT-AlN- Multilayer und innerhalb der AlGaN/GaN- Struktur gefunden. Innerhalb des Quantenwells (QWs) zeigen CV-Messungen negative differentielle Widerstands- und Kapazitätsverläufe, die durch Tunnelprozesse innerhalb des QWs erklärt werden können. Die Ergebnisse werden in Hinblick auf den Einfluss der Grenzflächendefekte und der Transportvorgänge im QW auf die elektrischen und optischen Eigenschaften der LED-Strukturen diskutiert.

HL 27.6 Tue 15:15 H15

Doping modulation in GaN investigated by cross-sectional scanning tunneling microscopy — Holger Eisele[1], Lena Ivanova[1], Svetlana Borisova[2], Mario Dähne[1], Momme Winkelnkemper[1], and •Philipp Ebert[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Cross-sectional scanning tunneling microscopy (XSTM) of III-V semiconductor structures on cleavage planes is a powerful technique providing a direct access to the atomically resolved geometric and electronic structure of semiconductor interfaces. Unfortunately, thus far XSTM has been only applied successfully to zincblende type materials. Here we investigated for the first time the imaging mechanisms of a Si doping modulation in wurtzite-structure GaN by cross-sectional scanning

tunneling microscopy. The Si doping modulation gives rise to a voltage and tip dependent height modulation of at least 0.04 nm. The origin of the height modulation in constant-current STM images is traced to two mechanisms. A doping-induced modulation of the band edge energies yields a voltage dependent electronic contrast and an additional mechanical relaxation of the doping-induced strain at the cleavage surface is responsible for a voltage independent modulation of 0.035 nm.

HL 27.7 Tue 15:30 H15

Röntgenographische Qualitäts- und Homogenitätsuntersuchungen an GaN Schichten auf Silizium — •Stephanie Fritze[1], Jürgen Bläsing[1], Oliver Schulz[2], Armin Dadgar[1] und Alois Krost[1] — [1]Otto-von-Guericke-Universität Magdeburg — [2]AZZURRO Semiconductors AG, Magdeburg

Die Heteroepitaxie von GaN auf Siliziumsubstraten stellt eine leistungsfähige und kostengünstige Alternative zum Wachstum auf anderen Heterosubstraten (Saphir, SiC) für die Herstellung effizienter LEDs dar. Es wurden dicke rissfreie GaN Schichten auf Silizium untersucht, die durch den Einsatz von verspannungsreduzierenden LT-AlN-Zwischenschichten eine hohe kristalline Qualität und Homogenität besitzen. Zur schnellen, strukturellen Mikro-Charakterisierung haben wir ein neues Röntgendiffraktometer mit einer Ortsauflösung entwickelt. Die Anlage besteht im Wesentlichen aus einer Drehanodenröhre, einem gekrümmten Johannsson-Monochromator für eine konvergente Strahloptik, einer justierbaren Schneidblende, sowie einem großen Flächendetektor. Im Vergleich zu herkömmlichen Systemen wird die Messzeit bei einer lateralen Auflösung von 10 μm um ca. einen Faktor 100 verkürzt. Mit dieser Anlage wurde an hochwertigem und rissfreiem c-GaN auf Si(111) mit 100 mm Durchmesser die Kristallqualität mittels konventioneller HRXRD und auch in in-plane Geometrie untersucht. Zusätzlich wurden optische Krümmungsmessungen durchgeführt und den röntgenographischen Topographiemessungen gegenübergestellt. Zuletzt wurde die laterale Homogenität der Al-Konzentration in den Zwischenschichten und dem Unterbau nachgewiesen.

HL 27.8 Tue 15:45 H15

Analyse und Interpretation von in-situ Krümmungsmessungen beim Wachstum von AlInN/GaN-Braggreflektoren — •Christoph Berger, Pascal Moser, Armin Dadgar, Jürgen Bläsing und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Die in-situ Messung der Waferkrümmung hat sich mittlerweile zu einer wirksamen Methode entwickelt, um den Verspannungszustand und die Zusammensetzung aufgewachsener Schichten schon während des Wachstums zu bestimmen. Wir zeigen anhand von Krümmungsmessungen, welche beim Wachstum von Braggreflektoren auf der Basis von AlInN/GaN durchgeführt wurden, wie die Durchbiegung des Substrates durch verschiedene Beiträge beeinflusst wird. Zunächst wurde die anfängliche Krümmung der Substrate untersucht, wobei sich eine starke Anisotropie innerhalb der Oberfläche zeigte. Ebenso wurde die Biegung des reinen Substrats beim Erwärmen quantitativ bestimmt, welche durch einen vertikalen Temperaturgradient verursacht wird. Darauffolgend konnten diese Beiträge zur Krümmung aus den Messungen entfernt werden, womit nur noch die Anteile übrig blieben, die durch die Gitterfehlanpassung und die verschiedenen thermischen Ausdehnungskoeffizienten von Schicht und Substrat zustande kommen. Die gemessenen Änderungen der Krümmung bei Temperaturänderungen werden mit berechneten Werten verglichen und es wird gezeigt, dass ein gitterangepasstes Wachstum der AlInN-Schichten erreicht wurde, wodurch keine zusätzliche Spannung in den Schichten induziert wird.

HL 27.9 Tue 16:00 H15

Effect of Mg codoping on Europium(Eu^{+3}) implanted GaN — •Jayanta Kumar Mishra[1], Torsten Langer[1], Uwe Rossow[1], Kirill Trunov[2], Rüdiger Schott[2], Andreas Wieck[2], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig — [2]Angewandte Festkörperphysik,Ruhr-Universität Bochum, Germany

Rare earth ions implanted into GaN are promising for optoelectronic applications. They show luminescence in the visible range while the luminescence from this material system is sharper as well as independent of temperature due to intra 4f transition of rare earth ions. To improve the emission efficiency we implanted Europium in GaN codoped with Mg at dose range from $10^9 cm^{-2}$ to $10^{14} cm^{-2}$ with an energy of 100keV. The red emission from $^5D_0 \rightarrow ^7F_2$ of europium was remarkably enhanced by Mg codoping. At low temperature this line was split into some additional lines due to the host crystal field effect. We observed higher intensity for lower Mg doped GaN but simultaneously relatively broader lines than that of higher Mg doped GaN. We derived the activation energy for both cases and found that it is increased from 4.4meV for high Mg concentation to 8.18meV for low Mg concentration in GaN.

HL 28: Invited Talk: A. Fontcuberta i Morral

Time: Tuesday 14:00–14:30 Location: H17

Invited Talk HL 28.1 Tue 14:00 H17

Ga-assisted MBE grown GaAs nanowires and related quantum heterostructures — •Anna Fontcuberta i Morral — Ecole Polytechnique Federale de Lausanne, Switzerland — Walter Schottky Institut, Technische Universitaet Muenchen

Nanowires represent model systems for studying a variety of low dimensional phenomena as well as building blocks for the future generation of nanoscale devices. The most exploited nanowire growth technique is the vapor-liquid-solid (VLS) method, which employs gold as a seed for the growth. Synthesis of nanowires by molecular beam epitaxy (MBE) and without using gold as a catalyst gives the opportunity to study nanowires produced in extremely clean conditions and correlate it with optical and electronic properties. We present the method for growing GaAs nanowires by MBE without using gold as a catalyst. By changing the growth conditions we have managed to obtain high quality radial and axial heterostructures. For the latter, nanowires with atomically sharp zinc-blende/wurtzite heterostructures have been obtained. These structures exhibit novel optical properties for a pure GaAs material. In particular, we show how the emission of the nanowire can be tuned from 1.51 eV down to 1.43 eV. Theoretical calculations of the band alignment between wurtzite and zinc-blende GaAs will be presented to explain the results. Finally, novel applications enabled by these types of quantum heterostructures will be also briefly discussed.

HL 29: Invited Talk: A. Marent

Time: Tuesday 14:45–15:15 Location: H17

Invited Talk HL 29.1 Tue 14:45 H17

Quantum Dot Flash Memories: The best of two worlds — •Andreas Marent, Tobias Nowozin, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

DRAM and Flash memories dominate presently the semiconductor memory market. DRAMs provide fast access times (>10 ns) but the information has to be refreshed every ten milliseconds. Flash memories are non-volatile with storage times of >10 years, but exhibit a slow write speed. Self-organized quantum dots (QDs) might provide a basis for new generations of memories. They can store just a few charge carriers with a retention time depending on the material combination. Furthermore, the carrier relaxation process into QDs is on the order of sub-picoseconds, an important prerequisite for a very fast write time in such memories.

We developed a memory concept based on QDs, which combines the best of DRAM and Flash and enables ultra fast write times (<ns) in combination with a long storage time (>>10 years). We already

demonstrated a write time in a QD based memory structure of 6 ns and a hole storage time of 1.6 seconds at room temperature. In addition, we predict a storage time of much more than 10 years using 8-band k*p theory. First prototypes of the QD-Memory with full functionality using InAs-QDs were designed and processed. The performance of the prototypes has been evaluated up to 200 K. This work is partly funded by the DFG, BI 284/29-1 and in the framework of the NanoSci-E+ project QD2D of the European Commision.

HL 30: Plasmonics and Nanophotonics II (Joint Session with O/DS)

Time: Tuesday 15:00–16:30 Location: H2

HL 30.1 Tue 15:00 H2

Nanolocalization of time-reversed optical fields propagating in random scattering media — •Dominik Differt[1], F. Javier Garćia de Abajo[2], and Walter Pfeiffer[1] — [1]Fakultät für Physik, Universität Bielefeld, Universitätstr. 25, 33516 Bielefeld, Germany — [2]Instituto de Optica, CSIC, Serrano 121, 28006 Madrid, Spain

The far field emission pattern of a nanoscale light emitter positioned in a nanoscale random scattering environment contains information about the localized emission. Because of the reciprocity of electromagnetic wave propagation time-reversing the outgoing wave creates an excitation that propagates back to the emitter and localizes on a sub-diffraction length scale. The electromagnetic response of a random scattering environment is calculated based on a multiple scattering approach. The here investigated scattering environment is characterized by a geometrical hierarchy. On a subwavelength scale the emitter is surrounded by metal nanoparticles acting as a random antenna coupling radiation to the far field. On the scale of tens of microns, several wavelengths distance to the emitter, this structure is embedded in randomly distributed dielectric scatterers acting a permeable reverberation shell. The degree of nanolocalization of a time-reversed planar wave component of the outgoing scattered wave depends on this geometrical hierarchy and the density of scatterers, i.e. the wave mixing occurring in the reverberation shell.

HL 30.2 Tue 15:15 H2

Towards Nanostructure-Enhanced High-Harmonic Generation — Murat Sivis[1], Katrin Siefermann[2], Yaxing Liu[2], Bernd Abel[2,3], and •Claus Ropers[1] — [1]University of Göttingen, Courant Research Center Nano-Spectroscopy and X-Ray Imaging, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [2]University of Göttingen, Department of Physical Chemistry, Tammannstr. 6, D-37077 Göttingen, Germany — [3]University of Leipzig, Wilhelm-Ostwald-Institute for Physical and Theoretical Chemistry, Linnestr. 2, D-04103 Leipzig, Germany

Recent efforts to utilize optical field enhancements in metallic nanostructures for high-harmonic generation (HHG) have generated significant interest [S. Kim *et al.*, Nature **453**, 575 (2008)]. Using local plasmon resonances, the threshold for HHG can be substantially reduced, allowing for HHG by using unamplified few femtosecond laser oscillators. To date, rather limited information on the characteristics and scaling behavior of the relevant processes is available.

Here, we present the first results of our study on harmonic generation with metallic nanostructures in the presence of a noble gas jet. We demonstrate the significant enhancement of harmonic generation of low orders. Experimental limitations and prospects of the approach are discussed.

HL 30.3 Tue 15:30 H2

Third-Harmonic Generation Spectroscopy in Hybrid Plasmonic Systems — •Tobias Utikal[1,2], Thomas Zentgraf[3], Markus Lippitz[1,2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]NFS Nano-Scale Science and Engineering Center, University of California, Berkeley, USA

In this work we perform third-harmonic generation (THG) spectroscopy in metallic photonic crystals consisting of gold nanowires buried in a dielectric slab waveguide. In these structures particle plasmon polaritons, which are optically excited in the wires, can be hybridized with photonic waveguide modes, which are excited due to the periodic arrangement of the wires. By tailoring the structure geometry the spectrally broad particle plasmon resonance can exhibit an ultra-narrow and pronounced extinction dip. We excite this hybrid plasmonic system with 150 fs laser pulses which can be spectrally tuned over the modulated plasmonic resonance and measure the generated third-harmonic light. The experiments show that it is insufficient to deduce the shape of the THG spectrum from the linear extinction. It is rather essential to consider the full information of the linear response, i.e. amplitude and phase. We find indications that the increased group index and the associated slow light around the extinction dip leads to an increase in the THG signal.

HL 30.4 Tue 15:45 H2

Ultrafast optical nonlinearities in hybrid metal-semiconductor nanostructures — •Parinda Vasa[1], Robert Pomraenke[1], Wei Wang[1], Stephan Schwieger[2], Erich Runge[2], and Christoph Lienau[1] — [1]Carl von Ossietzky Universitaet, Institut fuer Physik, 26111 Oldenburg, Germany — [2]Technische Universitaet Ilmenau, Institut fuer Physik, 98684 Ilmenau, Germany

Understanding and manipulating the interactions between quantum emitters and Surface Plasmon Polaritons (SPPs) is the key to designing and implementing novel nano-optical devices such as nanolasers or ultrafast optical switches. We report the first measurement of an ultrafast optical nonlinearity resulting from the strong interaction between SPPs excited on a gold grating and excitons in either a semiconductor QW or a J-aggregated cyanine dye. The hybrid nanostructures are characterized using far-field linear reflectivity as well as photoluminescence measurements and exhibit enhanced SPP-exciton coupling in the linear optical regime. The experimental results are explained within a phenomenological, coupled oscillator model. The nonlinearity is investigated by low-temperature, angle-resolved, ultrafast pump-probe spectroscopy with 20-fs-time resolution. Due to the strong coupling a significant shift in the resonance wavelength and changes in the response time of the third order nonlinearity of the exciton are observed. Such a strong ultrafast nonlinear interaction between metal and excitons will be of key importance to amplify SPP excitations in such hybrid structures.

HL 30.5 Tue 16:00 H2

Plasmon Hybridization Enhances the Nonlinear Response of Single Metal Nanoparticles — •Thorsten Schumacher[1,2], Kai Kratzer[1,2], David Molnar[1,2], and Markus Lippitz[1,2] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart

The optical investigation of single metal nanoparticles is limited to rather large sizes due to their weak influence on focused laser radiation. Therefore it is very difficult to detect small dielectric variations, which is crucial for modern plasmonic nanosensors. We induce small, periodic variations of a nanoparticle's plasmonic properties by a heating pump puls that triggers acoustical breathing oscillations. The particle's response is monitored by a probe pulse. An optical nanoantenna increases the influence of these single dielectric objects on the laser focus. Such an antenna can be implemented by placing a bigger nanoparticle close to the smaller one that is probed.

We will show measurements of single metal nanoparticles' acoustic breathing modes as well as their first antenna enhanced detection. A model of the antenna-effect of plasmon hybridisation is presented. At the end, it allows us to analyze the individual nanomechanical properties of tiny single metal nanoparticles and study plasmonic coupling effects, without averaging over big ensembles.

HL 30.6 Tue 16:15 H2

Enhanced Raman scattering at nanoparticles and gratings with nanoparticles — •Manuel Gonçalves and Othmar Marti — Universität Ulm - Inst. für Experimentelle Physik, Albert-Einstein-Allee 11, 89081 Ulm, Deutschland

Silver and gold nanoparticles of triangular shape in periodic arrays are appropriate templates for molecular detection by means of surface enhanced Raman scattering (SERS). The near-field enhancements may reach 100 and the corresponding Raman electromagnetic enhancements are of the order of 10^8. On the other hand, surface plasmon modes supported in gratings contribute as well to near-field enhance-

ments, and allow an easy excitation of the long-range surface plasmons in the grating.

We show how plasmonic systems built of gratings and nanoparticles can be of interest for SERS, and how strong near-fields may be achieved. SERS measurements done with a confocal Raman microscope permit to study the dependence of near-field intensity on the shape of the particle and on the excitation conditions.

HL 31: Poster I: Devices, Quantum Dots and Quantum Wires

Time: Tuesday 18:30–20:30 Location: Poster D1

HL 31.1 Tue 18:30 Poster D1

Quantum Electrodynamics on a Chip — •Peiqing Jin[1], Alessandro Romito[1], Jared Cole[1], Alexander Shnirman[2], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, 76131 Karlsruhe — [2]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76131 Karlsruhe

Circuit QED [1], where a superconducting qubit, playing the role of an artificial atom, is coupled to an on-chip superconducting resonator, provides novel methods for studying quantum optics in electrical circuits and for realizing elements for quantum computing. Recently, single qubit lasing and cooling were demonstrated in such a system [2].

We investigate extensions of the circuit QED concepts to situations where the electron spin of an ensemble of quantum dots is coupled to a microwave resonator. The total spin of the electrons in the ensemble can be controlled via a train of laser pulses, as shown in recent experiments [3]. We explore the possibilities offered by such a spin manipulation to achieve Sisyphus amplification and damping of the resonator.

Reference: [1] A. Wallraff, et al., Nature 431, 162 (2004) [2] M. Grajcar, et al., Nature Physics 4, 612 (2008) [3] A. Greilich, et al, Science 317, 1896 (2007)

HL 31.2 Tue 18:30 Poster D1

Small and large signal analysis of quantum dot lasers — •Roland Aust[1], Christian Otto[1], Joshua Horowitz[2], Kathy Lüdge[1], and Eckehard Schöll[1] — [1]Institut f. Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Massachusetts Institute of Technology, Cambridge

In this work a quantum dot laser with an external cavity is modeled using a rate equation system treating electron and hole dynamics separately and including microscopically calculated carrier-carrier scattering rates. We show under which conditions the model reproduces the dynamics of an experimental setup perfectly, and, which additional effects are observed by introducing the external cavity. The laser's small signal response is discussed in detail as well as a large signal analysis in terms of eye diagrams.

HL 31.3 Tue 18:30 Poster D1

Cavity design and heat management in Vertical-External-Cavity Surface-Emitting Lasers (VECSELs) — •Jens Herrmann[1], Alexej Chernikov[1], Martin Koch[1], Tsuei-Lian Wang[2], Yushi Kaneda[2], Mike Yarborough[2], Jörg Hader[2], Jerome V. Moloney[2], Bernardette Kunert[1], Wolfgang Stolz[1], Sangam Chatterjee[1], and Stephan W. Koch[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg — [2]College of Optical Sciences, University of Arizona, Tucson, USA

Vertical-External-Cavity Surface-Emitting Lasers (VECSELs) represent a combination of high output power, high efficiency and good beam quality with compact design in the infrared spectral range. Furthermore large areas of the visible spectrum are accessible due to high-speed frequency-doubled SDLs. In high-power applications cavity design combined with heat management is very important.

We experimentally investigate a model high-power device at 1040nm. The linear cavity consists of the semiconductor chip and a spherical external output coupler. The performance dependence on the reflectance of the output coupler is discussed before we vary the pump spot with the help of the pump optics.

Following we compared the impact of different materials (copper and diamond) for the heat spreader and different heat management concepts. The performance of the device, spectrally resolved emission and the characteristic, curve is investigated under comparable high-power pump conditions and cavity design. In the end the impact of different cavity designs on the performance of the device is compared.

HL 31.4 Tue 18:30 Poster D1

Design and Characterisation of InGaN-based vertical external cavity surface emitting lasers — •Ralph Debusmann[1], Nacef Dhidah[2], Veit Hoffmann[3], Leonhard Weixelbaum[3], Uwe Brauch[2], Markus Weyers[3], Michael Kneissl[1], and Patrick Vogt[1] — [1]Institut für Festkörperphysik, TU-Berlin, EW 6-1, Hardenbergstr. 36, 10623 Berlin — [2]Institut für Strahlwerkzeuge, Universität Stuttgart, 70569 Stuttgart — [3]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4; 12489 Berlin

Optically pumped semiconductor disk lasers (SCDL) with external resonator allow the scaling of laser sources to higher output power levels with diffraction limited beam quality. This idea has already been successfully demonstrated in the infrared spectral region with SCDL based on the material system InGaAs. Here we present a SCDL emitting in the blue-violet wavelength region that is based on the material system InGaN. We have investigated different designs of the InGaN quantum well active region, in particular the application of a resonant periodic gain (RPG) structure and the influence of the cavity length onto the device parameters.

We will discuss implications for the design of the active region besides the presentation of basic device parameters i.e. output-power vs. pump-power, slope efficiency and the far- and near-field pattern.

Pumped by a pulsed nitrogen laser at 337 nm emission wavelength and pulse width of 3 ns the SCDL emits at a wavelength of 394 nm with a threshold power density of 700 kW/cm^2 and a peak output power of 300 W. The conversion efficiency is 3.5

HL 31.5 Tue 18:30 Poster D1

Micro-Printing Setup for Selective Biofunctionalization of Micro-Resonators — •Julian Fischer[1], Torsten Beck[1], Simone Schleede[1], Mario Hauser[1], Tobias Grossmann[1,2], Christoph Vannahme[2], Timo Mappes[2], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institut für Mikrostrukturtechnik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Optical resonators with rotational symmetry like micro-spheres and micro-toroids have been introduced for label-free biomolecule detection. Semiconductor fabrication methods in combination with reflow processes are used to build high-Q optical cavities made of silica or PMMA. Whispering gallery-modes that are excited in the resonators polarize molecules attached to the resonator. This leads to a shift of the mode frequencies. For the parallel detection of different types of bio-molecules, each resonator on a chip has to be functionalized for a specific type of molecules. Therefore a high-voltage micro-printer was set up. A pipette (tip diameter 10-50 μm) is fabricated by thermally extending a glass capillary tube using a standard glass tube puller. A shaped electric pulse is amplified to high voltage ($\sim$ 1kV). The amplifier is connected to the capillary as anode and the substrate holder as cathode. The high electric field due to the voltage pulse generates a droplet impinging on the substrate. The scope of this economic and robust technique, that allows the precise depletion of femto- to nanoliters droplets, is presented.

HL 31.6 Tue 18:30 Poster D1

Oxygen vacancies in ultrathin gate dielectric of MOSFETs and their influence on the leakage current: an ab initio investigation — •Ebrahim Nadimi[1,2], Philipp Plänitz[1,2], Christian Radehaus[2], and Michael Schreiber[1] — [1]Institut für Physik, Technische Universität Chemnitz, D-09107 Chemnitz, Germany — [2]GWT-TUD GmbH - Geschäftsstelle Chemnitz, Annaberger Str. 240, D-09125 Chemnitz, Germany

Oxygen vacancies are known to be the dominant defect in dielectric layer of the MOSFET transistors and are responsible for stress induced leakage current (SILC) as well as degradation of the the gate oxide.

In this work a combination of density functional theory (DFT) within the generalized gradient approximation (GGA) and non-equilibrium Green*s function formalism (NEGF) as implemented in ATOMISTIX TOOLKIT 2.0 (ATK) has been applied to investigate neutral oxygen vacancies in the vicinity of Si/SiO_2 interface. The formation energy of single and double oxygen vacancies at different layers of the oxide, the correlation between the position of vacancies and the carrier tunneling probability as well as the tunneling probability through vacancy chains have been investigated. The single vacancies are shown to be energetically more stable at the Si/SiO_2 interface, where unfortunately they have destructive impact on the leakage current. The formation energies of different arrangements of two vacancies indicate an attractive interaction between them. A chain of five vacancies is shown to drastically increase the leakage and could build a percolation path which results in an electrical breakdown of the dielectric.

HL 31.7 Tue 18:30 Poster D1

High-gain integrated inverters based on ZnO MESFET technology — •Friedrich Schein, Heiko Frenzel, Alexander Lajn, Holger von Wenckstern, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut fürExperimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We combine Schottky diodes and metal-semiconductor field-effect transistors (MESFETs), both based on ZnO and MgZnO thin films grown by pulsed-laser deposition, to fabricate integrated inverters. The MESFETs exhibit low switching voltages which are about one order of magnitude smaller than that for metal-insulator-semiconductor FETs, channel mobilities up to $27\,cm^2/Vs$ and with that faster switching speeds [1]. The integrated circuit design approach used here is known from GaAs technology as Schottky diode FET logic (SDFL) [2]. Our SDFL inverters show high peak gain values up to 197 at 3 V operating voltage and low uncertainty levels in the range of 0.13 V. By adding one additional Schottky diode, we successfully fabricated a NOR-gate, allowing the creation of a complete ZnO-based logic.

[1] H. Frenzel *et al.*, Appl. Phys. Lett., **92**, 192108 (2008)
[2] R. C. Eden *et al.*, IEEE JSSC **SC-13**, 419 (1978)

HL 31.8 Tue 18:30 Poster D1

Characterization of interface traps in stable and efficient Tb-implanted SiO_2 light-emitting devices — •Michael Seeger, Lars Rebohle, Jan Lehmann, Wolfgang Skorupa, Manfred Helm, and Heidemarie Schmidt — Forschungszentrum Dresden-Rossendorf e. V., Bautzener Landstr. 400, 01328 Dresden

The strong green electroluminescence from the Tb^{3+} ions in SiO_2 is excited by hot electrons from the conduction band of the SiO_2 matrix in metal oxide semiconductor light emitting devices (MOSLED)[1]. Charge trapping in the oxide layers and at the oxide layer-semiconductor interface cause a short lifetime of the MOSLED.

This has been investigated by means of frequency dependent admittance-voltage measurements to determine if the MOSLED will perform satisfactorily for different annealing times. Our results on unimplanted MOSLEDs reveal the largest interface trap density of $10^{13}\ eV^{-1}cm^{-2}$ for 60 s rapid thermal annealing at 1000°C. Also the effect of Tb^+ implantation on interface trap properties in MOSLEDs containing double-stacked dielectric layers has been investigated. Quasistatic charge-voltage (QV) measurements have been used to probe the interface trap occupancy versus voltage.

[1] J. M. Sun, W. Skorupa, T. Dekorsy, M. Helm, L. Rebohle, T. Gebel, *Bright green electroluminescence from Tb^{3+} in silicon MOS devices*, J. Appl. Phys. **97**, 123513 (2005).

HL 31.9 Tue 18:30 Poster D1

Analyse der Verstärkungs- und Rekombinationsprozesse in blauen InGaN Laserdioden mittels Kleinsignalmodulationsmessungen — •Jens Müller, Manfred Scheubeck, Sönke Tautz, Georg Brüderl, Sarah Fröhlich, Dimitri Dini, Andreas Breidenassel, Teresa Lermer und Stephan Lutgen — OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg

Blaue InGaN-Laser mit Wellenlängen von 450nm dienen als Lichtquelle für mobile Projektionsanwendungen. Eine möglichst hohe Modulierbarkeit ermöglicht dabei eine größere Bildauflösung. Die Antwort des Laserlichts auf eine frequenzabhängige Kleinsignalmodulation des Stroms lässt sich dabei durch die gekoppelten Differenzialgleichungen für Ladungsträger- und Photonendichte im Laserresonator beschreiben. Als Lösung für die optische Leistung ergibt sich ein harmonischer Oszillator mit einer Resonanzfrequenz und einem Dämpfungsfaktor. Eine direkte Bestimmung der Resonanzfrequenz gestaltet sich aber aufgrund parasitärer Effekte schwierig. Durch Subtraktion zweier frequenzabhängiger Antwortfunktionen konnten jedoch Resonanzfrequenzen von 1-2GHz für blaue InGaN Laser ermitteln werden. Aus der Stromabhängigkeit der Resonanzfrequenz ließ sich darüber hinaus der Gewinnkoeffizient g0 des logarithmischen Gewinnmodells bestimmen. Hierzu wurde zunächst aus Abgleich eines einfachen Rekombinationsmodels mit Ladungsträgerlebensdauer- und Quanteneffizienzmessungen die Ladungsträgerdichte an der Laserschwelle sowie die Rekombinationsparameter bestimmt. Hiermit ergab sich ein Gewinnkoeffizient von 7500/cm.

HL 31.10 Tue 18:30 Poster D1

Crack-free AlGaN-based UV LED on Si(111) substrate — •P. Saengkaew, A. Dadgar, J. Bläsing, H. Witte, M. Müller, K. M. Günther, T. Fey, B. Bastek, F. Bertram, M. v. Kurnatowski, M. Wieneke, T. Hempel, P. Veit, R. Clos, J. Christen, and A. Krost — FNW/IEP/AHE Otto-von-Guericke-Universität Magdeburg

To achieve low-cost UV LEDs on large-diameter substrates it is a very interesting approach to grow AlGaN on low-cost Si substrates. Here, AlGaN layers and AlGaN LED structures grown on Si(111) were additionally monitored by in-situ curvature measurements. They show that with the insertion of AlN-based SL buffer layers and LT-AlN interlayers, the AlGaN layers are under compressive stress during growth enabling to compensate tensile stress after cooling. To characterize the crystalline quality, HR-XRD measurements were performed. Cross-sectional TEM to investigate dislocation propagation and annihilation. N- and p- conductivities were achieved by Si and Mg doping of the layers, respectively. By C-V and Hall-effect measurements, the maximum free-electron concentration of 2.6E+18 cm-3 and free-hole concentration of 2.4E+17 cm-3 by using a structure of Mg-doped GaN/Al0.1Ga0.9N multilayers for the latter were determined. A GaN/Al0.1Ga0.9N MQW structure showed near UV-luminescence around 350-360 nm. The optical and electrical properties of AlGaN-based LED samples were further characterized by I-V, EL, PL and CL measurements. The I-V measurements show forward-diode characteristics with turn-on voltage about 2.6-3.1 V.

HL 31.11 Tue 18:30 Poster D1

AlInN-BASIERTE HYBRIDE VCSEL STRUKTUREN — •Pascal Moser., Armin Dadgar, Alexander Franke, Jürgen Bläsing, Thomas Hempel, Jürgen Christen und Alois Krost — Institut für experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Hybride nitrid-basierte VCSEL Strukturen, welche mittels metallorganischer Gasphasenepitaxie gewachsen wurden, werden praesentiert. Die Strukturen wurden auf 2-Zoll c-achsenorientiertem Saphirsubstrat in einem AIXTRON 200/4 RF-S Reaktor gewachsen. Auf einer AlN/AlGaN-Keimschicht wurde ein ca. 2 mikrometer dicke GaN-Bufferschicht gewachsen. Dieser enthaelt eine Niedertemperatur AlN-Schicht, welche die im Spiegel auftretende Spannung kompensiert und eine SiN-Maske, um die Versetzungdichte zu reduzieren. Der darauf abgeschiedene epitaktische 30-40 fach Spiegel enthält die GaN und AlInN lambda/4-Schichten, welche entsprechend unserer Zielwellenlaenge von 430 nm eine Dicke von 47.1 nm für AlInN bzw. 43.2 nm für GaN aufweisen. Die mit einen In0.15Ga0.85N (2.1 nm) / GaN:Si (5.0 nm) Mehrfachquantengraben versehende 3/2 lambda Kavitaet wurde direkt auf dem Spiegel gewachsen, sodass abschließend ein oberer dielektrischer Ta2O5 / SiO2 Spiegel mit Elektronenstrahlverdampfung deponiert werden konnte.

HL 31.12 Tue 18:30 Poster D1

Enhanced light emission from nitride based UV light-emitting diodes using multifinger contact geometry — •M. Hoppe[1], N. Lobo[2], H. Rodriguez[1], A. Knauer[1], V. Küller[1], P. Vogt[2], S. Einfeldt[1], M. Weyers[1], and M. Kneissl[1,2] — [1]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin, Germany — [2]Technische Universität Berlin, Institut für Festkörperphysik, Berlin, Germany

For ultraviolet LEDs, current crowding at the edges of large area contacts is a serious issue due to low mobility and low donor activation in the n-AlGaN current spreading layer resulting in a high resistivity. It is hence necessary to switch from a simple square contact to more sophisticated contact geometries. In this work, the influence of a multifinger contact geometry on the emission characteristics of 320 nm and 380 nm LEDs has been studied. The emission and the heating of LEDs with constant total contact areas but varying finger widths have

been investigated. Experimental LI-curves and their thermal roll-over and wavelength shift are compared with simulations of current and heat distribution in the LEDs. Data shows that as the finger width decreases from 150 μm to 10 μm the maximum optical output power, which is limited by the self-heating of the unmounted device, increases by 50% for the 380 nm LED. For the 320 nm LED a rise in power of 44% is found when the finger width decreases from 100 μm to 20 μm. Corresponding simulations reveal that the maximum device temperature decreases with the finger width.

HL 31.13 Tue 18:30 Poster D1

Electrical characterization of metal contacts on p-doped Galliumnitride nanowires — •Jörg Kinzel[1], Ahsan Nawaz[1], Jens Ebbecke[2], Raffaella Calarco[3], Toma Stoica[3], Hubert Krenner[1], and Achim Wixforth[1,4] — [1]Lehrstuhl für Experimentalphysik 1, Universität Augsburg, Germany — [2]NanoSYD - Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark — [3]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, Germany — [4]Center for NanoScience, Ludwig-Maximilians-Universität, München, Germany

GaN nanowires as a Group III-nitride semiconductor offer an interesting potential for optoelectronics and nano-electronics devices running at ambient temperatures.

We report on recent investigations on the realization of electric contacts on p-doped GaN nanowires. After growth of the NW by molecular beam epitaxy with in situ Magnesium doping we define individual metal source-drain electrodes by electron-beam lithography. We study the characteristics of different metal contact material combinations. The fabricated contacts and the influence of rapid thermal annealing steps are characterized by IV-measurements at room temperature. We find that Ti/Au contacts commonly used for n-type GaN exhibit poor contact properties in contrast to combinations using Ag or Pd to contact the wire.

HL 31.14 Tue 18:30 Poster D1

Analysis of contact resistance for p-type GaN — •Majdi Salman, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

The overall efficiency of optoelectronic devices such as light emitting diodes (LEDs) or laser diodes (LDs) is strongly affected by the contact resistance of metal contacts, in particular at high current densities. To measure the contact resistance, one typically uses the "transmission line method" (TLM) with rectangular contact geometry or Reeves' CTLM method with circular contacts. In this contribution we study the impact of the rather high resistivity of typical p-type GaN layers on the TLM or CTLM analysis. Using state-of-the-art MOVPE-grown p-type GaN layers with specific resistivities down to 0.8 Ωcm together with Ni/Au- and Pt-based contacts we investigate the influence of the contact geometry, the specific resistivity of the p-GaN layer, and the thickness of the p-type layer on the TLM results. We discuss a simple model explaining the experimental results.

HL 31.15 Tue 18:30 Poster D1

Combining shallow etched quantum wires and sub-micron top gates for acoustoelectric quantum devices — •Marcin Malecha[1], Hubert J. Krenner[1], Jens Ebbecke[2,3], and Achim Wixforth[1,3] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg — [2]Mads Clausen Institute, University of Southern Denmark, Alsion 2, DK-6400, Sonderborg — [3]Center for NanoScience (CeNS), Geschwister-Scholl-Platz 1, 80539 München

Nanostructures, such as quantum wires (QWRs) or quantum dots (QDs), are considered to be the future of the electronics and therefore widely under investigation. Basically the operation of such devices bases upon the controlling of electric potentials on mesoscopic lengthscales within the devices and the leads. We are investigating new sample designs on AlGaAs/GaAs heterostructures where two fabrication processes - shallow etched QWRs and sub-micron sized evaporated topgates - are combined. From this approach we expect a robust QWR definition by the etched structure and precision tuning of the potential landscape along the QWR by the topgates. The goal is a highly controllable system where we are able to transport single electrons e.g. via QD levels using surface acoustic waves. Here electrons are transported in potential valleys, which move along with the wave. We present first characterization experiments of devices combining both fabrication steps.

HL 31.16 Tue 18:30 Poster D1

Mg-doped GaN nanowires: Their optical and morphological properties — •Friederich Limbach[1], Toma Stoica[1], Roberta Caterino[1], Eike Oliver Schäfer-Nolte[1], Tobias Gotschke[1], Eli Sutter[2], and Raffaella Calarco[1] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Center Jülich GmbH, D-52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology — [2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973, USA

High crystal quality GaN nanowires doped by Mg were obtained using plasma assisted molecular beam epitaxy growth in N-rich conditions. The influence of the growth temperature on the morphology, structural and optical properties of NW growth is studied. An additional Mg flux increases the tendency of the wires to coalesce. The morphology of the doped wires with respect to their undoped counterpart is otherwise not changed. With decreasing substrate temperature the NW density decreases, at the same time the coalescence is enhanced.

The samples have been investigated by means of photoluminescence (PL) as well as Raman spectroscopy. By increasing the Mg doping and reducing the deposition temperature, the ultra violet (UV) luminescence band due to Mg doping increases with respect to the near band edge emission. In addition the dominance of D^0X_A emission of the near band edge peak is diminished and an increased contribution of the A^0X_A can be observed. Raman spectroscopy indicates that there is no significant degradation in material quality due to Mg supply during growth.

HL 31.17 Tue 18:30 Poster D1

Selective area growth of InAs nanowires by molecular beam epitaxy — •Christian Blömers, Mihail Ion Lepsa, Thomas Grap, Thomas Schäpers, Hans Lüth, and Detlev Grützmacher — Institute of Bio- and Nanosystems (IBN-1) and JARA - Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich

We report on the growth of InAs nanowires by selective area molecular beam epitaxy. Semiconductor nanowires are interesting for future nanoscale devices and furthermore provide an easy way to study quantum effects in one dimensional structures. InAs is particularly attractive because of its low direct band gap, low effective mass and high mobility making it suitable for electronic (charge and spin related) and optoelectronic applications. A critical issue for the fabrication of nanowire devices is the ability to control the position of the grown wires on the substrate. For this purpose, we have used a SiO_x (Hydrogen silsesquioxane, HSQ) mask with hole patterns. The nucleation of the nanowires takes place in the holes, leading to selectively grown nanowire arrays. Other methods use arrayed metal particles (e.g. Au) which catalyze the growth of the wires. In contrast, our method has the advantage that the wires are of high purity and without contamination of metal atoms. We show results obtained for different growth conditions (varying substrate temperature, beam-fluxes of In and As), different substrates (InP and GaAs) and different preparation methods of the holes in the HSQ.

HL 31.18 Tue 18:30 Poster D1

Fabrication and electrical characterization of silicon nanowires synthesized via electroless etching method — •Guodong Yuan[1], Saskia F. fischer[1], Dennis König[2], and Alfred Ludwig[2] — [1]Fakultät für Elektrotechnik und Informationstechnik, Ruhr-Universität Bochum, Bochum — [2]Fakultät für Maschinenbau, Ruhr-Universität Bochum, Bochum

Silicon nanowires have attracted much attention recently due to their potential applications in future nanoelectronic devices and integrated nanosystems. A facile electroless etching method has been demonstrated for preparing large-area single crystalline silicon nanowire arrays[1]. This novel approach for silicon nanowires is fascinating with respect to the traditional chemical vapour deposition (CVD) method with vapour-liquid-solid (VLS) mechanism, which always needs high temperature, hazardous precursors, expensive source materials and complex vacuum furnace systems. With the catalysis of metallic Ag particle covering on the surfaces of silicon wafer, electroless etching was conducted in aqueous solution of HF and H_2O_2 at room temperature. The as-synthesized silicon nanowire arrays have an epitaxially single crystal structures, a diameter distribution of 50-300nm and controllable length up to 50μm. Electrical transport properties on single silicon nanowire are intestigated. [1] K. Q. Peng, et al, Angew. Chem., Int. Ed. 2005, 44, 2737.

HL 31.19 Tue 18:30 Poster D1

Individual GaAs nanorods imaged by coherent X-ray diffraction — Ullrich Pietsch[1], •Andreas Biermanns[1], Anton Davydok[1], Hendrik Paetzelt[2,4], Ana Diaz[3], Volker Gottschalch[2], and Hartmut Metzger[3] — [1]Universität Siegen, Germany — [2]Universität Leipzig, Germany — [3]ID01 beamline, ESRF, France — [4]IOM Leipzig, Germany

Semiconductor nanorods are of particular interest for new semiconductor devices because the nanorod approach can be used to form heterostructures of materials with a large lattice mismatch and to define nanorod arrays with tailored inter-rod distance. However, all applications require objects with uniform physical properties based on uniform morphology. Complementary to electron microscopy techniques, destruction free X-ray diffraction techniques can be used to determine structural and morphological details. Using scanning x-ray diffraction microscopy with a spot size of 220x600 nm^2 we were able to inspect individual GaAs nanorods grown by seed-free MOVPE through circular openings in a SiN_x mask in a periodic array with 3 μm spacing on GaAs[111]B. The focussed x-ray beam allows the determination of the strain state of individual rods and in combination with coherent diffraction imaging, we were able to characterize also morphological details. Rods grown at different positions in the array show significant differences in shape, size and strain state.

HL 31.20 Tue 18:30 Poster D1

Influence of SiO_2 matrices on electronic and optical properties of silicon nanocrystals — •Kaori Seino[1], Friedhelm Bechstedt[1], and Peter Kroll[2] — [1]nstitut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität, Jena, Germany — [2]Department of Chemistry and Biochemistry, University of Texas at Arlington, Arlington, TX, USA

In recent years, there has been considerable interest in nanostructured silicon since it is a promising material for quantum devices of next generations. Nanocrystals (NCs) have attracted much attention due to the effects of the quantum confinement. Effects due to the confinement of electrons and holes in a region of reduced dimensions promise to overcome the limitation of the indirect-gap semiconductor Si for optoelectronic applications.

We perform calculations of Si dots in SiO_2 matrices for various dot sizes by means of density functionary theory within the local-density approximation (DFT-LDA). Many theoretical results are available for isolated NCs, e.g. hydrogenated Si NCs or partially or fully oxidized Si NCs. On the other hand, theoretical studies for Si NCs embedded in SiO_2 are limited. In our approach amorphous SiO_2 is used as matrix region, which leads to first calculations of electronic and optical properties within a realistic model. We demonstrate the strong influence of SiO_2 matrix on the electronic and optical properties of nanocrystalline silicon.

HL 31.21 Tue 18:30 Poster D1

Ion beam doped semiconductor nanowires for energy applications — •Steffen Milz[1], Vladimir Sivakov[2], Gerald Brönstrup[2], Martin Gnauck[1], Raphael Niepelt[1], Silke Christiansen[2], and Carsten Ronning[1] — [1]Institute of Solid State Physics, University of Jena, Germany — [2]Institute of Photonic Technology, Albert Einstein Straße 9, D-07745 Jena, Germany

Semiconductor nanowires are attractive candidates for thermoelectric and photovoltaic devices due to an increased thermoelectric figure of merit (ZT-value) compared to bulk material and supreme light scattering and absorption performance. In both cases, p- as well as n-type doping is necessary, but doping of nanowires during growth is difficult and inaccurate. Ion implantation was used instead in order to overcome these limitations. However, ion implantation causes also damage, which can be removed by subsequent annealing procedures. In this presentation we report on simple thermoelectric devices based on etched Si nanowires, as well as on photovoltaic devices based on VLS grown Si and ZnO nanowires.

HL 31.22 Tue 18:30 Poster D1

Ion Beam Induced Alignment of Semiconductor Nanowires — Christian Borschel[1], •Susann Spindler[1], Raphael Niepelt[1], Sebastian Geburt[1], Christoph Gutsche[2], Ingo Regolin[2], Werner Prost[2], Franz-Josef Tegude[2], Daniel Stichtenoth[3], Daniel Schwen[4], and Carsten Ronning[1] — [1]Institute for Solid State Physics, University of Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institute for Semiconductor Technology, University of Duisburg-Essen, Lotharstraße 55, 47057-Duisburg, Germany — [3]II. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [4]Department of Materials Science and Engineering, University of Illinois, 1304 W. Green St., Urbana, IL 61801, USA

Epitaxially grown GaAs nanowires were irradiated with different kinds of energetic ions. The growth substrates were <100> GaAs, and the nanowires grow under an angle of 35°. A bending of the nanowires was observed under ion beam irradiation, where the direction and magnitude of the bending depends on the energy, the species, and fluence of the incident ions. By choosing suitable ion beam parameters the nanowires could be realigned towards the ion beam direction. In order to understand the underlying mechanisms, computer simulations of the ion irradiation were done using a special version of TRIM which accounts for the geometry of the nanowires. The simulated distributions indicate vacancy and interstitial formation within the implantation cascade as the key mechanism for bending.

HL 31.23 Tue 18:30 Poster D1

Nanostructured Graphene Devices — •Jan Dauber[1], Bernat Terres[1], and Christoph Stampfer[1,2] — [1]JARA-FIT and II. Institute of Physics, RWTH Aachen, Germany — [2]Institute of Bio and Nanosystems, FZ Jülich, Germany

Graphene is the first real two-dimensional solid consisting of a hexagonal lattice of carbon atoms, revealing a high carrier mobility and quantum Hall effect even at room temperature. First graphene quantum devices have been recently demonstrated, such as graphene nanoribbons, quantum interference devices, graphene single electron transistors and quantum dots. Here, we report on the fabrication and characterization of nanostructured graphene devices based on width-modulated graphene nanoribbons. The graphene nanodevices are fabricated by mechanical exfoliation, lithography and dry etching techniques. We show that to a large extend the device functionality can be engineered by the shape of the nanostructured device. Finally, we discuss the electrostatic tunability of graphene nanodevices.

HL 31.24 Tue 18:30 Poster D1

Magnetotransportmeasurements on epitaxially grown GaAs/(Ga,Mn)As core-shell nanowires — •Christian Butschkow, Stefan Geissler, Silvia Schmidmeier, Andreas Rudolph, Dieter Schuh, Elisabeth Reiger, Matthias Kiessling, Christian Back, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik , Universität Regensburg, Deutschland

We performed magnetotransport measurements on epitaxially grown GaAs/(Ga,Mn)As core-shell nanowires to investigate the magnetic anisotropies of individual nanowires. We found an uniaxial anisotropy with a magnetic hard axis perpendicular to the axis of the nanowire in agreement with SQUID characterizations done on an ensemble of identically grown nanowires. Depending on the direction of magnetization with respect to the nanowire axis, a single domain-switching process takes place at applied fields between 200 mT (parallel configuration) and 1.7 T (near perpendicular configuratian). For saturating the nanowire in the perpendicular configuration a magnetic field of more than 3 T is required. Sweeping the applied magnetic field to high values we observe a rather high negative magnetoresistance if compared to(Ga,Mn)As-films. Furthermore, we determined a Curie-Temperature of about 18K by transport measurements, which is consistent with the results of the SQUID characterizations.

HL 31.25 Tue 18:30 Poster D1

Phonon-mediated vs. Coulombic Back-Action in Quantum Dot circuits — •Daniel Harbusch[1], Daniela Taubert[1], Peter Tranitz[2], Werner Wegscheider[3], and Stefan Ludwig[1] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany — [2]Institut für Experimentelle Physik, Universität Regensburg, Regensburg, Germany — [3]Laboratory for Solid State Physics, ETH Zürich, Zürich, Switzerland

Biased quantum point contacts (QPC) are commonly employed to detect the charge states of qubits composed of coupled quantum dots (QD). Although a biased QPC can be a very sensitive charge detector, it emits energy that can be reabsorbed by the nearby QDs and thereby cause unwanted decoherence. We investigate such back-action of a QPC charge detector on coupled QDs.

Our nano-devices are defined by means of Schottky gates on the surface of a GaAs/AlGaAs heterostructure containing a two-dimensional electron system with an electron temperature of T $\approx$ 100 mK.

Here we observe indirect back-action of a biased QPC onto a double QD. Energy is emitted by non-equilibrium charge carriers in the leads

of the biased QPC. Part of this energy is reabsorbed by the double QD where it causes charge fluctuations. The latter can be observed under certain conditions in the stability diagram of the double QD. By investigating the spectrum of the absorbed energy, we identify two different mechanisms mediating the back-action, namely acoustic phonons and Coulomb interaction. Depending on coupling constants and the geometry of the device either of the two mechanisms can be dominant.

HL 31.26 Tue 18:30 Poster D1

Scattering of hot electrons in 1D versus 2D — •Daniela Taubert[1], Georg Schinner[1], Hans-Peter Tranitz[2], Werner Wegscheider[3], and Stefan Ludwig[1] — [1]Center for NanoScience and Fakultät für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [3]Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland

We measure the energy relaxation of excited electrons in high mobility two-dimensional electron systems (2DES). If hot electrons scatter with the cold degenerate Fermi sea, they exite additional electrons which leave behind conduction band holes. In a suitable three-terminal device, injection into one contact followed by separation of electrons and holes by a gate-defined barrier can lead to an amplification of the injected electron current. From this amplification effect, we extract information about the scattering processes in form of e.g. energy and power dependence.

By applying a perpendicular magnetic field, we observe the crossover from scattering in two dimensions to electrons moving in 1D edge channels.

For energies above 36 meV, emission of optical phonons becomes a relevant scattering process. In a high magnetic field, electron-electron scattering is reduced but electrons relax very efficiently by emission of optical phonons, which can be observed as a periodic reduction of the amplification effect with a period of 36 meV, up to 11th order.

HL 31.27 Tue 18:30 Poster D1

Temperature dependent study of counting statistics of electron transport through a quantum dot — •Nandhavel Sethubalasubramanian, Lukas Fricke, Christian Fricke, Frank Hohls, and Rolf J Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Study of fluctuations in current through a semiconductor device provides information about the transport dynamics of the charges involved in transport through the device. The fluctuations are indirectly and discretely measurable using Quantum Point Contacts as charge detectors. Full counting statistics of mean, variance and higher moments are determined, which provide new information about the system. The work to be presented investigates the effects of temperature and asymmetric tunneling rates across the dot and the evolution of the counting statistics due to these effects. The device under investigation is fabricated through local anodic oxidation on a GaAs/AlGaAs heterostructure. The current study also investigates the statistics of transport through the dot, due to excited electrons.

HL 31.28 Tue 18:30 Poster D1

Noise measurements of a quantized charge pump — •Lukas Fricke[1], Niels Maire[1], Frank Hohls[1], Bernd Kästner[2], Christoph Leicht[2], Philipp Mirovsky[2], Hans Werner Schumacher[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Delivering a quantized number of electrons per cycle in a reliable fashion and at high repetition rate could satisfy the need for a current-quantum standard. A promising candidate is the non-adiabatic electron pump in semiconductor nanostructures, especially considering parallelization of these devices for higher current outputs.

We performed low frequency ($f_n < 10$ kHz) current-noise measurements [1] of such a device at a pumping frequency of $f_p = 600$ MHz. We observe a strong suppression of the noise power when the current is quantized in good agreement with a prediction for an ideal pump whereas in the intermediate region between two quantization plateaus an enhanced noise power can be measured. With these measurements different pumping processes can be distinguished.

[1] N.Maire et al., Appl. Phys. Lett. 92, 082112 (2008)

HL 31.29 Tue 18:30 Poster D1

Wave Packet Propagation and Transport Phenomena in Multi-Terminal Nanodevices — •Christoph Kreisbeck[1] and Tobias Kramer[1,2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We introduce a time dependent approach to describe stationary transport in multi-terminal semiconductor nanostructures. The Landauer-Büttiker formalism relates current voltage-characteristics to transmission amplitudes. Using wave packet propagation the scattering matrix can be computed efficiently for a large energy range (up to 27000 transmission amplitudes with a single wavepacket run), even for complicated potential geometries.

The investigated time dependent approach enables the simulation of recent experiments on 4-terminal Aharonov-Bohm (AB) rings etched in GaAs/AlGaAs semiconductors. The phase of the AB oscillation shows a strong dependency on the Fermi energy. Even though the phase should be continuously adjustable in a four terminal setup, strong phase rigidity prevails in the local setup. In order to explain this behavior one has to go beyond simplified 1D models and the 2D scattering potential has to be modeled realistically. This requires to include depletion effects as well as rounded lead-ring junctions. Under these conditions, the experimentally observed phase change can be reproduced within the Landauer-Büttiker framework. Finite temperature and finite bias voltage does break symmetry in the local setup and the phase rigidity is slightly lifted.

HL 31.30 Tue 18:30 Poster D1

Transient characteristics of a parabolic quantum wire quenched by one or two QPCs — •Cosmin M. Gainar[1], Valeriu Moldoveanu[2], Andrei Manolescu[3], and Vidar Gudmundsson[1] — [1]Science Institute, University of Iceland, Dunhaga 3, IS-107 Reykjavik, Iceland — [2]National Institute of Materials Physics, P.O. Box MG-7, Bucharest-Magurele, Romania — [3]School of Science and Engineering, Reykjavik University, Kringlan 1, 103 Reykjavik, Iceland

We describe theoretically the time-dependent transport through a "sample system" defined as a parabolic quantum wire of a finite length coupled to two semi-infinite leads. The sample may also include one or two embedded quantum point contacts (QPCs) created with Gaussian potentials. The coupling between the leads and the sample is described by a non-local kernel connecting the wave functions from both sides and by a time-dependent coupling function with a smooth onset at the initial moment $t = 0$. Starting with an initial occupation of the sample we calculate the time-dependent currents by solving the generalized master equation of the reduced density operator in the presence of a bias. We investigate and discuss the charge accumulation in the sample, the transient currents along the leads, and the final steady state. We use various initial states of the sample and various coupling functions. The embedded QPCs may considerably slow down the transient processes and affect the shape of the propagating signal.

HL 31.31 Tue 18:30 Poster D1

Quantum point contacts in quantum wire systems — •E. Sternemann[1], S.S. Buchholz[1], S.F. Fischer[1], U. Kunze[1], D. Reuter[2], and A.D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

Quantum point contacts (QPCs) attract high interest for applications as magnetic focussing, beam splitting (quantum Hall edge states), spin filtering and electron thermometry. Here, we investigate QPCs in complex quantum wire (QWR) systems such as quantum rings. The QPCs were realized by lithographical definition of a short (150 nm) constriction (170 nm width) in (a) a 540 nm wide QWR and (b) 520 nm wide QWR leads of a QWR ring as in [1]. Nanogates on top of the constrictions allow for the control of occupied modes in the QPCs. The devices are based on a GaAs/AlGaAs heterostructure with a 2DEG 55 nm below the surface, patterned by electron beam lithography and wet-chemical etching. Two- and four-terminal conductance measurements at temperatures between 23 mK and 4.2 K were performed using lock-in technique. Our measurements reveal that QPCs in 1D nanostructures can be prepared to show subband separations of 6 meV, clear conductance quantization as well as the 0.7 anomaly. We further show that electron injection across a QPC into a QWR ring allows for electron interference (Aharonov-Bohm effect).

[1] S.S. Buchholz, S.F. Fischer, U. Kunze, D. Reuter, A.D. Wieck, APL **94**, 022107 (2009).

HL 31.32 Tue 18:30 Poster D1

Nanoscale ferromagnetic gates on shallow etched quantum wires — •Lakshmy Ravindran[1], Rasmus Ballmer[1], Saskia F. fischer[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Angewandte Festkörperphysik, Ruhr-universität Bochum, D-44780 Bochum, Germany

The effect of magnetic fringing fields on electron transport is a focus of worldwide research because of the promising aspect of utilizing the electron spin for logic operations in spin- and magnetoelectronics (spintronics). Recently, large magnetoresistance phenomena have been reported for nanoscale ferromagnetic gates placed on ballistic quantum channels [1]. We are investigating such a ferromagnetic/semiconductor device with a Permalloy(Py) finger gate only 35nm apart from the GaAs/AlGaAs channel. We define the nanostructures using electron-beam lithography. Patterning of the quantum wire is done by shallow wet-etching. The Py finger gate is fabricated by thermal evaporation and lift-off processing. We have performed the two-terminal conductance measurements using a lock-in-amplifier at a low temperature of 4.2 K. We are investigating the sample with respect to applied gate voltages, cooling top gate bias and magnetic field.

[1] J.-U Bae et al. IEEE Trans, Magn, 44, 4707, (2008).

HL 31.33 Tue 18:30 Poster D1

Ladespektroskopie unter optischer Anregung an InAs-Quantenpunkten — •Patrick Labud, Dirk Reuter, Arne Ludwig, Ashish Kumar Rai und Andreas Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr Universität Bochum

Die Ladespektroskopie an InAs-Quantenpunkten (QDs) findet ihren Anfang im Jahre 1991, als Drexler et al. zum ersten Mal mittels Kapazitäts-Spannungs-Messungen (C(V)-Messungen) das gezielte Beladen von QDs mit einzelnen Elektronen nachweisen konnten. Anhand der Resultate wurde eine schalenartige Energieniveaustruktur nachgewiesen, weshalb man bei QDs auch von "künstlichen" Atomen spricht.

Während die Standard-C(V)-Spektroskopie mit n-Typ Proben nur Informationen über die Energiestruktur im Leitungsband gibt, sollten Messungen unter optischer Anregung auch Informationen über das Valenzband geben. Hierzu werden QD-Halbleiterproben verwendet, auf denen transparente ITO(Indiumzinnoxid)-Gates aufgedampft sind.

In diesem Beitrag werden wir das Konzept erläutern und erste Ergebnisse präsentieren.

HL 31.34 Tue 18:30 Poster D1

Ladungsträgerdichtesteuerung in einer invertierten $GaAs/Al_xGa_{1-x}As$ Heterostruktur mit eingebetteten InAs Quantenpunkten mittels Rückseitengate. — •Sascha Valentin, Arne Ludwig, Dirk Reuter und Andreas Wieck — Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum

InAs Quantenpunkte (QDs) gekoppelt an ein zweidimensionales Elektronensystem (2DES) sind bereits in größerem Umfang studiert worden, aber die Ladung in den QDs ließ sich bei diesen Experimenten, die nur mit einem Oberflächengate durchgeführt wurden, nicht einstellen, ohne auch die Dichte im 2DES zu ändern. In diesem Beitrag stellen wir eine Struktur mit einem zusätzlichen Rückseitengate vor, so dass sich die Beladung der QDs unabhängig von der Dichte der QDs einstellen lässt. Außerdem erlaubt diese Zweigate Struktur, den Abstand zwischen QDs und Elektronenwellenfunktion elektronisch zu beeinflussen, und damit in Abhängigkeit davon den Transport zu studieren.

HL 31.35 Tue 18:30 Poster D1

Investigations of the conductance anomaly in strongly confined Si/SiGe quantum wires — •J. von Pock[1], D. Salloch[1], G. Qiao[1], U. Wieser[1], U. Kunze[1], and T. Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerChrysler Forschungszentrum Ulm, D-89081 Ulm

We investigate the influence of temperature and high parallel magnetic field ($B \leq 15$ T) on a conductance anomaly observed below the first conductance plateau at $G_0 = 4e^2/h$ in Si/SiGe quantum wires. The quantum wires are fabricated from a high-mobility Si/SiGe heterostructure with an electron density of $n = 8.4 \cdot 10^{11}$ cm^{-2} and a mobility of $\mu = 207,000$ cm^2(Vs)$^{-1}$ at 4.2 K. The constriction of the wires is realised by an etch transfer in a low-damage CF_4/O_2 plasma, which provides a strong 1D confinement. The linear transport measurements are performed in a temperature range between 400 mK and 4.2 K. Besides the first regular conductance plateau at G_0 an additional anomal plateau is observed near 0.6 G_0 at $B = 0$ T. With increasing magnetic field the anomal plateau shifts to 0.5 G_0 indicating the Zeeman splitting. Our results agree well with the behaviour of the 0.7 anomaly reported in AlGaAs/GaAs quantum point contacts and quantum wires [1]. For $T = 500$ mK we do not observe a zero-bias anomaly [2] in the subband spectroscopy around the conductance anomaly.

[1] K. J. Thomas *et al.*, Phys. Rev. Lett. **77**, 135 (1996)
[2] S. M. Cronenwett *et al.*, Phys. Rev. Lett. **88**, 226805 (2002)

HL 31.36 Tue 18:30 Poster D1

Geometry Dependent Transport Properties of Undoped InAs Nanowires — •H. Yusuf Günel[1], Christian Blömers[1], Kamil Sladek[1], Andreas Penz[1], Hilde Hardtdegen[1], Martina Luysberg[2], Steffi Lenk[1], Jürgen Schubert[1], Thomas Schäpers[1], and Detlev Grützmacher[1] — [1]Institute of Bio- and Nanosystems (IBN-1) and JARA-Fundamentals of Future Information Technology, Research Centre Jülich GmbH, 52425 Jülich, Germany — [2]Institute of Solid State Research and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forchungszentrum Jülich, 52425 Jülich, Germany

In recent time nanowire (NW) structures attracted much attention, for electronics, optoelectronics and fundamental quantum properties. On account of different application purposes basic transport properties are crucially important at room temperature as well as low temperatures. In this respect InAs NWs are particularly important due to the low band gap and high carrier concentration.

We characterized the basic transport parameters of undoped InAs NWs at room temperature, which were grown on GaAs (001) substrate by MOVPE without catalyst. The NWs that we used in this work had diameters ranging from 25 nm to 200 nm and lengths up to 3.5 μm. Basic transport parameters, such as carrier concentration and mobility, were determined by using two- and four-terminal measurement configuration. The carrier concentration could be controlled by a SiO_2 -isolated back-gate structure. By analyzing the transfer characteristics of the NW FET, we observed very good gate controllability.

HL 31.37 Tue 18:30 Poster D1

Electrical Properties of CVD-grown in situ doped silicon nanowires using silane as a precursor — •Björn Hoffmann, Uwe Hübner, Gerald Brönstrup, Vladimir Sivakov, Florian Talkenberg, and Silke Christiansen — Institut für Photonische Technologien e.V., Abt. Halbleiter-Nanostrukturen, 07745 Jena

In order to use silicon nanowires (SiNWs) for photovoltaic or sensor devices, defined electrical properties are needed. We use electron beam lithography to prepare up to 20 ohmic contacts to one single wire. Thereby we are able to measure the resistivity along the wire in a 4-point-probe-measurement setup. By using a highly doped thermally oxidized Si-substrate as a back gate, we can produce single nanowire FETs.

Doping of SiNWs is performed in situ by adding diborane or phosphine into the CVD-chamber during growth.

Furthermore we use atomic layer deposition (ALD) of aluminium oxide to passivate the wire surface in order to reduce the surfaces recombination rate and thus enhance the carrier lifetime.

HL 31.38 Tue 18:30 Poster D1

Optical manipulation of a Mn spin in a quantum dot via light hole exciton transitions — •Doris E. Reiter[1], Gisel-mar Hemmert[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

The coherent manipulation of a single spin is of great interest in the field of quantum computing. One very promising candidate for an ultra fast spin manipulation is a single Mn spin doped into a single semiconductor quantum dot. The goal is an all-optical manipulation of the Mn spin, which becomes possible via the optical manipulation of the quantum dot exciton. The exciton couples to the Mn via a strong exchange interaction. When transitions of the heavy hole excitons are considered, only a spin transfer from the electron to the Mn spin is possible, while the heavy hole is pinned. In contrast, if light hole excitons are excited both electron and hole can transfer spin to the Mn, which opens up the possibility for an efficient spin control. In this contribution different switching schemes for a coherent manipulation of the Mn spin in a CdTe quantum dot are presented either to address well defined eigenstates or create coherent superposition states. Two

different kinds of dots are studied. In a neutral dot the Mn spin can be changed by two while excitons are only in the system during the switching. In a negatively charged dot an inversion of the Mn spin can be achieved. The optical signal in a pump probe setup should be well suited to monitor the dynamics of the Mn spin.

HL 31.39 Tue 18:30 Poster D1

Electrical spin-injection into single InGaAs quantum dots: circular polarization degree of light from different excitonic complexes — Pablo Asshoff, •Gunter Wüst, Andreas Merz, Michael Hetterich, and Heinz Kalt — Karlsruhe Institute of Technology (KIT) and DFG Center for Functional Nanostructures (CFN), 76131 Karlsruhe, Germany

Quantum dots embedded in spin light-emitting diodes (spin-LEDs) can be charged with spin-polarized electrons and unpolarized holes. The subsequent radiative recombination leads to a circular polarization of the emitted light, revealing the excitonic spin state inside the quantum dot. Spin-injection efficiencies are very high for individual quantum dots [1]. Pulsed electrical injection shines light on the temporal evolution of the spin polarization [2]. Here, we compare the power-dependent behavior of single quantum dot emission lines due to recombination of different excitonic complexes, when optical and electrical pumping are used, respectively. This allows for measuring the circular polarization degree related to different excitonic species during all-electrical spin-injection.

[1] M. Hetterich et al., in Advances in Solid State Physics, edited by R. Haug (Springer, Berlin, 2009), Vol. 48, p. 103; [2] P. Asshoff et al., Appl. Phys. Lett. 95, 202105 (2009)

HL 31.40 Tue 18:30 Poster D1

Electric Field and Excitation-Power Dependent Micro-Photoluminescence Spectroscopy of Single In(Ga)As Quantum Dots — •Florian Stockmar, Daniel Rülke, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

We investigate the excitation-power dependent photoluminescence (PL) of In(Ga)As quantum dots embedded in reversed GaAs micro-pyramids. The pyramidal resonators are fabricated with molecular-beam epitaxy and a combination of e-beam lithography and wet-chemical etching, taking advantage of an AlAs sacrificial layer.By placing the quantum dot layer close to the tip of the pyramids these resonators offer an easy access to the emission of single quantum dots which makes them promising candidates for the realization of single photon sources. Furthermore, we investigate the quantum-confined Stark effect (QCSE) due to laterally applied electric fields. To reveal current-induced thermal contributions to the observed shifts in quantum-dot PL, temporally modulated electric fields are applied in our experiments.

HL 31.41 Tue 18:30 Poster D1

Control of the charge state of quantum dots and quantum posts by surface acoustic waves — •Florian J. R. Schülein[1], F. Knall[1], S. Völk[1], D. Reuter[2], A. D. Wieck[2], T. A. Truong[3], H. Kim[3], J. He[3], P. M. Petroff[3], A. Wixforth[1], and H. J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Universitätsstr. 100, 44780 Bochum, Germany — [3]Materials Department, University of California, Santa Barbara, CA 93106, United States

We demonstrate that surface acoustic waves (SAW) can be used to control the carrier capture dynamics into zero-dimensional semiconductor nanostructures. Sharp emission lines from a single self-assembled quantum dot (QD) are identified which change dramatically under the influence of a SAW: We observe the switching between different emission lines as the SAW power is increased. We observe both red and blue spectral shift which allows us to exclude heating effects as the underlying mechanism. In a defined SAW power range, we observe switching between the two emission lines of positively charged and neutral excitons. For QDs, we observed a hysteretic behavior during SAW sweeps attributed to carrier localization and release from shallow traps in the surrounding wetting layer by the SAW. Switching between negatively charged and neutral excitons was also observed for self-assembled quantum posts (QP) which are embedded in a lateral matrix quantum well. These QPs exhibit an even sharper switching behavior without hysteresis at lower SAW power compared to QDs.

HL 31.42 Tue 18:30 Poster D1

Optical spectroscopy on single charge tunable InGaAs/GaAs quantum dots — •Jan Kettler[1], Claus Hermannstädter[1], Petr Siyushev[2], Fedor Jelezko[2], Jörg Wrachtrup[2], Lijuan-Wang[3], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany — [2]3. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Institut für Integrative Nanowissenschaften IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

We investigate optical properties of self-assembled InGaAs quantum dots. Those are embedded in a n-i-Schottky diode structure, placed on top of a distributed Bragg reflector to increase the photoluminescence (PL) extraction. The application of a bias voltage allows deterministic charging of single quantum dots. Furthermore, a magnetic field, provided by a superconducting magnet in Faraday geometry, as well as a microwave field can be applied to the sample. The latter is achieved by pulling a wire over the sample surface that is covered by an insulation layer. We monitor the excitonic states and the deterministic charging of single quantum dots using micro-PL and excitation spectroscopy. Selective excitation of a negatively charged exciton with a particular spin configuration is aimed at by using a narrow-band laser tuned in to resonance with an excited state of the charged exciton.

HL 31.43 Tue 18:30 Poster D1

Temperature Dependent Photoluminescence of Wet Chemically Etched Silicon Nanowires — •Viktor Gerliz[1], Vladimir Sivakov[2], Silke Christiansen[2], Felix Voigt[1,2], and Gottfried H. Bauer[1] — [1]University of Oldenburg, Institute of Physics, Carl-von-Ossietzky-Str.9-11, D-26129 Oldenburg, Germany — [2]Institute of Photonic Technology, Albert Einstein Str.9, D-07745 Jena, Germany

Silicon nanowire (Si-NW) samples were prepared by Wet Chemical Etching of crystalline silicon wafers. The diameters of these Si-NWs ranged from 30 to 200 nm. Photoluminescence (PL) measurements were performed with excitation at 458 nm and a laser power of 3.2 mW with 1.1 mm beam diameter. According to the Si-NW diameter size $>$ 10 nm, from quantum confinement theory no shift in PL peak energy compared to crystalline silicon is expected. However, PL measurements show peak emission energies in the range 1.4 to 1.6 eV. After further treatment of the samples with HF, substantial PL emission was still detectable and the measured PL peak was pinned at 1.4 eV, irrespective of etching time. For samples treated such way the high energy wing of the steady state PL spectra show a linear behavior in the log-PL vs. photon energy plot pretending - according to Planck′s generalized law - a temperature of 10^3 K. By temperature PL-experiments we are able to discriminate between the influence of temperature on the slope of the high energy Pl wing and a distribution of sites with individual, say, non-overlapping wave functions which also leads to exponentially decaying PL emission.

HL 31.44 Tue 18:30 Poster D1

Growth, Characterization and Lasing of CdS Nanostructures — •Julian Kühnel[1], Sebastian Geburt[1], Christian Borschel[1], Michael Kozlik[1], Amanda McDonnell[1], Kristen Sunter[2], Federico Capasso[2], and Carsten Ronning[1] — [1]Institute for Solid State Physics, University of Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts, USA

CdS is a direct II-VI semiconductor with a band gap of 2.42 eV at room temperature, making it a promising material for optoelectronics and photovoltaic applications. Their geometry and optical properties allow the integration as building and functional elements for nanodevices.

CdS nanowires are synthesized by CVD using the VLS mechanism. The morphology and stoichiometry was investigated by SEM and EDX. Dependent on temperature and pressure conditions during growth, an experimental phase diagram was developed. Straight nanowires with diameters around 200 nm and lengths up to several 10 μm have been synthetisized. TEM measurements confirm the high quality of the single crystalline nanowires. CL measurements were performed to study the optical properties of the nanowires and allow a correlation with their morphology. μPL on single nanowire was utilized to investigate the luminescence at high excitation powers. The CdS nanowires show a broad band edge emission with a linear intensity increase up to 2 MW/cm^2. At higher excitation powers, sharp peaks with defined spacing are evolving. The power dependence clearly shows lasing action in single CdS nanowires above the threshold of 2.5 MW/cm^2.

HL 31.45 Tue 18:30 Poster D1

Optical properties of transition metal doped ZnO nanowires — •Sebastian Geburt, Christian Borschel, and Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Semiconductor nanowires (NWs) offer ideal properties as building elements for next generation optoelectronic devices as e.g. waveguides, LEDs or nanoscaled lasers. Optically pumped ZnO nanowire lasers have already been realized; nevertheless, the lasing threshold of 300 kW/cm^2 is too high for realistic device integration. A solution to lower the threshold could be the change from the quasi-2-niveau system of undoped ZnO to a 4-niveau system of ZnO with optically active impurities like transitions metals (Fe and Co). To cope with the unsolved problem of doping during VLS growth, ZnO nanowires were ion implanted with Fe and Co (0.05 to 8 at%). The ion induced lattice damage was reduced by annealing in different atmospheres. The structural properties were investigated by SEM, TEM and EDX. The optical properties are studied by spatial resolved CL as a function of annealing environment, impurity concentration, temperature and excitation power. The luminescence of single NWs gives insights to the correlation between morphology and light emitting properties.

HL 31.46 Tue 18:30 Poster D1

Optical spectroscopy of ZnO nanowires — •Nils Neubauer[1], Martin Lange[2], Marius Grundmann[2], and Frank Cichos[1] — [1]Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig — [2]Semiconductor Physics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

Semiconductor nanowires are promising building blocks for nanoscale light emitting devices. Especially, ZnO has gained much attention due to its large exciton binding energy and energy bandgap, offering the possibility for room temperature nanoscale light emitters in the blue and UV spectral region as well as in the visible region caused by deep level defect emission. Among different synthesis methods, PLD enables defined nanowire shapes and allows the growth of nanoheterostructures, which is important for device applications, defining optical and electronic properties. We have investigated low area-density, homogeneous core/shell ZnO/ZnMgO quantum well structured nanowires grown by a two step PLD process. Optical studies were carried out in a confocal photoluminescence setup, enabling one and two photon excitation. Spectroscopic studies as well as the study of the emission characteristics were done to investigate the optical properties of these nanowires.

HL 31.47 Tue 18:30 Poster D1

Electrically active dopant profiles in individual silicon nanowires — •Pratyush Das Kanungo[1], Xin Ou[1,2], Reinhard Kögler[2], Peter Werner[1], Ulrich Gösele[1], and Wolfgang Skorupa[2] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, Halle D-06120, Germany — [2]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf e.V., P.O. Box 510119, 01314 Dresden, Germany

Controlled doping and profiling of electrically active dopants in individual silicon nanowires (Si NWs) are two important factors that can decide the use of Si NWs as future building blocks in nano-electronics. We have investigated individual Si NWs doped either by ion implantation or by in-situ dopant incorporation during growth via molecular beam epitaxy, by scanning spreading resistance microscopy (SSRM). In case of the phosphorus ion-implanted and subsequently annealed NWs the SSRM profiles revealed a radial core-shell distribution of the activated dopants. The maximum carrier concentration close to the surface of a phosphorus-doped NW was found to be by a factor of 6-7 higher than the value in the core, and on average only 25% of the implanted phosphorus was electrically active. In contrast, for the in-situ boron-doped NW, the activation rate of the boron atoms was significantly higher than for phosphorus atoms, and the carrier profile was relatively flat over the NW diameter.

HL 32: Poster I: Group II - Oxides

Time: Tuesday 18:30–20:30 Location: Poster D1

HL 32.1 Tue 18:30 Poster D1

Parameter-free calculations of electronic properties and optical transitions of MgO, ZnO, and CdO — •André Schleife, Claudia Rödl, Frank Fuchs, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Jena, Germany

With the computational capabilities that are available nowadays it is possible to drive modern parameter-free calculations towards predictive accuracy. This development made *ab-initio* methods an inevitable tool for materials science when experimental access is impossible, e.g., for non-equilibrium crystal structures.

In our calculations for three important oxide materials we employ the nonlocal hybrid HSE03 functional as approximation to exchange and correlation, even including spin-orbit coupling. Quasiparticle energies are calculated by means of Hedin's *GW* approximation, involving screening of the electron-electron interaction from the fully frequency-dependent dielectric function.

This sophisticated approach is used to derive unknown quantities for MgO, CdO, and ZnO in the wurtzite structure: fundamental gaps, effective electron and hole masses, crystal-field and spin-orbit splittings, optical transition matrix elements, and even exciton binding energies. Chemical trends are pointed out.

HL 32.2 Tue 18:30 Poster D1

Oxygen vacancy and nitrogen substitutional in ZnO: An ab initio study — •Fabian Hachenberg, André Schleife, Jürgen Furthmüller, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

In the last decade, the wide-gap semiconductor ZnO has attracted large attention due to its potential use in optoelectronic applications. Still the difficulty of reliable and reproducible p-type doping is an obstacle in using ZnO for light-emitting devices. Therefore, a comprehensive understanding of the behaviour of point defects in ZnO is crucial. We present first-principles calculations for the electronic and structural properties of two important point defects in different charge states in ZnO. Using a supercell approach we study the oxygen vacancy and the nitrogen substitutional. The calculations are carried out using generalized-gradient corrected density functional theory (DFT-GGA) and pseudopotentials within the projector-augmented wave (PAW) framework. For studying the electronic structure we also employ the GGA+U method and the nonlocal HSE03 exchange and correlation functional. We discuss errors induced by the semilocal GGA, as well as supercell-specific finite-size effects. We derive formation energies and transition levels for both point defects and compare to other calculations and also experimental results.

HL 32.3 Tue 18:30 Poster D1

First principles calculation of inter- and intra-band Auger recombination rates in ZnMgO — •Markus Heinemann and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392 Giessen, Germany

Recent theoretical work on GaInN [1] indicates that inter-band Auger recombination causes a resonance in the Auger coefficient in the blue to green spectrum which leads to a loss in quantum efficiency of nitrite based light emitters. We report ab initio investigations on non-radiative loss mechanisms due to band-to-band Auger recombination in wurtzite ZnMgO alloys. We use density functional theory to compute inter- and intra-band Auger recombination rates as a function of the Mg concentration.

[1] K. T. Delaney, P. Rinke, and C. G. Van de Walle, Appl. Phys. Lett. 94, 191109 (2009)

HL 32.4 Tue 18:30 Poster D1

Ab initio studies on the structural parameters of ZnMgO alloys — •Marcel Giar, Markus Heinemann, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, 35392 Giessen, Germany

Experimental and theoretical investigations on the lattice parameters of $Zn_{1-x}Mg_xO$ alloys in wurtzite structure show a decreasing *c*-axis and an increasing *a*-axis with increasing Mg concentration [1,2]. The *ab*

initio computations [2] are based on density functional theory (DFT) in the local density approximation (LDA). We perform first-principle DFT calculations using the LDA as well as the generalized gradient approximation (GGA) for the exchange correlation functional. We determine the equilibrium lattice parameters of wurtzite $Zn_{1-x}Mg_xO$ alloys for different compositions ranging from $0 \leq x \leq 31.25$ %. For the lattice constants a and c we find the same qualitative behavior as reported in [1] and [2]. LDA results show the typical underestimate of the lattice parameters while the values obtained by GGA excess the experimental results. We further find a deviation from Vegard's law. For the unit cell volume we see a constant behavior independent of the Mg concentration.

[1] A.Ohtomo and A. Tsukazaki, *Semicond. Sci. Technol.* **20**, S1-S12 (2005)
[2] X. F. Fan, H. D. Sun, Z. X. Shen, Jer-Lai Kuo and Y. M. Lu, *J. Phys. Cond. Mat.* **20** 235521 (2008)

HL 32.5 Tue 18:30 Poster D1

Capacsim - numerical modelling of the capacitance of a current-free Schottky diode — •Matthias Schmidt, Martin Ellguth, Holger v. Wenckstern, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany

Schottky diodes (SD) are under investigation for more than 50 years and are a powerful tool in semiconductor defects research. A number of different techniques, each of them somehow connected to the capacitance, or more generally the admittance, were established: e.g. capacitance - voltage spectroscopy (CV), thermal admittance spectroscopy (TAS), and photo capacitance (PCAP).

We developed a numerical model to calculate the admittance of a SD. It provides a realistic reproduction of the influence of six independent parameters - the applied bias, the probing voltage and frequency of the capacitance bridge, the temperature, and illumination of the sample, parameterised by the photon flux and the photon energy. The model takes into account the potential distribution at the Schottky barrier which is calculated numerically in the general case. In case of homogeneous doping of the sample, an analytical solution is used. Furthermore, the time evolution of the occupancy of a trap surrounded by an oscillating electron environment is considered and provides information on the contribution of the local trap density to the measured admittance.

Finally exemplary simulations and a comparison with CV, TAS, and PCAP measurements on real zinc oxide Schottky diodes are presented.

HL 32.6 Tue 18:30 Poster D1

Spin Noise Spectroscopy of ZnO — •Hauke Horn[1], Xavier Marie[2], Andrea Balocchi[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]INSA-CNRS-UPS, LPCNO, Université de Toulouse, 135 Av. de Rangueil, 31077 Toulouse, France

ZnO is a promising material for optical spintronics showing long electron spin lifetimes due to the large band gap and low amount of nuclear spin isotopes. Here, we use spin noise spectroscopy to access the electron spin dynamics of this material in thermal equilibrium while avoiding carrier heating and excitation of electron hole pairs.

A linear polarized laser beam ($E_{\mathrm{UV-Laser}} = 3.32$ eV) close to the direct band gap of ZnO ($E_{D^0X} = 3.36$ eV) is used to detect the spin dynamics of neutral donors in ZnO with off–resonant, non–demolition Faraday rotation. The stochastic oriented electron spins induce polarization fluctuations of the transmitted laser beam. The fluctuation strength of N non–interacting, paramagnetic spins follow the Poisson statistics and generate measurable noise $\propto \sqrt{N}$ spins. These fluctuations are measured via a polarization bridge in the radio frequency regime and Fourier transformed in real–time. A magnetic field B is applied in Voigt–geometry and modulates the noise signal with the Larmor frequency of the electron spins $\omega_L = g\mu_B \mathrm{B}/\hbar$. From the recorded noise spectra we can extract the electron g–factor, spin lifetimes, and densities.

HL 32.7 Tue 18:30 Poster D1

Investigation of piezoelectric and thermoelectric properties of ZnO microstructures — •Irina Laubenstein[1], Marcel Ruth[1], Alexander M. Bernhart[2], Johannes Schaffert[2], Christian A. Bobisch[2], Rolf Möller[2], and Cedrik Meier[1] — [1]University of Paderborn, Experimental Physics & CeOPP - Center for Optoelectronics & Photonics Paderborn, Warburger Str. 100, 33098 Paderborn — [2]University of Duisburg-Essen, Experimental Physics, Lotharstr. 1, 47057 Duisburg

Metal oxides are highly attractive in high-temperature thermoelectric applications due to their inherent oxidation resilience and thermal resistance. Especially zinc oxide (ZnO) is a promising candidate. Alloying can increase the electric conductivity and at the same time decrease the thermal conductivity. Going to nanoscale dimensions, even less thermal conductivity is expected, because of phonon barriers caused by additional interfaces.

We demonstrate the first results of Seebeck-coefficient measurements on especially developed ZnO-microstructures as an intermediate step towards ZnO-nanostructures. Commercially available hydrothermally grown ZnO-crystals as well as plasma-assisted MBE (molecular beam epitaxy) grown ZnO-epilayers on c-plane sapphire substrates are used as basis materials. Furthermore, we investigate the piezoelectric properties of the devices by controllably exerting an external force using a UHV-four-probe scanning tunneling microscope (STM).

Financial support by BMBF via the NanoFutur grant 03X5509-NanoPhox & DFG via SFB616.

HL 32.8 Tue 18:30 Poster D1

Transport properties of ZnO along a- and c-crystallographic directions — •Christian H. Will, Matthias T. Elm, Sebastian Eisermann, Stefan Lautenschläger, Bruno K. Meyer, and Peter J. Klar — 1. Physikalisches Institut, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen

ZnO layers were grown on r-plane and c-plane sapphire substrates by chemical vapor deposition (CVD) resulting in c- and a-plane orientated ZnO layers, respectively. In order to investigate the transport properties along the different crystal directions, the samples were Hall-bar-structured by photolithography, followed by a wet chemical etching step in a solution of water (H_2O), phosphoric acid (H_3PO_4) and acetic acid ($C_2H_4O_2$) in parts of 30:1:1 by volume. On the a-plane ZnO, the Hall-bars were orientated such that the current could be applied either parallel to the a- or parallel to the c-direction of the crystal. For c-plane ZnO, the current direction is along the crystallographic a-direction. Magneto-transport measurements were performed in the temperature range from 1.6 to 280 K in external magnetic fields up to 10 T in order to determine the magnetoresistance, the Hall constant and the mobility as functions of temperature. The resulting transport properties for the different Hall-bar orientations will be compared and analyzed.

HL 32.9 Tue 18:30 Poster D1

Investigations on the stability of zinc oxide based metal-semiconductor field-effect transistors — •Michael Lorenz, Heiko Frenzel, Alexander Lajn, Holger von Wenckstern, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Metal-semiconductor field-effect transistors (MESFETs) were fabricated by reactive dc-sputtering of Ag, Pd and Pt as Schottky-gate contact on ZnO thin films grown by pulsed-laser deposition and by rf magnetron sputtering on glass substrates. With on/off-current ratios of up to 10^6 and channel mobilities at around 1 $\mathrm{cm}^2/\mathrm{Vs}$ [1] the devices are a potential alternative to currently used a-Si based switching thin film transistors (TFTs) in display applications. For a reasonable operation the MESFETs have to be resistent against light illumination, raised temperatures and require a long lifetime under bias stress without the degradation of their field-effect properties. We present studies of the influence of light with different wavelenghts as well as effects of temperatures in the range of 25°C and 150°C on the electrical properties of the MESFETs. Beside the influence of time the bias stress stability and different gate geometries on the field-effect charactersitics of the TFTs are shown.

[1] H. Frenzel *et al.*, Appl. Phys. Lett. **95**, 153503 (2009)

HL 32.10 Tue 18:30 Poster D1

Space-charge regions in ZnO-based metal-semiconductor field-effect transistors and metal-semiconductor-metal photodetectors — •Zhipeng Zhang, Michael Lorenz, Lucie Behnke, Christian Czekalla, Heiko Frenzel, Gisela Biehne, Holger Hochmuth, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstraße 5, 04103, Leipzig

We present current-voltage and light beam induced current (LBIC) investigations of metal-semiconductor field-effect transistors (MESFETs) and interdigital metal-semiconductor-metal photodetectors (MSM-PDs). The Schottky-contacts were fabricated by reactive DC-sputtering of palladium (Pd) with a Pd-capping [1] on nominally undoped ZnO thin films, heteroepitaxially grown by pulsed-laser deposition on sapphire and quartz glass [2]. They exhibit ideality factors < 1.5 and effective barrier heights $> 0.8\,\mathrm{V}$. The normally-on PdO_x-gate MESFETs have an on/off-ratio of 10^3 and channel mobilities of $0.3\,\mathrm{cm}^2/\mathrm{Vs}$. The LBIC measurements enable us to probe the lateral extension of the space-charge regions and homogeneity of the carrier distribution in the samples.

[1]: A. Lajn *et. al.*, J. Vac. Sci. Technol. B, **27**, 1769 (2009)
[2]: H. Frenzel *et. al.*, Appl. Phys. Lett., **95**, 153503 (2009)

HL 32.11 Tue 18:30 Poster D1

Growth and doping of ZnO nanorods — •Cornelius Thiele, Janos Sartor, Felix Eilers, Jonas Conradt, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The growth of ZnO nanorods has attracted a large interest in recent years, due to the abundance of the material and the relative ease of manufacturing such structures. The controllable doping of these structures is in the focus of our work, because almost all applications would benefit from a controllable conductivity. In our case the particular interest is to increase the electron transport in P3HT:PCBM hybrid solar cells by integrating ZnO nanorods. We grow nanorods on different substrates in a vapor phase transport process under high (950°C) and low (500°C) temperatures and investigate different methods of dopant integration. We examine in-situ doping during growth as well as evaporation and in-diffusion of donator materials afterwards. The effects of annealing time, temperature and atmosphere on the donor diffusion are studied by low-temperature photoluminescence measurements.

HL 32.12 Tue 18:30 Poster D1

ZnO-based Nanowire Structures and Heterostructures — •Martin Lange, Christof Peter Dietrich, Christian Czekalla, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

Nanowires are ideal building blocks for future optoelectronic applications. For the fabrication of devices based on heterostructures, bandgap engineering is required, alloying ZnO e.g. with Mg and Cd. The alloys of ZnO with Mg results in a larger bandgap whereas it is reduced for Cd. The growth of alloy nanostructures is often much more challenging than the growth of the alloy thin films as the freedom in the choice of the growth parameters is reduced.

We report on the growth and optical properties of ZnO-based nanowire structures and heterostructures grown by pulsed laser deposition. A ZnO layer on *a*-sapphire was used as substrate to grow the nanowires in the regime of low density, allowing a more controlled growth mode and easier access to single nanowires than for high densities. For the implementation of quantum wells into the heterostructures, a core with a large bandgap is reasonable. In this context, MgZnO-nanowires were investigated. For the quantum well itself ZnCdO is a promising material. Therefore (Mg)ZnO nanowires were coated with a ZnCdO shell and an outer (Mg)ZnO shell forming a nanowire core-shell-structure.

HL 32.13 Tue 18:30 Poster D1

Growth and characterization of ZnO- and ZnO:P-microwires — •Christof P. Dietrich, Martin Lange, Jan Zippel, Jörg Lenzner, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Currently, there is an extreme interest in fabricating small sized ultraviolet emitting devices such as LEDs or lasers. The wurtzite semiconductor ZnO is a promising candidate for such applications due to its band gap at 3.4 eV and its large exciton binding energy allowing the observation of excitonic recombination at room temperature and above.

ZnO is a native *n*-type semiconductor. Stable *p*-type conductivity can be achieved by the incorporation of phosphorus atoms into ZnO [1]. Micrometer sized ZnO- and ZnO:P-rods were grown by a thermal reduction process using carbon as reductant.

We give detailed insight into the growth process of ZnO-based microstructures and their morphology. Furthermore, we present a comprehensive study of the optical and electrical properties of ZnO- and ZnO:P-microwires using cathodoluminescence spectroscopy and Hall effect measurements, respectively.

[1] B.Q. Cao et al., phys. stat. sol. (RRL) **2**, 37-39 (2008).

HL 32.14 Tue 18:30 Poster D1

Implantationsuntersuchungen von ^{100}Pd in ZnO und GaN — •Patrick Kessler[1], Heiko Timmers[2], Aidan P. Byrne[3], Mark Ridgway[4] und Reiner Vianden[1] — [1]Helmholtz Institut für Strahlen- und Kernphysik, Universität Bonn — [2]School of Physical, Environmental and Mathematical Sciences, University of New South Wales at the Defence Force Academy, Canberra — [3]Department of Nuclear Physics and Department of Quantum Science, Research School of Physics and Engineering, Australian National University, Canberra — [4]Electronic Materials Engineering, Australian National University, Canberra

Durch eine Dotierung mit Übergangsmetallen (ÜM) wie Co, Mn oder Fe ist nach Dietl et al [1] Ferromagnetismus von ZnO und GaN bei Raumtemperatur möglich. Mit der Sonde ^{100}Pd, die isoelektronisch zu Co ist, wurde mit der Methode der gestörten Winkelkorrelation (PAC) ZnO und GaN untersucht. Durch das große magnetische Moment der Sonde ist man sehr empfindlich auf interne Magnetfelder am Ort des ÜM.

^{100}Pd wurde am 14UD Pelletron der ANU in Canberra Rückstoßimplantiert. Um das Ausheilverhalten zu studieren wurde ein isochrones Anlassprogramm durchgeführt. Dabei zeigen die untersuchten Halbleiter keinen substitutionellen Einbau der Sonden, obwohl dies mit anderen implantierten Sonden problemlos möglich ist (In, Br, Cd). RBS-Channelling-Messungen an stabilem Pd deuten auf Clusterbildung des ÜM hin.

[1] T. Dietl, Science, vol. 287, pp. 1019-1022 (2000)

HL 32.15 Tue 18:30 Poster D1

Sputter deposited gallium doped ZnO for TCO applications — •Marc Dietrich[1], Achim Kronenberger[1], Angelika Polity[1], Bruno Meyer[1], Jürgen Bläsing[2], and Alois Krost[2] — [1]I. Physikalisches Institut, Justus Liebig Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]FNW/IEP/AHE, Otto-von-Guericke Universität Magdeburg, Postfach 4120, 39016 Magdeburg, Germany

Transparent conducting oxides to be used for flat panel or display applications should exhibit low electrical resistivity in line with a high optical transmission in the visible spectral range. Today indium-tin-oxide is the material which meets these requirements best. However, the limited availability of indium makes it useful to search for alternatives and ZnO doped with group III elements are promising candidates. While the Al doping in high concentrations causes problems due to the formation of insulating Al-oxides, Gallium related oxides are typically n-type conducting wide band gap semiconductors. Therefore we deposited Gallium doped ZnO thin films on quartz and sapphire substrates by radio frequency magnetron sputtering with a ZnO/Ga_2O_3(3at%) composite target. The substrate temperature and the oxygen flow during the sputtering process were varied to optimise the layer properties. Introducing oxygen to the sputtering gas allowed to vary the resistivity of the films by three orders of magnitude from about 1 Ωcm down to less than 1 mΩcm.

HL 32.16 Tue 18:30 Poster D1

Properties of hydrogen doped ZnO films prepared by RF magnetron sputtering — •Achim Kronenberger, Marc Kostantin Dietrich, Steve Petznick, Daniel Horn, Andreas Laufer, Jan Eric Stehr, Angelika Polity, Detlev Michael Hofmann, and Bruno Karl Meyer — I. Physics Institute, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

It is well known that hydrogen incorporated into ZnO induces shallow donor levels while in most other semiconductors hydrogen counteracts the prevailing conductivity by being incorporated as H+ (a donor) in p-type and as H- (an acceptor) in n-type material. Therefore, besides the Group III elements Al, Ga and In, hydrogen is suitable to control n-type conductivity in ZnO.

In our work hydrogen doped ZnO thin films were prepared by reactive radio frequency magnetron sputtering using a ceramic ZnO target. In the deposition process argon was used as sputtering gas and hydrogen and oxygen as reactive gases.

The structural (XRD), electrical (Hall-effect) and optical (Transmission) film properties were analyzed. Secondary ion mass spectrometry (SIMS) was used to quantify the hydrogen incorporation and electron

spin resonance (ESR) measurements were used to detect the nature of the shallow donor. The thermal stability of hydrogen in the ZnO layers was examined by annealing experiments. Also long-term stability was investigated.

By varying the deposition parameters we were able to adjust the carrier concentrations from 10^{13} cm^{-3} up to the 10^{20}.

HL 32.17 Tue 18:30 Poster D1

Influence of ion-beam etching on the transport properties and the structural quality of microstructured zinc-oxide layers — •Markus Piechotka, Martin Fischer, Torsten Henning, Bruno K. Meyer, and Peter J. Klar — 1. Physikalisches Institut, Justus-Liebig-Universität, 35392, Gießen

We developed a wire pattern which is defined on zinc-oxide layers using photolithography and transfered into the layer using ion-beam etching. We investigated the transport behavior and the structural quality of the wire samples obtained. Ion-beam etching is a promising alternative to wet-chemical etching as higher aspect ratios may be achieved. A possible disadvantage is the structural damage of the layer due to ion implantation (gas or mask ions) as well as due to ion scattering processes deep inside the layer or substrate.

The structured samples were investigated by Raman microscopy in back scattering geometry using a 633 nm, 532 nm and 325 nm laser excitation, respectively. This yields information about vibrational modes and possible lattice defects such as impurities or vacancies. In addition the surfaces of the samples were studied via AFM and SEM in order to examine the structural quality and to determine the geometric dimensions of the individual wires. Furthermore we performed magnetotransport measurements to study the electronic transport properties after the etching treatment, mainly to investigate the influence of the damaged region on the electronic properties.

HL 32.18 Tue 18:30 Poster D1

Nitrogen Doping of Homoepitaxial a-plane ZnO — •Sebastian Eisermann, Stefan Lautenschlaeger, Michael Hofmann, Melanie Pinnisch, Andreas Laufer, Peter Jens Klar, and Bruno Karl Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen

Reproducible p-type doping of ZnO by nitrogen remains a challenge and evidence is found that the nitrogen incorporation depends on the growth plane during epitaxial growth. Thus we investigated the growth of nitrogen doped non-polar ZnO on a-plane ZnO-single-crystals using a metallic precursor CVD process. The nitrogen incorporation into the thin films has been analyzed by secondary ion mass spectrometry (SIMS) and the N-related vibrational modes were observed in Raman spectroscopy. Optical features of the layers such as the donor- and acceptor-bound-excitons have been investigated using low temperature photoluminescence (PL) measurements. The nitrogen incorporation in the non-polar films is possible while the incorporation of other impurities, especially group III impurities, seems to be diminished. This leads to a lower residual n-type conductivity.

HL 32.19 Tue 18:30 Poster D1

Nitrogen incorporation in ZnO thin films grown by chemical vapour deposition (CVD) — •Michael N. Hofmann, Stefan Lautenschlaeger, Sebastian Eisermann, Udo Roemer, Melanie Pinnisch, Andreas Laufer, Swen Graubner, Peter J. Klar, and Bruno K. Meyer — 1. Physics Institute, Justus-Liebig-University, Heinrich Buff Ring 16, 35392 Giessen, Germany

We determined the effect of different growth temperatures on the amount of nitrogen incorporation in thin ZnO films grown by chemical vapour deposition in a vertical growth configuration. Ammonia was chosen as nitrogen percurser, while ZnO a-plane and c-plane bulk crystals served as substrates. The grown films were investigated by Raman spectroscopy, photoluminescence and secondary ion mass spectroscopy. It turned out that low growth temperatures promote the incorporation of nitrogen. In contrast high growth temperatures are indispensable for achieving good crystal quality. We will show how to combine high nitrogen amounts with high crystal quality by in situ modulation of growth temperature and ammonia flux. Furthermore we investigated the influence of an additional annealing step on the samples.

HL 32.20 Tue 18:30 Poster D1

Electrical characterization of defects in MgZnO thin films grown by pulsed-laser deposition — •Kerstin Brachwitz, Holger von Wenckstern, Matthias Schmidt, Christof P. Dietrich, Marko Stölzel, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

We present electrical investigations on $Mg_xZn_{1-x}O$ semiconductor alloys, grown by pulsed-laser deposition. The Mg-content in the samples ranged from 0% to 40%. We investigated the structural and electrical properties of the thin films in dependence on the Mg-content. Furthermore we monitored changes of the activation energy of defect states after annealing for 30 minutes at different temperatures (500°C, 700°C and 900°C) in 700 mbar oxygen. High quality Schottky contacts were realized by reactive dc-sputtering of Pd. These Schottky diodes were used to investigate shallow and deep defect states using depletion layer spectroscopy. The thermal activation energy and the capture cross-section of the E3 defect have been determined in dependence on the Mg-content [1]. Shallow defects, already known in ZnO [2] were also observed in MgZnO and correlated with near band edge recombination spectra.

[1] H. von Wenckstern *et al.*, J. Electron. Mater., DOI: 10.1007/s11664-009-0967-0 (2009)

[2] F. D. Auret *et al.*, J. Phys. Conf. Ser. **100**, 042038 (2008)

HL 32.21 Tue 18:30 Poster D1

Laplace-transform deep-level transient spectroscopy in ZnO thin films — •Florian Schmidt, Holger von Wenckstern, Matthias Schmidt, Martin Ellguth, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik, Linnéstraße 5, 04103 Leipzig

Deep-level transient spectroscopy (DLTS) is a space charge spectroscopic method commonly used for the characterization of semiconducting materials. The time constant resolution of standard DLTS using boxcar or lock-in techniques is however too poor for studying fine structure in emission processes. Digital transient processing, e.g. used in Laplace-transform deep-level transient spectroscopy (LDLTS), enables more sensitive deconvolution of capacitance transients.

We investigated ZnO thin films grown by pulsed-laser deposition by using LDLTS and demonstrated, that DLTS is not suited to characterize the two closely lying levels E3/E3' [1] appropriately. Instead, LDLTS is necessary to determine defect parameters as thermal activation energy E_t and apparent capture cross-section σ unambiguously. We found for E3 $E_t = 295$ meV and $\sigma = 4 \times 10^{-16}$ cm^2 and for E3' $E_t = 386$ meV and $\sigma = 4 \times 10^{-14}$ cm^2.

[1] F.D. Auret et al., Physica **B** 401-402 (2007) 378

HL 32.22 Tue 18:30 Poster D1

Defekt-Komplexbildung nach Ionenimplantation in ZnO — •Valentin Germic, Patrick Kessler und Reiner Vianden — Helmholtz Institut für Strahlen und Kernphysik, Universität Bonn

Nach der Implantation der Winkelkorrelationssonden ^{111}In oder ^{117}Cd und einer Anlasstemperatur von 900 K tritt ein Defekt auf, der allerdings bei höheren Temperaturen wieder ausheilt. Ein ähnlicher Defekt wurde bereits bei Winkelkorrelationsmessungen (PAC) von ^{111}In in ZnO nach der Dotierung mit Zn beobachtet [1]. Beides deutet auf eine mögliche Sauerstoffleerstelle hin. Dies könnte Hinweise für einen möglichen Mechanismus von Ferromagnetismus in Halbleitern geben, der durch die Bildung von magnetischen Polaronen aus Übergangsmetall-Ionen und einer Sauerstoffleerstelle entstehen [2].

Es kann gezeigt werden, dass die Defektbildung abhängig vom Implantationswinkel und unabhängig von der Ausheilatmosphäre ist. Durch eine PAC Orientierungsmessung wurden mögliche Positionen der Leerstelle im Kristallgitter bestimmt. Mit β-γ Korrelationsmessungen der Sonde ^{111}Ag ist abschließend die Bestimmung des Defekt-EFG Vorzeichens möglich.

[1] D. Forkel et al Mat. Res. Soc. Symp. Proc. 46 (1985) [2] J. M. D. Coey, Nature Materials 4, 173 - 179 (2005)

HL 32.23 Tue 18:30 Poster D1

Optical properties of transition metal doped ZnO — •Stephanie Jankowski[1], Limei Chen[1], Jonatan Helzel[1], Shuangli Ye[2], Carsten Ronning[3], Detlev Schulz[4], Birk Heimbrodt[4], Detlef Klimm[4], and Wolfram Heimbrodt[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, D-35032, Germany — [2]Institute of Microelectronics and Information Technology, Wuhan University, Wuhan 430072, China — [3]Physikalisch-Astronomische Fakultät, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena — [4]Leibniz-Institut für Kristallzüchtung, Max-Born-Str. 2 D-12489 Berlin, Germany

Various optical spectroscopy techniques have been used to investigate

Co and Mn doped ZnO. Two series of samples were prepared for both (Zn,Co)O and (Zn,Mn)O. One series of ZnCoO thin films was grown by UHV-magnetron reactive sputtering and the other consists of ion implanted ZnO wires on a silicon substrate. The Mn doped series were fabricated by diffusion or by ion implantation of Mn in ZnO bulk material. The Mn and Co doped samples exhibit distinct differences in optical properties. In the case of the (Zn,Co)O the intern 3d transitions can be seen in PL as well as in absorption spectra. A broad Mn induced band is observable below the band gap in the absorption of the Mn doped samples. Details will be discussed at the poster.

HL 32.24 Tue 18:30 Poster D1

Photocurrent measurements of *a*- and *c*-plane oriented ZnO layers — •Richard K. Thöt, Thomas Sander, Sebastian Eisermann, Stefan Lautenschläger, Bruno K. Meyer, and Peter J. Klar — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

We present in-plane photocurrent measurements of CVD-grown ZnO layers on different substrates. The measurements were performed at temperatures in the range from 80 K to 300 K. The spectra yield information about the influence of strain and crystal orientation on the interband transitions. At liquid nitrogen temperature a finestructure of the photocurrent response is visible due to transitions from multiple valence band energies. In another experiment we recorded photocurrent spectra using linearly polarized probe light varying the polarization angle. For *a*-plane grown ZnO samples the photocurrent confirms the expected anisotropy of the semiconductor layers. The finestructure of the valence band can be studied and the orientation of the *c*-axis within the layer can be determined.

HL 32.25 Tue 18:30 Poster D1

The refractive index of zinc oxide microwire single crystals — Christian Czekalla, Philipp Kühne, Chris Sturm, •Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

Among a large number of applications, zinc oxide (ZnO) single crystals (bulk and micro- and nanowires) are expected to form important building blocks for future optoelectronic devices like light emitting and laser diodes. Optical resonances from ZnO structures have been observed by a number of groups in the past years.

In most of the publications, modeling of the mode structure, especially in the near bandgap spectral region, is difficult because the energy dependent refractive index $n(E)$ is typically not known. Additionally, in case of the self assembled micro- and nanowires, the structures are too small to perform spectroscopic ellipsometry to determine $n(E)$.

We compare $n(E)$ obtained from (a) spectroscopic ellipsometry measurements of ZnO bulk single crystals and (b) spatially resolved photoluminescence measurements of ZnO microwires employing a plane wave whispering gallery mode model for the observed resonances. We discuss the differences between the results obtained from the two methods and their mutual impact, leading to a highly precise determination of $n(E)$ in an energy range between 1.80 eV and 3.25 eV and for temperatures between 10 K and 295 K.

HL 32.26 Tue 18:30 Poster D1

Photolumineszenz- und Transmissionsmessungen an ZnO/MgZnO-Quantengrabenstrukturen — •Johannes Kupper, Alexander Müller, Gabriele Benndorf, Martin Lange, Matthias Brandt, Michael Lorenz und Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnestr. 5, 04103 Leipzig

Eine Möglichkeit zur Einstellung der Emissionswellenlänge von optischen Bauelementen bieten Quantengrabenstrukturen. Die Confinementenergie lässt sich über die Barrierenhöhe und Grabenbreite einstellen. Für Gräben aus ZnO eignet sich MgZnO als Barrierenmaterial. Mittels gepulster Laserabscheidung wurden einzelne ZnO/MgZnO-Quantengräben (QWs) mit unterschiedlicher Grabenbreite bei verschiedenen Züchtungsbedingungen auf *a*-Saphir abgeschieden. Dabei war es möglich QWs mit und ohne quantenunterstütztem Stark-Effekt (QCSE) darzustellen. Zur besseren Gitteranpassung wurde zwischen Grabenstruktur und Substrat eine MgZnO-Pufferschicht eingebracht.

Die QWs wurden mit Hilfe von Photolumineszenz(PL)- und Transmissions(TM)-Messungen zwischen 2K und 300K untersucht. Neben dem intensiven Hauptpeak der QW-PL zeigen sich mehrere Phononenwiederholungen, wobei die QWs mit QCSE eine zusätzliche Rotverschiebung der PL aufweisen. Die Grabenabsorption zeigt bis zu zwei Maxima. Das niederenergetische Maximum kann dem e1-h1-Übergang zugeschrieben werden. Die Zuordnung des höherenergetischen Maximums wird diskutiert.

HL 33: Poster I: Transport, including Magnetic-Field Effects

Time: Tuesday 18:30–20:30 Location: Poster D1

HL 33.1 Tue 18:30 Poster D1

Atomistic Description of Large Nanostructures based on III-Nitride semiconductors — •Alejandro Molina-Sánchez[1], Alberto García-Cristóbal[1], Andres Cantarero[1], Aleksandrs Terentjevs[2], and Giancarlo Cicero[2] — [1]Instituto de Ciencia de Materiales de la Universidad de Valencia, P.O. Box 22085, E-46071 Valencia, Spain — [2]Physics and Materials Science and Chemical Engineering Departments, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

Semiconductor nanocolumns exhibiting a growth without dislocatinos and high crystalline quality are of great interest in nanotechnology applications. Specifically, InN-based nanocolumns are good candidates to develop multi-junction solar cells due to their small gap, 0.67 eV, and the posibility of alloying with other nitrides (as GaN and AlN) to cover the entire solar spectrum. A proper description of optical properties of the nanostructures described above can start with an atomistic treatment of the electronic structure in order to keep the essential geometry and symmetry of the objects. Unfortunately, the best description realized with ab initio electronic structure software is strongly limited by the nanocolumn diameter to a few nanometers. By using a combination of ab initio and empirical tight-binding methods, we can connect the quality of the first principles calculations (performed with the Espresso code), with the versatility of an empirical approach. Once we have an ab initio quality parameter set for the empirical tight-binding code, we can study larger nanostructures with this approach, reducing the computation time in orders of magnitud.

HL 33.2 Tue 18:30 Poster D1

Non-linear properties of ballistic electron-focusing devices — •Arkadius Ganczarczyk[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Experimental Physics and CeNIDE, Universität Duisburg-Essen — [2]Chair of Applied Solid State Physics, Ruhr-Universität Bochum

This poster has been withdrawn.

HL 33.3 Tue 18:30 Poster D1

Transport through a molecular junction within P(E)-theory — •Denis Kast and Joachim Ankerhold — Institut für Theoretische Physik, Universität Ulm

Directed charge transfer in isolated molecular aggregates originates from a fluctuating environment consisting e.g. of internal vibronic modes or solvent degrees of freedom. Corresponding transfer rates can be derived within the P(E)-formalism known from the theory of Coulomb-blockade in single charge transfer. This methodology can be extended to describe incoherent charge transport through molecular junctions including the electromagnetic environment of the actual circuitry. We present first results for simple molecular junctions and for internal vibronic degrees of freedom in and out of thermal equilibrium. Findings are compared with data from real-time Quantum Monte Carlo simulations.

HL 33.4 Tue 18:30 Poster D1

Electrical Properties of Graphene- Carbon Nanotube junction — •Pablo Thomas Robert, Julien Bordaz, Romain Danneau, and Frank Hennrich — Karlsruher Institut für Technologie, Campus Nord, Institut für Nanotechnologie

Since it has been in 2004 first isolated, it has become one of the hottest

research topics in condensed matter physics. The peculiar band structure of this zero-gap semiconductor leads to novel electronics properties and mades it a high promising material for electronic devices. Our aim is to study the electrical transport properties of graphene-nanotube hybrid carbon systems by carrying out 4 point-probe measurements and the graphene/carbon nanotube interface resistance. We want to compare those measurements with the ones obtained when using the metal electrodes standard technique to connect the graphene sheet.

To fabricate our probes, we first deposit on highly doped silicon substrates some graphene by mechanical exfoliation of graphite. After spin-coating a multi-walled carbon nanotube solution on the probe, the nanotubes are then dragged on the graphene sheet using an atomic force microscope in non-contact mode. We also pattern metal contacts on the graphene sheet using standard electron beam lithography followed by ultra-high vacuum metal evaporation.

HL 33.5 Tue 18:30 Poster D1

Pure orbital photocurrents in (111) Si-MOSFETs — •J. Kamann[1], J. Karch[1], P. Olbrich[1], S.A. Tarasenko[2], E.L. Ivchenko[2], T. Schönberger[1], Z.D. Kvon[3], and S.D. Ganichev[1] — [1]THz Center, University of Regensburg, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Russian Academy of Sciences, Novosibirsk, Russia

We report on pure orbital photocurrents in (111) grown Si-MOSFET structures. Photocurrents are generated by illumination with a pulsed high power THz laser of several wavelengths. We obtain photon-helicity dependant currents, changing sign when we switch the circular polarization of the incident pulse from left- to righthanded. Furthermore we were able to measure currents that vary with the orientation of linear polarized radiation. In addition to the spin, free carriers in solid states can be characterized by other internal properties, e.g., a valley index in manyvalley semiconductors. In this case, one can consider pure orbit-valley currents, where partial electron fluxes in valleys are nonzero but the net electric current $\sum I_\nu$ vanishes. Here, the role of spin-up and spin-down states is replaced by the valley index: there is no net charge current, but the electrons in different valleys travel in different directions. Si-MOSFETs grown in (111) direction belong to the symmetry group C_{3v}, denying currents that are sensitive to unpolarized or circular polarized radiation under normal incidence. However, a net electric current induced by linearly polarized light is allowed. In this case, the partial fluxes become nonequal and do not compensate each other. This is demonstrated in our experimental results.

HL 33.6 Tue 18:30 Poster D1

Magnetoconductance switching in arrays of oval quantum dots — •Christian Morfonios — PCI Heidelberg

Employing oval shaped quantum billiards connected by quantum wires as the building blocks of a linear quantum dot array, we calculate the ballistic magnetoconductance in the linear response regime. Optimizing the geometry of the billiards, we aim at a maximal finite- over zero-field ratio of the magnetoconductance. This switching effect arises from a relative phase change of scattering states in the oval quantum dot through the applied magnetic field, which lifts a suppression of the transmission characteristic for a certain range of geometry parameters. It is shown that a sustainable switching ratio is reached for a very low field strength, which is multiplied by connecting only a second dot to the single one. The impact of disorder is addressed in the form of remote impurity scattering, which poses a temperature dependent lower bound for the switching ratio, showing that this effect should be readily observable in experiments.

HL 33.7 Tue 18:30 Poster D1

Magneto-Transport Studies on Evenly Curved Two-Dimensional Electron Systems in Semiconductor-Microtubes with Hall Bar Contact-Geometry — •David Sonnenberg, Karen Peters, Stefan Mendach, Andrea Stemmann, and Wolfgang Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

We present magneto-transport studies on evenly curved two-dimensional electron systems (2DES) in InGaAs-microtubes. The microtubes are fabricated from epitaxial films, by releasing thin strained semiconductor layers from the substrate. Strain relaxation causes the film hosting the 2DES to roll-up into tubes with micrometer sized diameters. The rolled-up 2DES are prepared in a Hall-bar contact-geometry along the curvature of the microtube. Low-temperature magneto-transport measurements are performed with current direction parallel to the modulation of the perpendicular magnetic-field component. An asymmetric behaviour of the Hall resistance in dependence of the magnetic field orientation will be discussed.

HL 33.8 Tue 18:30 Poster D1

Serial arrays of square Quantum Hall devices for resistance standards — •Jens Könemann, Franz-Josef Ahlers, Klaus Pierz, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Combining several Hall bars in series or in parallel with the help of the multiple series connection technique [1] allow to realize quantum resistance standards for resistance values from, e.g., 100 Ω to 1 MΩ. One of the necessary checks for verifying such a device as a resistance standard comprises the reversal of the magnetic field orientation. However, for serial arrays such a reversal intrinsically results in different resistance values for the two field orientations. Here, we propose a scheme to circumvent this restriction. It relies on interchanging the voltage and current probes together with the magnetic field inversion using a totally symmetric design based on square Hall bars. First device realizations are presented.

[1] F. Delahaye, J. Appl. Phys., Vol. 73, 7914 (1993).

HL 33.9 Tue 18:30 Poster D1

Anomalous magnetotransport of magnetic 2DHGs in the quantum-Hall regime — •Stefan Knott[1], Ursula Wurstbauer[1], Thomas Hirschmann[1], Werner Wegscheider[2,3], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [3]Solid State Physics Laboratory, ETH Zürich, Switzerland

The interaction of localized magnetic moments with a two-dimensional hole gas is studied with low-temperature magnetotransport measurements. The hole gas is confined in manganese modulation-doped InAlAs/InGaAs/InAs quantum wells grown by molecular beam epitaxy. If Mn ions are inside the quantum well the holes are strongly localized at zero field, while it shows quantized transport at high field featuring Shubnikov-de Haas oscillations and the quantum-Hall effect. Here we present high-field data that show pronounced deviation from the behavior of samples with no Mn ions in the quantum well: The Hall voltage is neither linear nor monotonous and the 1/B-periodicity is not given anymore. Moreover, a significant weak anti-localization signature is present still at 4.2K in samples without Mn ions in the channel, indicating strong spin orbit coupling. The observed temperature dependency of both types of samples and possible explanations will be discussed.

HL 33.10 Tue 18:30 Poster D1

Collective Excitations of Interacting Two-Dimensional Electrons in High Magnetic Fields — •Guenther Meissner and Uwe Schmitt — Theoretische Physik, Universitaet des Saarlandes, Postfach 151150, D-66041 Saarbruecken

A hierarchy of fractional quantum Hall states at odd-denominator rational filling factors of the lowest Landau level is associated with a correspoding hierarchy of liquid phases. At sufficiently high magnetic fields such liquid phases are terminated by an insulating phase which could be identified as being a quantum solid phase related to the Wigner crystal. Therefore, we have explored, in as far, as a many-body approach for interacting two-dimensional electrons in high magnetic fields [1] is suitable for investigating collective excitations of these states. Composites of 1, 2, and 3 electron charges (e), with 3, 5, and 7 magnetic flux quanta (ch/e), respectively, are considered in view of recent experimental invastigations of magneto-rotons [2]. The anyonic statistics of the resulting fractionally charged quasiparticles of charge e/3, e/5, and e/7 is of importance for studying topological order and might find application for building a topological quantum computer.

[1] G. Meissner, Physica B 184, 66 (1993). [2] I.V. Kukushkin, J.H. Smet, V.W. Scarola, V. Umansky, and K. von Klitzing, Science, 324, 1044 (2009).

HL 33.11 Tue 18:30 Poster D1

Spin photocurrents in diluted magnetic semiconductors — •M. Schmalzbauer[1], P. Olbrich[1], S.D. Ganichev[1], S.A. Tarasenko[2], V.V. Bel'kov[2], Ch. Brinsteiner[1], W. Eder[1], D.R. Yakovlev[2,3], V. Kolkovsky[4], W. Zaleszczyk[4], G. Karczewski[4], T. Wojtowicz[4], and D. Weiss[1] — [1]THz Center, University of Regensburg, Germany — [2]Ioffe Physico-Technical Institute, Rus.

Academy of Sciences, St. Petersburg, Russia — [3]Exp. Physics 2, TU Dortmund, Germany — [4]Institute of Physics, Warsaw, Poland

We report on the observation of spin photocurrents resulting from the zero-bias spin separation in diluted magnetic semiconductors (DMS). We show that in (001)-grown (Cd,Mn)Te/(Cd,Mg)Te quantum wells the absorption of THz radiation leads to pure spin currents. Although the electric current is zero, spin up and down carriers pile up on opposed sample edges. By means of an in plane magnetic field $\boldsymbol{B}$ the balance between the spin currents is disturbed due to the Zeeman splitting and leads to a electron flow increasing with $\boldsymbol{B}$. In DMS this conversion is strongly enhanced due to the giant Zeeman splitting and the spin-dependent exchange scattering of e^- by Mn^{2+} ions polarized in the external magnetic field [1]. Both contributions affect the balance between the contrarily spin flows additionally and give rise to the electric current. For weak $\boldsymbol{B}$ and a degenerated 2DEG the scattering mechanism dominates the conversion. We demonstrate the importance of the spin-dependent scattering in the current generation giving an additional access to the manipulation of spin-polarized currents.

[1] S.D. Ganichev *et. al.*, *Phys. Rev. Lett.* **102**, 156602 (2009)

HL 33.12 Tue 18:30 Poster D1

Tuning of Structure Inversion Asymmetry (SIA) by the δ-Doping Position in (001)-Grown GaAs Quantum Wells (QW) — •Vera Lechner[1], Sebastian Stachel[1], Peter Olbrich[1], Leonid Golub[2], Dieter Schuh[1], Werner Wegscheider[1], Vasily Belkov[2], and Sergey Ganichev[1] — [1]Terahertz Center, University of Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia

We demonstrate that the preparation of QWs with various δ-doping layer positions accompanied by measurements of the magnetogyrotropic photogalvanic effect (MGPE) [1] allows to grow samples with controllable SIA. The THz-laser induced MPGE in the presence of an in-plane magnetic field B measured in n-type GaAs structures originates from bulk inversion asymmetry (BIA) and SIA and therefore reflects their behaviour. We show that for a proper experimental geometry, currents measured along and perpendicular to B are proportional to BIA and SIA, respectively [2]. We studied a set of samples with fixed QW width and different δ-doping positions as well as with fixed doping position but different in the QW width. Our experiments prove that shifting the δ-doping layer from one side of the QW to the other results in a change of sign of the SIA-caused MPGE. We were able to grow structures without Rashba constant and structures with equal Rashba and Dresselhaus spin splittings. We also detected a MPGE-caused current in undoped samples via carrier generation with near-infrared light.

[1] V.V. Belkov and S.D. Ganichev, Sem. Sci. Tec. 23, 114003 (2008) [2] V. Lechner et al., Appl. Phys. Lett. 94, 242109 (2009)

HL 33.13 Tue 18:30 Poster D1

Towards a local spin-valve signal in all-semiconductor lateral spin injection devices. — •Christian Wolf, Andreas Einwanger, Mariusz Ciorga, Martin Utz, Dieter Schuh, and Dieter Weiss — Universität Regensburg, Universitätsstrasse 31, D-93040 Regensburg

In our recent experiments [1] we demonstrated a successful all-electrical spin injection and detection scheme in lateral semiconductor devices using (Ga,Mn)As/GaAs spin Esaki diode structures as spin aligning contacts. The experiments were performed in a $non-local$ configuration, i.e., without a charge current flowing between injector an detector contacts.

In this paper we explore a possibility of an observation of a *local* spin-polarized charge current between source an drain in similar devices. According to Fert *et al.*[2] a local spin valve (SV) signal is proportional to $(\rho_N \lambda_{sf}/r_b)\cdot(\lambda_{sf}/L)$, where ρ_N, λ_{sf} are, respectively, the resistivity and spin diffusion length in the semiconducting channel, r_b is the unit area interface resistance and L a source-drain separation. Taking advantage of the relatively low value of r_b in Esaki diode contacts ($\sim 10^{-8}\Omega\cdot m^2$) in our devices, we optimize the latter in order to obtain a measurable local SV signal. The optimization involves (i) increasing a spin diffusion length of the semiconductor channel by lowering its doping and (ii) decreasing the source-drain distance.

[1] M. Ciorga *et al.*, Phys. Rev. B **79**, 165321 (2009)
[2] A. Fert *et al.* IEEE Trans. on Electr. Dev. **54**, 921 (2007).

HL 33.14 Tue 18:30 Poster D1

Linear and non-linear noise spectroscopy of fluctuating signals — •Rachel Fainblat, Sebastian Starosielec, Jörg Rudolph, and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany

Spin noise spectroscopy has recently become a popular tool for studying incoherent dynamics in semiconductor spin systems. The usually measured (linear) noise power spectrum however can not discriminate between noise mechanisms that yield e.g. either Gaussian or non-Gaussian noise. An extension to non-linear noise spectroscopy is therefore highly desirable. We have implemented a real-time measurement systems that apart from the linear noise spectrum also calculates a non-linear noise spectrum. The non-linear spectrum is based on the square of the original noise signal and contains expectation values up to the fourth order. The non-linear spectrum is especially sensitive to correlations between spectral frequency components and non-Gaussian behaviour of the noise amplitude. As a demonstration we measure strong frequency correlations in the signal of FM radio broadcasting. On the contrary, the white photon shot noise of a laser above threshold shows no frequency correlations within the measured range from 0 to 90 MHz. We also performed measurements on biased and unbiased resistors (industrial metal-film and carbon) exhibiting white and 1/f-noise, respectively. The possible application of non-linear fluctuation spectroscopy for studying magnetic phase-transitions will be pointed out.

HL 33.15 Tue 18:30 Poster D1

Electron spin relaxation in bulk GaN: Temperature and magnetic field dependence — Jan Heye Buss, Jörg Rudolph, •Henning Hillebrand, and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany

Spin-orbit coupling (SOC) is the main reason for spin relaxation in most semiconductors (SC). A thorough understanding of SOC is therefore essential, e.g. for the realization of spintronic devices requiring long spin relaxation times. In contrast to the extensive research on SOC in SCs with zinc-blende structure, the effect of SOC on the electron spin dynamics in GaN with wurtzite structure was only rarely studied. We present measurements of the temperature (T = 80 - 300K) and magnetic field (B = 0 - 1T) dependence of the electron spin relaxation time in bulk wurtzite GaN by time-resolved Kerr-rotation. The observed temperature dependence and an intrinsic anisotropy [1] of the spin relaxation are explained by the D'yakonov-Perel mechanism with a k-linear (Rashba-like) and k^3-dependent (Dresselhaus-term) contribution to the conduction band splitting.

[1] J. H. Buss et al., Appl. Phys. Lett. **95**, 192107 (2009)

HL 34: Poster I: III-V Semiconductors

Time: Tuesday 18:30–20:30 Location: Poster D2

HL 34.1 Tue 18:30 Poster D2

Theoretical Description of optical properties in III-V Semiconductor Nanostructures — •Marc Landmann, Michal Pochwala, Jens Förstner, Torsten Meier, Eva Rauls, and Wolf Gero Schmidt — Universität Paderborn

We present a joint theoretical study of the optical properties of GaAs and AlAs bulk and heterostructures. Thereby, we compare the theoretical description of optical excitation on several levels of theory. Results obtained from kp theory [1] are discussed along with data from ab initio calculations within the frameworks of independent-particle (DFT), independent quasiparticle (GW), or Coulomb-correlated quasiparticle (BSE) approximation. [2]

[1] M. Reichelt et al., Phys. Rev. B 68, 045330 (2003)
[2] W. G. Schmidt et al., Phys. Rev. B 67, 085307 (2003)

HL 34.2 Tue 18:30 Poster D2

In situ characterization of homo- and heteroepitaxial GaP(100) surfaces by reflectance anisotropy spectroscopy — •Sebastian Brückner, Henning Döscher, Oliver Supplie,

Anja Dobrich, Peter Kleinschmidt, and Thomas Hannappel — Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin

Reflectance anisotropy spectroscopy (RAS) is an extremely surface sensitive optical probe applicable for in situ measurements during metal-organic vapour phase epitaxy (MOVPE). Here, we study gallium phosphide deposition on Si(100) as an exemplary model system for the heteroepitaxial III-V growth on non-polar substrates.

The created heterointerface gives rise to the formation of anti-phase domains (APDs) according to the step structure of the substrate. The quantitative in situ RAS control over this crucial defect mechanism requires at first reliable surface preparation and the correct consideration of all influences on the structure and intensity of the characteristic spectra such as surface reconstruction, atomic order or temperature.

Then the reliable in situ quantification of the ADP content of a sample is still corrupted by interferences of the signal with interfacial reflections. These mainly affect the normalization of the RAS signal, which we were able to correct by the empirical calculation of the appropriate relative reflectance. Minor deviations still occur due to the specific anisotropy of the III-V/Si heterointerface, which may be derived by optical simulations.

HL 34.3 Tue 18:30 Poster D2

Structuring the sample surface of MOVPE grown InP QDs on $(Al_xGa_{1-x})_{0.51}In_{0.49}P$ barriers by nanosphere photolithography — •Elisabeth Koroknay, Wolfgang-Michael Schulz, Clemens Wächter, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Stuttgart, Germany

Systems of single and coupled quantum dots (QDs) are of high interest for quantum information processing. The material system of InP QDs embedded in $(Al_xGa_{1-x})_{0.51}In_{0.49}P$ barriers is a promising candidate for applications at elevated temperatures [1]. However MOVPE grown InP QDs in (Al)GaInP barriers show a high quantum dot density of $1.3 \cdot 10^{10}/cm^2$ to $8 \cdot 10^{10}/cm^2$. This requires additional structuring of the sample surface after the growth process for microphotoluminescence (μ-PL) measurements on single quantum dots and quantum dot molecules. As standard structuring methods are either time consuming (electron-beam-lithography) or limited to feature sizes of 1 μm (contact photolithography), microsphere photolithography [2] is used in order to get large area patterns in a standard UV-sensible photoresist. Here, polystyrene microspheres are used as lenses to focus the UV-light. In this way feature sizes from 300 nm to 700 nm can be realized in the photoresist which can be used for the fabrication of shadow masks and pillar structures.

[1] W.-M. Schulz et al, PRB 79, 035329 (2009)
[2] W. Wu et al, Nanoscale Res Lett 03, pp. 123 (2008)

HL 34.4 Tue 18:30 Poster D2

Entwicklung einer Kohlenstoff-Flüssigmetallionenquelle für die fokussierte Ionenimplantation — •Markus Greff, Paul Mazarov, Dirk Reuter und Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum, Germany

Seit ihrer Entwicklung am Ende der 70er Jahre wurde die fokussierte Ionenimplantation (FIB-Implantation) stark weiter entwickelt, so dass mit ihr heutzutage ein hochleistungsfähiges Werkzeug zur maskenlosen, lokalen Dotierungen und zum Sputtern mit Auflösungen um 10nm zur Verfügung steht. Für viele Anwendungen, wie z.B. das lokale p-typ Dotieren von GaAs, Implantation in Diamant, Carbon-Nanoröhrchen und Graphen sowie die Materialmodifikation in organischen Materialien, ist eine fokussierte Kohlenstoffimplantation wünschenswert. Jedoch stellt die Herstellung einer entsprechenden Flüssigmetallquelle eine große Herausforderung dar. In diesem Beitrag stellen wir erste Ergebnisse für eine C-Ce-Quelle vor.

HL 34.5 Tue 18:30 Poster D2

Low energy focused ion beam implantation on GaAs substrate for the preparation of site selected self-assembled InAs quantum dots — •Yu-Ying Hu and Andreas D. Wieck — Ruhr-Universität Bochum, D-44780 Bochum, Germany

Focused ion beam (FIB) technology has received attention for its utilization in fabricating nanostructures. The purpose of this study is to gain low energy ions by applying a high voltage on the target, e.g. in a retarding mode: the high potential will decelerate the 30 keV ions, generating a very low landing energy ion beam of the order of a few tens to a few hundreds of eV for deposition or implantation which yields implantation depths of about 1 nm according to SRIM simulations. In this manner, Indium atoms are placed in the uppermost monolayers which should enhance the self organization of InAs QDs inside the implanted region of a few μm size, resulting in local growth instead of random distribution which is the conventional growing characteristic of self-assembled QDs. For this experiment, an Indium liquid metal ion source is produced. Using an *in situ* focus ion beam connected with a molecular beam epitaxy (MBE) system allows then the growth of the QDs including an subsequent MBE-overgrowth without breaking the ultra high vacuum. The decelerating voltage to be employed on the GaAs target is at maximum 30 kV while the beam current will be scaled in the range of a few pA. IMPRS-SurMat is greatly acknowledged for providing the scholarship and T-courses.

HL 34.6 Tue 18:30 Poster D2

Fabrication of μ-Schottky diode by using molecular beam epitaxy and ion beam lithography — •Asha Bhardwaj[1], Ashish Rai[1], Oleg Petracic[2], Philipp Szary[2], Hartmut Zabel[2], Hans-Werner Becker[3], Dirk Reuter[1], and Andreas Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Experimentalphysik IV, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [3]Fakultät für Physik und Astronomie, Ruhr-Universität Bochum, 44780 Bochum, Germany

Schottky junctions of the metal-intrinsic-n-doped type are widely used to apply electric field to quantum dots (QD) and thus control the charge in the QDs. To apply this concept to single QD is a significant technical challenge and requires μ-Schottky diodes with an active area of approximately 1 μm. In this contribution, we present a novel approach to create such μ-diodes: After growing the basic layer sequence by molecular beam epitaxy, we define a buried stripe in the n-layer by Ar ion implantation. After that a metal line oriented perpendicular to the buried stripe is defined on the surface by electron beam lithography, so that the active area of the junction is only the overlap region of both stripes. The diode characteristic was confirmed by I-V measurements at room temperature as well as at low temperature (4.2K).

HL 34.7 Tue 18:30 Poster D2

Photo-modulated reflectivity and photocurrent measurements of $B_xGa_{1-x}As$ layers grown by MOVPE — •Thomas Sander, Richard K. Thöt, and Peter J. Klar — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

$B_xGa_{1-x}As$ samples were grown by low-pressure metal-organic vapour-phase epitaxy (MOVPE) on semi-insulating (001) GaAs substrates with boron concentrations between 0% and 3.4% determined by high-resolution x-ray diffraction. Prior to the BGaAs growth a 150 nm thick GaAs buffer layer was deposited.

Photo-modulated reflectivity measurements were performed between 77 K and 300 K using a halogen lamp as a light source and a 20 mW red diode laser (635 nm) for modulation. To clearly identify the optical transitions photocurrent measurements in the same temperature range have been carried out. Applying a voltage of up to 10 V over the sample and using the same halogen lamp as light source.

The optical transitions in the spectra will be assigned and discussed in terms of the band structure and the boron localized states. The changes of the spectra as a function of temperature and of boron concentration will be analysed.

HL 34.8 Tue 18:30 Poster D2

Carbon doped InAlAs/InGaAs/InAs heterostructures — •Marika Hirmer[1], Imke Gronwald[1], Dieter Schuh[1], and Werner Wegscheider[1,2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg, Germany — [2]present address Laboratorium für Festkörperphysik, ETH Zürich, Schafmattstr. 16, 8093 Zürich, Switzerland

InAlAs/InGaAs heterostructures with a high In content are promising candidates for spintronic applications such as spin-valve mesoscopic devices due to their large Landé g-factor (around 15 in InAs) and large Rashba effect.

Here we present results on carbon doped InGaAs/InAlAs heterostructures with embedded InAs channel. Two different types of structure, one with the doping layer in growth direction above the InGaAs/InAs conducting channel (normal structure) and one with the doping layer below the conducting channel (inverted structure) were

investigated. As expected, magnetotransport experiments with these samples show no magnetic effects as a similar Mn doped structures [1] but a direction dependent longitudinal resistance. In addition the influence of the thickness of the embedded InAs channel and the influence of the In content on carrier density and on longitudinal resistance were investigated.

[1] U. Wurstbauer, I. Gronwald, U. Stöberl, A. Vogl, D. Schuh, D. Weiss, W. Wegscheider, Physica E 40, 1563 (2008).

HL 34.9 Tue 18:30 Poster D2

Gate-controlled zero-magnetic-field spin splitting in the valence band of asymmetric AlGaAs/GaAs Quantum Wells — •Michael Hirmer, Marika Hirmer, Dieter Schuh, Werner Wegscheider, Tobias Korn, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

Zero-Magnetic-Field-Spin-Splitting (ZMFSS) in two-dimensional quantum wells (QW) induced by the structure inversion asymmetry, and its control, are of major importance for both fundamental research and spintronic applications, due to its influence on the dynamics and manipulation of the spin. In hole systems the asymmetry leads to a ZMFSS of the heavy hole (HH) states in third order of the in-plane wave vector $k_{||}$. In our experiments, we focus on highly p-doped asymmetric 2D AlGaAs/GaAs quantum wells (QW). with different QW widths and spacer thicknesses and the manipulation of the Rashba spin splitting via top gates. We utilize electronic intersubband Raman measurements in backscattering geometry at 4.2K. Using polarization selection rules, one can distinguish between charge-density excitation (CDE, polarized spectra) and spin-density excitation (SDE, depolarized spectra) in the Raman spectra. In all samples we observe a low-energy SDE with excitation energies in the range of 0-2 meV. Comparing these excitation energies to 8 band k·p calculations of the valence subbands, the SDE can be interpreted as an intersubband excitation of the spin-split HH ground state, reflecting directly the ZMFSS.

HL 34.10 Tue 18:30 Poster D2

Spin dynamics in high-mobility (110) GaAs based quantum wells — •Roland Völkl[1], Tobias Korn[1], Michael Griesbeck[1], Andreas Maurer[1], Dieter Schuh[1], Werner Wegscheider[2], Sergey Tarasenko[3], Eugenius Ivchenko[3], and Christian Schüller[1] — [1]Universität Regensburg, Germany — [2]ETH Zurich, Switzerland — [3]A. F. Ioffe Physical-Technical Institute, Russia

[110]-grown quantum wells have been studied intensely in recent years, due to the observation of long spin life times, which are caused by the suppression of the Dyakonov-Perel mechanism. Here, we present the results of electron/spin diffusion experiments in (110) grown GaAs-based quantum wells. The Hanle-MOKE method is used to determine the spin lifetime and for mapping the motion of spin-polarized electrons. Spins are continuously injected with a circularly polarized CW laser and the net spin polarization perpendicular to the sample plane is measured by detecting the Kerr rotation of a linearly polarized laser. Both laser beams are focused through an optical microscope onto the sample. Measurements of the spin lifetime show two regions with different increase of the dephasing rate with respect to the excitation intensity due to a saturation of the spin polarization. The pump beam spot can be moved on the sample with a motorized mirror. Hereby, a mapping of the spin diffusion is possible and the spin polarized electrons can be followed up to a distance of about 50 microns from the excitation spot. The effect of the saturation of the spin polarization affects also the diffusion behavior at high intensities.

HL 34.11 Tue 18:30 Poster D2

Temperature dependent investigation of spin dynamics in a Mn-contaminated AlGaAs/GaAs quantum well near an epitaxial GaMnAs layer — •Sebastian Krinner, Michael Griesbeck, Sebastian Fehringer, Robert Schulz, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany

GaMnAs is a candidate for future semiconductor-based, all electrical spin injection devices. Due to the diffusion of the Mn^{2+} ions, the properties of quantum structures in the vicinity of a GaMnAs layer can be dramatically affected [1]. In our sample, consisting of two nominally undoped AlGaAs/GaAs quantum wells, where one is close to an 50 nm thick GaMnAs layer and the other (as a reference) is separated by a 100 nm AlGaAs barrier, we could observe long spin lifetimes on the order of a few ns and an increase of the spin lifetime with increasing Mn contamination. In this system we observed strong dependences of the spin lifetime on applied inplane magnetic fields, the sample temperature and the excitation intensity, using all optical techniques like time-resolved Kerr rotation (TRKR), time-resolved photoluminescence (TRPL) and the resonant spin amplification technique (RSA). The dependence on temperature and excitation intensity shows that for $T > 30\,K$ the system is in the motional narrowing regime of the D'yakonov-Perel mechanism.

[1] R. Schulz et al., Physica E **40**, 2163 (2008)

HL 34.12 Tue 18:30 Poster D2

Spin-injection by resonant tunneling of optically excited carriers — •Stefan Oertel[1], Jens Hübner[1], Dieter Schuh[2], Werner Wegscheider[2,3], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover — [2]Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D-93040 Regensburg — [3]*Now at:* Solid State Physics Laboratory, ETH Zürich, Switzerland

High efficient spin injection is a desirable prerequisite for threshold reduction of optically pumped spin VCSELs. The injection wavelength differs in this kind of experiments significantly from the emission wavelength and the maximum spin injection polarization is thereby usually restricted to 50 %. Here we investigate a specially designed spin injection heterostructure based upon resonant tunneling of optically injected spins. The MBE grown (110) GaAs structure consists of a 9 nm QW seperated by 3 nm $Al_{0.36}Ga_{0.64}As$ barriers from two adjacent 4 nm QWs. The resonant excitation of the lowest heavy hole exciton transition of the thin QWs enables the generation of up to 75 % electron spin polarization in the thick QW, which is in our experiment detected by time- and polarization resolved photoluminiscence spectroscopy. The spin injection efficiency and the spin dynamics in the drain QW is investigated in dependence on excitation energy and density.

HL 34.13 Tue 18:30 Poster D2

Anisotropic g-factors and isotropic spin lifetimes in reduced symmetry (100) GaAs/AlGaAs quantum wells — •Peter S. Eldridge[1], J. Hübner[1], S. Oertel[1], M. Henini[2], R. T. Harley[3], and M. Oestreich[1] — [1]Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, UK, NG7 4RD — [3]School of Physics and Astronomy, University of Southampton, Southampton, UK, SO17 1BJ

Zincblende semiconductor quantum wells grown on (100) substrates possessing low symmetry (C_{2v}) provide an interesting medium for the study of electron spin dynamics as the in-plane lifetime and g-factor can be anisotropic. The origin of the expected lifetime anisotropy is interference of bulk (BIA) and structural (SIA) inversion anisotropy terms in the conduction band spin-orbit splitting while that of the g-factor is the effective conduction band electric field. Interpretation of cw Hanle measurements is difficult as the depolarisation half width depends on both g-factor and spin lifetime simultaneously. In this work we investigate separately the in-plane electron spin lifetime and the g-factor in GaAs/AlGaAs quantum wells with alloy asymmetry using time-resolved spin quantum-beat spectroscopy. The measurements show easily detectable in-plane anisotropy of the electron g-factor but no anisotropy of the spin lifetime. The results therefore demonstrate that the electron g-factor can be readily engineered through the effective conduction band electric field but that the SIA splitting in such systems is unmeasurably small.

HL 34.14 Tue 18:30 Poster D2

Spin Injection in GaAs by Cleaved Edge Overgrowth — •Arne Ludwig[1], Hasmik Harutyunyan[2], Sani Noor[2], Mingyuan Li[3], Henning Soldat[3], Dirk Reuter[1], Andreas Wieck[1], Ulrich Köhler[2], and Martin Hofmann[3] — [1]Lehrstuhl für Angewandte Festkörperphysik — [2]Oberflächenphysik — [3]Lehrstuhl für Photonik und Terahertztechnologie, all Ruhr-Universität Bochum

Spin injection in semiconductors is still a challenging topic. Successful spin injection has been demonstrated by the detection of circularly polarized light, resulting from the recombination of spin polarized electrons and unpolarized holes in a n-i-p-diode. In a conventional approach, the spins are injected from a ferromagnetic metal grown on top of the n-i-p diode. At the interface either a tailored Schottky bar-

rier or an inserted MgO layer serves as tunnel-barrier into the n-doped region of the device. Some technical problems occur, e. g., protecting the semiconductor surface from impurities before depositing the metal/tunnelling barrier and the need for a magnetic material with out-of-plane anisotropy. In our approach, the sample is patterned and ohmic contacts to the p-doped region are evaporated before transferring the sample to a metal-MBE, where it is cleaved under ultra high vacuum conditions. Then, the FM-contacts with MgO- tunnel-barriers are evaporated in situ on the cleavage plane. The spins in this device are thus injected from the side. We will discuss the advantages of this spin injection method as well as the electroluminescence and polarization results from these diodes.

HL 34.15 Tue 18:30 Poster D2

generating InxGa1-xAs quantum dots with low areal density and tailored ground state emission — •ashish rai, dirk reuter, and andreas wieck — Lehrstuhl für Angewandte Festkörperphysik Ruhr-Universität Bochum, Universitätsstraße 150, Gebäude NB, D-44780, Bochum, Germany

In a new concept for an electrically pumped single photon source,quantum dots with low areal density ($\sim 1\times10^8/\mathrm{cm}^2$) and a ground state emission wavelength below 1000nm at 4.2K are required.To achieve this low density, we use a gradient approach where on one side of the wafer the density is high and on other side no QDs are present at all.In the transition region, the desired QD density is present. The evolution of the QD density gradient is checked by photoluminescence spectroscopy. We will also present two growth protocols to obtain the desired emission wavelength.

HL 34.16 Tue 18:30 Poster D2

Surface band structure of GaN(0001)-2×2 — Pierre Lorenz[1], Liverios Lymperakis[2], Richard Gutt[3], •Marcel Himmerlich[1], Juergen A. Schaefer[1], Jörg Neugebauer[2], and Stefan Krischok[1] — [1]Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany — [2]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [3]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastraße 72, 79108 Freiburg, Germany

The results of an in-situ angle-resolved ultraviolet photoelectron spectroscopy investigation of 2×2 reconstructed GaN(0001) surfaces prepared by plasma assisted molecular beam epitaxy are presented. The valence band dispersion was measured by variation of the detection angle with respect to the surface normal along the $[1\bar{1}00]$ ($\overline{\Gamma}-\overline{K}$) and the $[11\bar{2}0]$ ($\overline{\Gamma}-\overline{M}$) direction using He I ($h\nu = 21.2\,\mathrm{eV}$) and He II ($h\nu = 40.8\,\mathrm{eV}$) radiation. In addition to the bulk states which exhibit strong dispersion, two non-dispersive surface states at 2 eV and 3 eV below the Fermi level are detected in both directions. In order to identify the origin of these states and to validate the experimentally determined *k*-dependence of the surface and bulk electron states we performed *ab-initio* calculations within the density functional theory and we calculated the band structures of different 2×2 surface reconstructions. Based on these calculations we could identify that the aforementioned states arise from a 2×2 N adatom surface reconstruction.

HL 34.17 Tue 18:30 Poster D2

Interaction of InN(0001)-(2×2) surfaces with water — •Anja Eisenhardt, Stephanie Reiss, Marcel Himmerlich, Juergen A. Schaefer, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany

The interaction of water with (2×2) reconstructed InN(0001) surfaces prepared by plasma assisted molecular beam epitaxy will be presented. Thin InN films were characterised in-situ by photoelectron spectroscopy (XPS, UPS) and exposed to water directly after growth. During molecular exposure changes in the core level as well as valence band spectra were measured. Upon H_2O interaction different oxidation stages can be identified due to the formation of several O1s states. Furthermore, three different electron states appear in the valence band at 5.2 eV, 10.2 eV and 8.2 eV. The first two structures can be assigned to oxygen adsorbates based on the comparison to experiments upon InN interaction with O_2, whereas the origin of the latter state is to be identified yet. Additionally the interaction with water molecules results in the disappearance of the (2×2) reconstruction as well as the related surface state at the Fermi level. In parallel the work function decreases and a change in the surface band bending is observed. The results of InN-water interaction will be compared to O_2-induced changes of the InN(0001) surface properties.

HL 34.18 Tue 18:30 Poster D2

Comparison of c- and a-plane aluminum nitride by cathodoluminescence and positron annihilation spectroscopy — •Martin von Kurnatowski[1], Barbara Bastek[1], Matthias Wieneke[1], Thomas Hempel[1], Frank Bertram[1], Armin Dadgar[1], Juergen Christen[1], Alois Krost[1], Jussi-Matti Mäki[2], and Filip Tuomisto[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Department of Applied Physics, Helsinki University of Technology, Espoo, Finland

Due to its large band gap of more than 6 eV AlN is an important material for III-nitride-based electronic and optoelectronic devices operating in the ultraviolet region. It has already been successfully applied in AlN/AlGaN heterostructures. However, for the reduction of internal polarization fields non- and semipolar III-nitride layers are mandatory, which has been attracting interest in research in the past few years.

In this contribution a set of c-plane and a-plane AlN samples grown under identical growth conditions was investigated. The growth temperature as well as the V/III-ratio was varied for each orientation. Plan-view FE-SEM-images show a brain-like surface structure of the c-plane samples. The surface quality improves with increasing growth temperature. Spatially averaged low temperature CL-spectra reveal a more intense near band edge emission from the c-plane AlN indicating higher material quality than in the a-plane samples. In addition to that, the luminescence attributed to Al-vacancies is less intense in the c-plane samples. These measurements are in agreement with the findings in positron annihilation spectroscopy.

HL 34.19 Tue 18:30 Poster D2

Growth and Doping of AlGaN in MOVPE — •Igor Kuznecov, Joachim Stellmach, Markus Pristovsek, and Michael Kneissl — TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany

There are numerous applications for ultraviolet (UV) light like water disinfection. Especially around 265 nm the DNA is most sensitive. To achieve this wavelength AlGaN light-emitting diodes (LEDs) with aluminium contents up to 60 % are required. However, for n-doped AlGaN the silicon ionization energy increases from 17 meV for GaN up to 50 meV for $Al_{0.4}Ga_{0.6}N$. The increase in aluminium content is accompanied by the increase in concentration of centers deeper then silicon that have to be filled with electrons before the Fermi level can be shifted to the silicon donor level [1].
Silicon doped $Al_xGa_{1-x}N$ ($0\leq x\leq 0.4$) layers have been grown on AlN/sapphire templates in a close-coupled showerhead (CCS) metalorganic vapour phase epitaxy (MOVPE) reactor. The influence of two key parameters reactor pressure and chamber height, i.e. the distance between showerhead and susceptor were investigated. The aluminium content was estimated with x-ray diffraction. Carrier concentrations and mobilities have been determined with temperature dependent Hall measurements. The surface quality was studied with atomic force microscopy (AFM).
[1] A. Polyakov, et al., Solid-State Electronics **42** (1998) 627

HL 34.20 Tue 18:30 Poster D2

Wachstum von Al(1-x)In(x)N mittels Molekularstrahlepitaxie — •Raimund Vöhringer, Dongzhi Hu und Daniel Schaadt — Karlsruhe Institut für Technologie, CFN, 76131 Karlsruhe,Deutschland

Um den großen Bereich der von Nitriden abgedeckten Bandlücke zu nutzen ist die Herstellung ternäre Legierungen unterschiedlicher metallischer Konzentration notwendig. Durch gezielte Vermischung von InN (Egap= 0,7eV) und AlN (Egap=6,2eV) könnten diese Halbleiter einen Bereich vom infraroten bis zum ultravioletten Spektrum abdecken.

Die Substratwahl ist bei dem epitaktischen Herstellungsprozess der Halbleiterschichten von entscheidender Bedeutung. So bietet die Si(111) Oberfläche nicht nur eine geeignete hexagonale Oberflächenstruktur, sondern stellt auch ein kostengünstiges und in bestehende Systeme leicht integrierbares Substrat dar. Wir untersuchen das Wachstum von ternären Gruppe III-Nitriden auf Silizium(111) mittels Plasma unterstützter Molekularstrahlepitaxie (PAMBE). Durch die in der Plasmazelle angeregten Stickstoffmoleküle können Nitridhalbleiter schon bei vergleichsweise tiefen Temperaturen gewachsen werden.

Wir haben gezeigt, dass sich ein direktes Wachstum von InN auf Si(111) als nicht erfolgreich erweist. Erst mit Verwendung einer AlN Pufferschicht konnten wir gute Kristallqualitäten erreichen. Kristall-

qualität und Morphologie der Halbleiterschichten wurde mittels Röntgendiffraktometrie und Elektronenmikroskopie untersucht.

HL 34.21 Tue 18:30 Poster D2

Winkelkorrelationsuntersuchungen an ^{172}Lu(^{172}Yb) in GaN und AlN und Messung bei tiefen Temperaturen — •Riccardo Valentini[1], Karl Johnston[2,3], Reiner Vianden[1] und Isolde Collaboration[3] — [1]Helmholtz - Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn — [2]Universität des Saarlandes, 66041 Saarbrücken — [3]CERN, 1211 Genf 23, Schweiz

Für optoelektronische Bauteile werden Halbleiter mit großer Bandlücke verwendet, die mit Seltenen Erden dotiert sind. Um deren Verhalten nach der Implantation zu untersuchen, hat sich die Methode der γ-γ-Winkelkorrelation (PAC) bewährt. Ein geeignetes Isotop zur Untersuchung solcher Halbleiter ist ^{172}Yb.

Die Temperaturabhängigkeit der Hyperfeinfelder für ^{172}Lu(^{172}Yb) in GaN wurde untersucht. Der Verlauf bei Temperaturen unter 50 K konnte bisher noch nicht eindeutig geklärt werden. Bei tiefen Temperaturen zwischen 13 K und 295 K wird generell eine Zunahme der Wechselwirkungsfrequenz erwartet. Hier konnte insbesondere das Vorzeichen des Gitterfeldgradienten bestimmt werden.

Es wurden erstmals temperaturabhängige Untersuchungen der Hyperfeinfelder für ^{172}Lu(^{172}Yb) in AlN durchgeführt. Die Ergebnisse werden präsentiert und diskutiert.

HL 34.22 Tue 18:30 Poster D2

Formation of Ga2O3 by the oxidation of p-type GaN thin films — •Melanie Pinnisch, Daniel Reppin, Jan Stehr, Andreas Laufer, Detlev M. Hofmann, and Bruno K. Meyer — 1. Physikalisches Institut, Justus-Liebig-University-Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen

Both GaN and Ga2O3 are wide band gap semiconductors with energies of 3.45 eV and 4.9 eV, respectively. While GaN can be achieved p- or n-type conducting by doping, Ga2O3 is n-type or high resistive dependent on the presence of oxygen vacancies. We studied the conversion of p-type Mg doped GaN thin films to Ga2O3 by thermal treatments in the temperature range from 600 °C to 1200 °C and in different atmospheres. Changes of the film properties were studied by means of X-ray diffraction, photo-electron spectroscopy and atomic force microscopy. Optical and magnetic resonance methods were used to investigate the evolution of the dopands and defects.

HL 34.23 Tue 18:30 Poster D2

Defect and intra-4f luminescence of rare earth doped group-III nitrides synthesized by high pressure high temperature method — Sven Müller[1], Takashi Taniguchi[2], •Ulrich Vetter[1], and Hans Hofsäss[1] — [1]Georg-August-Universität Göttingen, II. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]National Institute for Materials Science, Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japan

Cubic boron nitride (c-BN) and AlN exhibit the largest band gaps among all group-III nitrides with 6.2 and 6.0 eV, respectively. Both materials posses the ability for optoelectonic building blocks which can operate at high temperatures, high power, high frequencies and under extreme chemical conditions. The intensive and narrow intra-4f luminescence of rare earth doped c-BN and AlN crystals could be employed for laser diodes or in optical communication technology. Rare earth doped c-BN and AlN crystals were synthesized via the high temperature high pressure method, with temperatures and pressures between 1450 - 1620 °C and 4.5 - 6.3 GPa, respectively. $Ba_3B_2N_4$ and Li_3AlN_2 were used as solvents with addition of rare earth fluorides as source material for the synthesis of c-BN and AlN, respectively. The luminescence of rare earth doped c-BN and AlN is a superposition of different defect transitions of the host material and intra-4f transitions of the rare earth dopant ion. Intrinsic defects as well as impurity defect complexes serve as origin for various defect bands in c-BN and AlN.

HL 34.24 Tue 18:30 Poster D2

Optical measurements on Gd doped GaN — •Ole Hitzemann[1], Martin Kaiser[1], Enno Malguth[1,2], Markus R. Wagner[1], Jan-H. Schulze[1], Axel Hoffmann[1], Shalini Gupta[2], Tahir Zaidi[2], Ian T. Ferguson[2], Martin Röver[3], Dong-Du Mai[3], Jörg Malindretos[3], and Angela Rizzi[3] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, USA — [3]IV. Physikalisches Institut and VISel, Georg-August Universität Göttingen, Germany

Gd doped GaN has recently gained considerable interest as a potential material for spintronics applications producing a large number of publications. The results, however, are inconsistent: While some authors claim to have achieved ferromagnetic behavior at RT with a high magnetic moment per Gd atom, others did not find any ferromagnetism at all. Optical measurements also showed varying results and there were several contradictory theories describing the role of defects and vacancies for the magnetization. In an attempt to bring clarity to this matter, we examined MOVPE and MBE grown layers of this diluted magnetic semiconductor with Gd concentrations ranging from 10^{17} cm^{-3} to 10^{19} cm^{-3}. p-type and n-type co-doping allowed the investigation of the effect of the position of the Fermi level. We present photoluminescence (PL) spectra of excitonic, DAP and defect luminescence that are related to the incorporation of Gd but also point to other defects and impurities. These results are discussed concerning the ferromagnetic behavior reported for GaN:Gd.

HL 34.25 Tue 18:30 Poster D2

Transport geometry dependence of magnetoresistance behaviour in wurtzite $Al_xGa_{1-x}N$/GaN heterostructures — •Andreas Jupe[1], Kirill Trunov[1], Rüdiger Schott[1], Stepan Shvarkov[1], Dirk Reuter[1], Yvon Cordier[2], and Andreas D. Wieck[1,2] — [1]Ruhr-Universität Bochum, Deutschland — [2]Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications, France

The use of a ferromagnetic semiconductor as a spin injector has attracted great interest because of possible applications in spintronics. Gd doped GaN was reported to exhibit ferromagnetism at room temperature and in this contribution, we present magnetotransport measurements at low temperature in Hall bar geometry, which were carried out on Gd doped $Al_xGa_{1-x}N$/GaN heterostructures. The doping has been performed by focussed ion beam implantation employing 100 kV Gd^{+++} ions with fluences up to 1×10^{12} cm^{-2} into molecular beam epitaxy grown wurtzite $Al_xGa_{1-x}N$/GaN heterostructures, containing a two dimensional electron gas 27 nm below the surface.

The influence of the Hall bar's in-plane orientation, perpendicular to the [0001] direction on the ferromagnetic signature will be discussed.

HL 34.26 Tue 18:30 Poster D2

Cathodoluminescence on heteroepitaxial grown a-plane GaN - reduction of the BSF-luminescence — •Martin Noltemeyer, Matthias Wieneke, Thomas Hempel, Armin Dadgar, Jürgen Bläsing, Alois Krost, and Jürgen Christen — Otto-von-Guericke-Univeristy Magdeburg, Germany

Until now heteroepitaxially grown a-plane GaN films have a high density of structural defects (basal plane stacking faults - BSF) that causes a luminescence-line at about $\lambda = 362$ nm. We present a Si-doped a-plane GaN film, grown on r-sapphire with a high temperature AlGaN nucleation layer without an evidence of basal plane stacking faults in x-ray diffraction measurements. Using highly spatially and spectrally resolved cathodoluminescence spectroscopy (CL) the Si doped, heteroepitaxially grown a-plane GaN sample was analyzed. Low temperature ($T = 5.2$ K) CL spectra, integral as well as local spectra of the three dimensionally grown crystallites, are dominated by the near band edge emission and have a comparatively weak intensity at the spectral region of the BSF-luminescence ($\lambda_{BSF} = 362$ nm). The broadening of the spectra, caused by the Si-doping, with a full width at half maximum of 105 meV is, following [1], appreciated to an impurity concentration ($N_D + N_A$) of about $n = 3 \cdot 10^{19}$ cm^{-3}. In addition, the defect-luminescence intensity in the yellow spectral region (around $\lambda = 550$ nm) is very weak compared to the near band edge emission which indicates a good crystalline quality. [1] E.F. Schubert, I.D. Goepfert, W. Grieshaber, J.M. Redwing, Appl. Phys. Lett. Vol. 71, No. 7 (1997)

HL 34.27 Tue 18:30 Poster D2

Entstehung selbstorganisierter GaN-Nano-Strukturen durch reaktives Ionenätzen in einer ECR-RIE-Anlage — •Mathias Müller, Thomas Hempel, Bernd Garke, Hartmut Witte, Armin Dadgar, Jürgen Christen und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Trockenätzen von GaN-Bauelementschichten ist ein wichtiger Prozessschritt zur Erzeugung von Mikrostrukturen. Hierbei ist das Abtragen der Oberflächen vorrangiges Ziel. Allerdings können unter bestimmten Voraussetzungen auch gezielt Oberflächenreliefs erzeugt werden, die zu Nanostrukturen führen. (Yoshida, H. et al., Jap. J. Appl. Ph. (2001), 12A, 1301-1304)

Die Entstehung von hohlkegelförmigen Nanostrukturen mit einem

Durchmesser von ca. 50 nm ohne eine Mikrostrukturierung wird für GaN-InGaN-basierte LED-Strukturen vorgestellt. Hierzu wurde eine ECR-RIE-Plasmaquelle, mit Cl_2 und Ar als Ätzgasen, verwendet. Die selbstorganisierten Strukturen entstehen sowohl im reinen RIE-Betrieb als auch im kombinierten ECR-RIE-Betrieb unter Verwendung von relativ hohen Prozessdrücken. Die Strukturen wurden mittels AFM, REM, XPS und verschiedenen optischen Methoden untersucht.

HL 34.28 Tue 18:30 Poster D2

Microscopic investigations of the optical and structural properties of nonpolar InGaN MQWs on a-plane GaN ELOG structures — •Torsten Schwarz[1], Barbara Bastek[1], Thomas Hempel[1], Peter Veit[1], Jürgen Christen[1], Tim Wernicke[2], Markus Weyers[2], and Michael Kneissl[2,3] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin, Germany — [3]Institute of Solid State Physics, Technical University Berlin, Germany

We present the optical and structural properties of InGaN MQWs which were grown by MOVPE on fully coalesced lateral epitaxially overgrown (ELOG) a-plane GaN on r-plane sapphire substrate and stripe masks orientated in the [01$\bar{1}$0] direction. Photoluminescence (PL) measurements exhibit a strong emission from the InGaN MQW at 3.109 eV at 4 K dominating the GaN (D^0,X) emission at 3.488 eV by two orders of magnitude. The emission from basal plane stacking faults (BSF) was even more suppressed. Transmission electron microscopy showed a drastic reduction of the BSF in the lateral overgrown area (I) compared to the area of coherent growth (II). μ-PL and highly spatially resolved cathodoluminescence (CL) measurements revealed an intensity increase of the MQW emission by a factor of two for the defect reduced region (I) compared to the defective region (II). Also a blue shift by 20 meV of the MQW peak emission wavelength in the area (I) in comparison with defective area (II) was observed.

HL 34.29 Tue 18:30 Poster D2

Morphology and atomic structure of InGaN(0001) surfaces — •Amelie Biermann[1], Christian Friedrich[1], Veit Hoffmann[2], Norbert Esser[3,1], Michael Kneissl[1], and Patrick Vogt[1] — [1]TU Berlin, Institute of Solid State Physics EW6-1, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut f. Hoechstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [3]ISAS-Berlin, Albert-Einstein Str. 9, 12489 Berlin, Germany

Group III-nitrides offer a broad application spectrum in optoelectronic devices. Although the fabrication of high-quality devices requires the control of nanometer thick layers, there is only limited knowledge about the atomic structure of the surface. Here we present a study on the morphology and atomic structure of (0001) $In_xGa_{1-x}N$ surfaces grown by MOVPE. Samples are prepared under UHV conditions by thermal annealing between 600°C and 800°C to achieve clean, decontaminated surfaces. Additionally thermally cracked ammonia and nitrogen plasma are used as nitrogen sources in order to vary surface stoichiometries and to prevent nitrogen depletion of the crystal. The chemical composition of the surface during preparation is determined by Auger Electron Spectroscopy. Clean (0001) $In_xGa_{1-x}N$ surfaces were prepared at 760°C revealing no surface carbon and low residual oxygen compounds. Depending on the surface preparation, surface structures showing different surface symmetries such as (1×1), (1+1/6) or (2×2) were obtained as determined by LEED. The chemical composition remains similar for all structures. In order to get further information STM measurements of the atomic structure are presented.

HL 34.30 Tue 18:30 Poster D2

Semipolar InN grown on m-plane sapphire using MOVPE — •Duc Van Dinh, Markus Pristovsek, and Michael Kneissl — Institute of Solid State Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Growth of InN is still a challenging issue even on (0001) c-plane sapphire. Thus very little results exist about growth of non-polar InN and nothing about growth of semi-polar InN on sapphire.

We have investigated the growth of InN layers on (0001) c-plane and (10-10) m-plane sapphire substrates by metal-organic vapor phase epitaxy. Similar to growth of GaN, for growth of InN on sapphire substrate, a nitridation process is employed to improve crystalline quality. By using X-ray diffraction we found that InN grown on m-plane sapphire exhibited one dominant peak of (10-13) InN. The surface morphology of (0002) InN on c-plane sapphire is much smoother than the InN grown on m-plane sapphire. The rougher surface of semi-polar InN on m-plane sapphire is likely caused by twinning of the (10-13) InN. The in-plane relationship for (10-13) InN was [30-3-2]InN//[1-210]sapphire and [1-210]InN//[0001]sapphire. The optical properties of the grown InN were also investigated by photoluminescence measurement and spectroscopic ellipsometry.

HL 34.31 Tue 18:30 Poster D2

Influence of growth rate and V/III ratio on the critical layer thickness for relaxation of thick MOVPE grown InGaN layers — •André Kruse, Martin Leyer, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

To improve the quality of InGaN light emitting diodes and laser diodes InGaN was grown on GaN templates with metal-organic vapour phase epitaxy (MOVPE). Two processes occur, depending on the growth parameters. First a 2D to 3D transition is seen. Depending on the indium content and the size of Quantum dots (QD) the InGaN layer decomposes lateral. For higher indium content the layer is rather homogeneous and reaches its critical thickness for relaxation. We studied systematically the influence of the InGaN growth rates at temperatures between 700 °C and 850 °C. Additionally the V/III ratio was varied from 2000 to 7000 to investigate the influence of surface kinetics and chemistry on homogeneity and the critical layer thickness. Growth rates and the onset of relaxation will be analysed with in-situ spectroscopic ellipsometry. Layer quality and strain state are measured ex-situ with x-ray diffraction.

HL 34.32 Tue 18:30 Poster D2

Intracavity contacts for nitride based monolithic surface emitters by focused ion beam processing — •Malte Fandrich, Heiko Dartsch, Christian Tessarek, Timo Aschenbrenner, and Detlef Hommel — Institut für Festkörperphysik - Halbleiterepitaxie, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

The realization of electrically driven nitride based vertical-cavity surface-emitting lasers (VCSELs) is challenging due to limitations in the conductivity of the distributed Bragg reflectors (DBRs). Therefore monolithic approaches are based on a doped cavity and one or two undoped DBRs. This requires the use of technologically complex intracavity contacts.

The presented process yields intracavity contacts applicable to monolithically grown VCSEL structures. Initially mesas are structured by photolithography and chemical assisted ion beam etching. The precise structuring of the prestructured mesas is performed in a focused ion beam system (FIB), where the micropillars are thinned stepwise down to a diameter of 0.5 - 5 μm. The contacting of the pillars is realized by FIB deposited metal and insulator structures. Insulator separated Pt ringcontacts connect the micropillars with large-scale contact pads. This procedure was applied to a VCSEL structure consisting of a bottom AlInN/GaN-DBR with 40 pairs, a p/n-doped 5 λ GaN-cavity with embedded InGaN quantum dots and a top 10 pair AlInN/GaN-DBR. The developed contacting structure enables a current up to 15 mA through the cavity which documents the capability for the electrical operation of VCSEL devices.

HL 34.33 Tue 18:30 Poster D2

Präparation von GaN-basierten Proben mittels Niedrigenergie-Ionendünnung für Transmissionselektronenmikroskopie — •Stephanie Bley, Thorsten Mehrtens und Andreas Rosenauer — AG Elektronenmikroskopie, Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Deutschland

Auf der Oberfläche von TEM-Proben (TEM - transmission electron microscopy) lagern sich durch die Präparation (mechanisches Dünnen oder FIB (focused ion beam)) und nach längerem Kontakt mit der Luft schwach gebundene Atome (z.B. O,C,N etc.) an. Durch die Niedrigenergie-Ionendünnung werden diese schwach gebundenen Atome von der Probenoberfläche entfernt. Anhand von GaN-basierten Proben wird gezeigt, welchen Einfluss die Ionendünnung auf die Proben hat. Dazu wurden Untersuchungen mittels HRTEM (high resolution TEM) und STEM (scanning TEM) durchgeführt. Unter anderem werden für verschiedene Ionenenergien Dickenprofile der Probe erstellt. Dickenprofile werden durch den Vergleich der normierten Intensität aus STEM-Bildern mit einer durch die Frozen Lattice-Methode simulierten Referenzintensität erzeugt.

HL 34.34 Tue 18:30 Poster D2

InGaN layers in visible LEDs and solar cells — •Samir Ham-

madi, Joerg Hisek, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

By applying InGaN quantum well layers in light emitting heterostructures, efficiencies greater than 80% in the blue-violet wavelength range can be achieved. This requires a high structural perfection of the underlying layers and the active region - grown by metal organic vapour phase epitaxy (MOVPE) - as well as suitable process steps in order to suppress the effects of the remaining dislocations as nonradiative recombination centers. Naturally, it should be possible to utilize similar structures for solar cells. By varying the In content of InGaN, the band gap can be altered between 0.67 * 3.4 eV, covering almost the whole solar emission spectrum. Such a heterostructure would, however, require InGaN layers with a rather high ($> 50\%$)) and low ($< 30\%$) In content. For a high In incorporation relatively low growth temperatures are necessary, making it difficult to achieve high quality layers with conventional MOVPE growth. Plasma assisted molecular beam epitaxy (RF-MBE) may overcome this problem, does, however not enable higher growth temperatures for low indium incorporation. In this contribution we compare high-In quantum wells (30-50%) grown by MOVPE and by MBE and study the influence of defects and recombination centers by analyzing X-ray diffraction, transmission electron microscopy, and photoluminescence data.

HL 34.35 Tue 18:30 Poster D2

Optical gain studies of green emitting GaInN based laser structures — •Moritz Brendel, Alexander Daniel Dräger, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig, Germany

Violet-blue emitting laser diodes based on GaInN with high output powers and long lifetimes are now commercially available. Recently, structures based on the same material system emitting in the green spectral range were obtained [1]. The aim of this work is to systematically investigate and characterize the parameters of c-plane GaInN single quantum well laser structures grown by MOVPE on c-plane sapphire substrates. For tuning the wavelength beyond 500 nm we increase the indium concentration of the active region far above 30% and by utilizing thin quantum wells of about 1.5 nm the evoking influence of the piezoelectric fields is reduced. We perform optical gain measurements using the variable stripe length technique to determine the optical gain and losses. Furthermore, by combining the measured data with model calculations of the optical gain spectra we have access to threshold power densities, carrier densities as well as to radiative and nonradiative lifetimes. We find a rather small broadening of the gain spectra but an increasing threshold pump power for longer wavelengths.

[1] Avramescu et al, APL vol95, p071103 (2009)

HL 34.36 Tue 18:30 Poster D2

Near-field microscopy on GaInN/GaN green light emitting quantum-well structures — •Peter Clodius, Holger Jönen, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

In contrast to blue emitting GaInN/GaN quantum well structures, which show a quite high internal quantum efficiency (IQE), the IQE of green emitting GaInN/GaN quantum well structures is dropping quickly towards longer wavelengths. Another difference between blue and green quantum wells is the fact that the effect of thermal annealing on the luminescence is much stronger for the structures emitting in the green. In this contribution we will present spatially resolved photoluminescence measurements on structures emitting in the blue and green respectively, before and after a thermal annealing process to further investigate the inferior performance of green-emitting structures. The measurements were done with a scanning near-field optical microscope (SNOM) with which we are able to investigate the luminescence structure with a spatial resolution far below the diffraction limit ($\approx 50nm$).

HL 34.37 Tue 18:30 Poster D2

Behaviour of the spontaneous polarisation field in polar and nonpolar GaInN/GaN quantum well structures — •Martina Finke, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig, Germany

The spontaneous and piezoelectric fields in wurtzite GaN-based quantum well structures induce the quantum confined Stark effect(QCSE). The QCSE causes a decrease in the effective bandgap and a reduction of the oscillator strength in the polar c-direction. Unlike in case of the polar direction, the electric fields and the QCSE vanishes in the nonpolar directions, like m-plane. We use GaInN quantum wells as a sensitive probe for the magnitude and changes of the spontaneous field. By using cathodoluminescence in an UHV environment we were able to investigate field induced effects in the polar direction and the absence of these effects in a nonpolar direction. The complex dynamics are observed as a shift of spectral position and a intensity variation. Various samples grown on polar and nonpolar substrates were investigated. By variation of the sample structure like cap thickness and doping level we study the different time dependent behaviour in screening and descreening of the spontaneous field at different electron beam penetration depth. In this contribution we present measurements on nonpolar heterostructures which clearly shows no electric field induced effects, like emission energy and intensity shifts. Compared to the strong effects on polar samples, these measurements prove the absence of the spontaneous field in nonpolar directions.

HL 34.38 Tue 18:30 Poster D2

TEM Investigation of c- and m-plane GaInN/GaN Quantum Well Structures with high Indium Content — •Lars Hoffmann, Heiko Bremers, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institute of Applied Physics, Braunschweig, Germany

While GaN-based blue light emitting diodes exhibit exceptionally large internal quantum efficiencies (up to 80% at room temperature) their green counterparts quickly become less efficient at longer wavelength. A green laser diode based on c-plane GaN has been demonstrated, but the origin of the green gap is still far from being understood. While LED efficiency greatly benefits from V-shaped pits decorating threading dislocations, laser diodes require highly perfect interfaces and homogeneous quantum wells. Using Transmission Electron Microscopy (TEM) we have studied ultrathin (< 2nm) high indium content quantum well (QW) structures suitable for blue-green laser diodes. We investigate the mechanisms of relaxation and possible misfit dislocation generation in c- and m-plane QW structures, partial relaxation and thermal degradation. Moreover, we investigate the appearance of defects in the low temperature grown upper waveguides.

HL 34.39 Tue 18:30 Poster D2

Characterization of m-plane InGaN multiple quantum wells by x-ray diffraction — •Alexander Schwiegel, Heiko Bremers, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig, Germany

The performance of InGaN-based optoelectronic devices grown in the usual [0001] direction is deteriorated by strong spontaneous and piezoelectric polarization fields. In order to avoid these effects ($1\bar{1}00$) oriented films can be used. However, higher defect densities and lower in-plane rotational symmetry of the unit cell make those structures harder to characterize. We investigate InGaN/GaN multiple quantum wells (MQW) grown on m-plane SiC by X-ray diffraction and are particularly interested in determining the lattice parameters, strain state and composition of the layers. Our fivefold MQWs typically have a period length of 10 nm, a QW thickness of about 1.5 nm and reach an In-content up to 30 %. Here we present our results together with a simulation model for symmetrical scans. The intensity profiles are obtained in analogy to optics by transfer functions in consideration of the strain state and composition of the samples assuming atomically smooth interfaces.

HL 35: New Materials: Optoelectronic and Photovoltaic Applications

Time: Wednesday 9:30–10:45 Location: H13

HL 35.1 Wed 9:30 H13

Characterization of $\beta - Ga_2O_3$ single crystals — •Jan Stehr[1], Albrecht Hofstaetter[1], Detlev Hofmann[1], Bruno K. Meyer[1], and Reinhard Uecker[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heirich-Buff-Ring 16, D- 35392 Giessen — [2]Leibniz-Institut für Kristallzüchtung, Max-Born-Strasse 2, D- 12489 Berlin

Ga_2O_3 is a wide band gap semiconductor with potential applications as transparent conducting oxide (TCO). $\beta - Ga_2O_3$ is typically an n-type conducting material due to oxygen vacancies, which act as shallow donors. To control the electrical properties of the material it is thus necessary to study defects and impurities in the material.
A $\beta - Ga_2O_3$ crystal was investigated by optical measurements and magnetic resonance spectroscopy. The band gap energy determined by UV-VIS spectroscopy is 4.6 eV parallel to the b-axis and 4.3 eV parallel to the c-axis at room temperature; we followed its dependence down to liquid helium temperature. By electron paramagnetic resonance we observe 3 signals (Signal A, B and C). Signal A consist of 8 lines with equal intensity therefore I = 7/2 is attributed to Co. Signal B shows a single line and is anisotropic, the g-value moves in angular dependent measurements from g=2.4 to g=1.5. Signal C with g=1.96 is the well known resonance of the oxygen vacancies causing the shallow donors in Ga_2O_3.

HL 35.2 Wed 9:45 H13

Alternative bufferlayers for CIGS solarcells. — •A. Beleanu, T. Gruhn, C.G.F. Blum, B. Balke, and C. Felser — Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany

Cadmium sulfide is a highly efficient buffer layer material in Cu(In,Ga)(S,Se2) [CIGS] solar devices [1], but for environmental reasons and possible gains in efficiency there is a great interest in replacing CdS by a cadmium-free alternative buffer layer. Using standard density functional theory (DFT) methods possible candidates like LiZnP and LiCuS have been proposed as alternative buffer layers. The experimental verificaition of the DFT results was quite challangeing due to the fact that LiCuS was an unknow and completely new material. In a first step, we tried to synthesised LiCuS through solid state reactions in a corrund crucible. After optimizing the parameters and successfully synthesising the material its properties were investigated. In a second step, huge amounts of LiCuS and LiZnP were synthesised and pressed using Spark Plasma Sintering as 3 inch targets. LiCuS and LiZnP films were grown by radio-frequency magnetron sputtering from these target and their properties as an alternative buffer layer in CIGS solar cells were investigated. The 1:1:1 stoichiometry of the films was delivered from in-situ XPS measurements. Absorption measurements show a band gap of $\approx$ 2.0 eV which is in good agreement with the theoretical estimates. [1]T. J. Coutts, Thin Solid Films, 90 (1982) 451-460.
This work was financially supported by the BMU project comCIGS.

HL 35.3 Wed 10:00 H13

Systematic ab initio study of half-Heusler materials for optoelectronic applications — Thomas Gruhn and •Claudia Felser — Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz

The development of new, optimized optoelectronic devices depends crucially on the availability of semiconductors with taylored electronic and structural properties. At the moment, the majority of applications is based on a rather small set of semiconducting materials, while many more semiconductors exist in the huge class of ternary compounds. Especially, the class of 8-electron half-Heusler materials comprises a large number semiconducters with various properties.

With the help of ab initio density functional theory we have studied essentially all 8-electron half-Heusler compounds that are of technological relevance. For more than 650 compounds we have determined the optimum configuration by varying the lattice constant and permuting the elements over the sublattices. Within this exceptionally large data set we have studied the band structure and the lattice constants as a function of the electronegativities of the elements, the arrangement of the atoms, and the atomic radii. The results are used to select suitable materials for the buffer layer in thin-film solar cells with a $Cu(In,Ga)Se_2$ (CIGS) absorber layer. Considering the bandgap and the geometrical matching with the CIGS film, we have obtained a set of 29 compounds that are promissing materials for cadmium-free CIGS buffer layer. The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

HL 35.4 Wed 10:15 H13

Nanosecond switching in GeTe phase change memory cells — •Gunnar Bruns[1], Philipp Merkelbach[1], Carl Schlockermann[1], Martin Salinga[1], Matthias Wuttig[1], Thomas Happ[2], Jan Boris Philipp[3], and Michael Kund[3] — [1]I. Physikalisches Institut (IA), RWTH Aachen University, 52056 Aachen, Germany — [2]Qimonda Dresden GmbH & Co. OHG, Königsbrücker Strasse 180, 01099 Dresden, Germany — [3]Qimonda AG, Bibergerstr. 93, 82008 Unterhaching, Germany

While phase change materials have already successfully been applied in rewriteable optical data storage, they are also promising to form the basis for novel non-volatile electronic data storage devices. To understand the underlying mechanism of these so-called Phase Change Memories (PCM) it is mandatory to gain a deeper insight into the switching process between the high resistive amorphous (RESET state) and the low resistive crystalline phase (SET state).

The electrical switching behavior of GeTe-based phase change memory devices is characterized by time resolved experiments. SET pulses with a duration of less than 16 ns are shown to crystallize the material. Depending on the resistance of the RESET state, the minimum SET pulse duration can even be reduced down to 1 ns [1]. This finding is attributed to the increasing impact of crystal growth upon decreasing switchable volume. Using GeTe or materials with similar crystal growth velocities, hence promises nonvolatile phase change memories with DRAM(dynamic random access memory)-like switching speeds.

[1] G. Bruns et. al., App. Phys. Lett. 95, 043108 (2009).

HL 35.5 Wed 10:30 H13

Valence and core excitations in $Li_{(1-x)}FePO_4$ — •Michael Kinyanjui[1,2], Peter Axmann[2], Margret Wohlfahrt-Mehrens[2], Philippe Moreau[3], Florent Boucher[3], and Ute Kaiser[1] — [1]University of Ulm, Albert Einstein Allee 11, 89081 Ulm, Germany — [2]Centre for Solar Energy and Hydrogen Research, Helmholtzstr. 8, 89081 Ulm, Germany — [3]Institut des Matériaux Jean Rouxel, UMR6502, CNRS - Université de Nantes, 2 rue de la Houssinière, B.P.32229, 44322 Nantes cedex, France

$LiFePO_4$ is a potential cathode material for Li ion batteries applications. However, its electronic properties and the mechanism by which lithium ions are extracted or inserted into the lattice are still unclear. The electronic properties of $LiFePO_4$ and $FePO_4$ have been investigated using valence electron energy loss spectroscopy (VEELS), core-loss EELS and *ab initio* calculations. The VEELS spectra of $FePO_4$ show interband transitions between 0-20 which are not observed in $LiFePO_4$ VEELS spectra. Using the calculated imaginary part of the dielectric function, the interband transitions were assigned as rising from valence states with mainly O-2p character. The core-loss spectra in $FePO_4$ show a pre-edge peak that is observed above the threshold of the main O-K edge. This is not observed in $LiFePO_4$. The position of the pre-edge peak is determined by a charge transfer process which shifts the position of the Fe 3d bands with respect to the conduction band with the extraction of lithium ions from the $LiFePO_4$ lattice. Therefore $FePO_4$ can be considered to be a charge-transfer insulator while the $LiFePO_4$ is a typical Mott-Hubbard insulator.

HL 36: Ge, GeSi, and Si

Time: Wednesday 9:30–13:00 Location: H14

HL 36.1 Wed 9:30 H14

Optical studies of P-, Al-, Ga- and As-doped Ge — •Matthias Allardt[1], Vladimir Kolkovsky[1], Paul Clauws[2], and Jörg Weber[1] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]Ghent University, 9000 Gent, Belgium

In the present work (P, As, Ga, Al) doped Ge was used to study the shallow impurities in this elemental semiconductor. Photoluminescence measurements at 4.2 K reveal for the first time the Al bound exciton observed in the LA region. The intensity of the Al bound exciton is consistent with the Al content inside the sample. Our results can be also correlated with the IR absorption measurements performed at low temperatures. We verify that Al is the dominant impurity in Al-doped Ge and the observed bound exciton signal is unambiguously related to Al.

HL 36.2 Wed 9:45 H14

Intrinsic and extrinsic diffusion of indium in germanium — •René Kube[1], Hartmut Bracht[1], Alexander Chroneos[2], Matthias Posselt[3], and Bernd Schmidt[3] — [1]Institut für Materialphysik, WWU Münster, Germany — [2]Department of Materials, Imperial College, London, UK — [3]Forschungszentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany

Diffusion experiments with indium (In) in germanium (Ge) were performed in the temperature range between 550 and 900°C. Intrinsic and extrinsic doping levels were achieved by utilizing various implantation doses. Indium concentration profiles were recorded by means of secondary ion mass spectrometry and spreading resistance profiling. The observed concentration independent diffusion profiles are accurately described on the basis of the vacancy mechanism with a singly negatively charged mobile In-vacancy complex. In accord with the experiment, the diffusion model predicts an effective In diffusion coefficient under extrinsic conditions that is a factor of two higher than under intrinsic conditions. The temperature dependence of intrinsic In diffusion yields an activation enthalpy of 3.51 eV and confirms earlier results of Dorner et al. [Z. Metallk. 7, 325 (1982)]. The value clearly exceeds the activation enthalpy of Ge self-diffusion and indicates that the attractive interaction between In and a vacancy does not extend to third nearest neighbor sites which confirms recent theoretical calculations.

HL 36.3 Wed 10:00 H14

The impact of interstitials on diffusion in germanium under proton irradiation — •Sebastian Schneider[1], Hartmut Bracht[1], Jan Klug[2], John Lundsgaard Hansen[3], Arne Nylandsted Larsen[3], Eugene Haller[4], Dominique Bougeard[5], Matthias Posselt[6], and Clemens Wündisch[6] — [1]Institut für Materialphysik, WWU Münster, Germany — [2]Ruhr-Universiät, Bochum, Germany — [3]Department of Physics and Astronomy, University of Aarhus, Denmark — [4]MS and E Dept. University of California, Berkeley, U.S.A — [5]Walter-Schottky-Institut, TU München, Germany — [6]FZ Dresden-Rossendorf, Dresden, Germany

Experiments on the influence of 2.5 MeV proton irradiation on self- and dopant diffusion in germanium (Ge) were performed at 600 and 570°C, respectively. Ge isotope heterostructures consisting of 20 layers were used for the self-diffusion study. Ge with boron (B) doped multilayers and samples implanted with phosphorus (P) were utilized for the investigation of irradiation mediated dopant diffusion. Self-diffusion under irradiation reveals an unusual homogenous broadening of the isotope structure. This behaviour and the enhanced diffusion of B and retarded diffusion of P under irradiation demonstrates that an interstitial-mediated diffusion process dominates in Ge under irradiation. This discovery establishes new ways to suppress vacancy-mediated diffusion in Ge and to solve the donor deactivation problem that limits Ge-based nanoelectronics.

HL 36.4 Wed 10:15 H14

Influence of electronic energy deposition on structural modification of SHI irradiated amorphous Ge layers — •Tobias Steinbach[1], Werner Wesch[1], Claudia S. Schnohr[1], Leandro L. Araujo[2], Raquel Giulian[2], David J. Sprouster[2], and Mark C. Ridgway[2] — [1]Institute of Solid State Physics, Friedrich Schiller University Jena — [2]Department of Electronic Materials Engineering, Australian National University, Canberra

During SHI irradiation of amorphous Ge a strong swelling of the amorphous layer accompanied by an enhanced plastic flow process was observed in previous studies. To study the effect of high electronic energy deposition ϵ_e on amorphous Ge layers in more detail the samples were irradiated with 185 and 89 MeV Au ions with different incident angles. In order to quantify the swelling and the plastic flow process, a grid of Au was evaporated on the sample surface and one half of the sample was masked to distinguish the irradiated from the unirradiated reference. We demonstrate for all used irradiation conditions that a strong swelling of the irradiated areas can be observed, which depends linearly on the ion fluence as well as on ϵ_e. XSEM revealed the transformation of the initially homogeneous amorphous Ge layer into a sponge-like porous structure with irregularly shaped voids thus establishing that swelling was a consequence of void formation. Moreover, an electronic energy deposition threshold has been estimated, at which the swelling, i.e. the formation of voids, begins. In addition, the ion beam induced plastic flow process is directly apparent in the XSEM and will be discussed as a function of the ion fluence and ϵ_e.

HL 36.5 Wed 10:30 H14

First Principles Study of the Oxide at the Ge-GeO_2 Interface — •Jan Felix Binder, Peter Broqvist, and Alfredo Pasquarello — Ecole Polytechnique Fédérale de Lausanne (EPFL), Institute of Theoretical Physics, CH-1015, Switzerland

As Si-based metal-oxide-semiconductor devices are approaching their technological and physical limits due to aggressive scaling, the search for new material solutions intensifies. Germanium shows high electron and hole mobilities together with a small electronic band gap, and is seriously being considered as a viable alternative to silicon. However, current stateof-the-art germanium-insulator interfaces show excessively high defect densities compared to conventional silicon/insulator interfaces. Hence, the characterization of both the structural and electronic properties of the Ge/GeO_2 interface is highly relevant. We study germanium suboxides within a density functional approach focusing on their energetic, atomic, and electronic properties. First, we calculate penalty energies of germanium suboxides, and find significantly smaller values than for silicon. This supports a higher concentration of suboxides at Ge/GeO_2 interfaces. Second, we generate amorphous models of GeO and GeO_2 through ab initio molecular dynamics and study their structural and electronic properties. The analysis of the electronic structure of GeO reveals the occurrence of suboxide states in the lower part of the band gap of GeO_2 consistent with several experimental observations at Ge/GeO_x interfaces.

HL 36.6 Wed 10:45 H14

Transient optical gain in Germanium quantum wells — •Sangam Chatterjee[1], Christoph Lange[1], Niko S. Köster[1], Martin Schäfer[1], Mackillo Kira[1], Stephan W. Koch[1], Daniel Chrastina[2], Giovanni Isella[2], Hans von Känel[2], and Hans Sigg[3] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D 35032 Marburg, Germany — [2]CNISM and L-NESS, Dipartimento di Fisica del Politecnico di Milano, Polo di Como, via Anzani 42, I-22100 Como, Italy — [3]Laboratory for Micro and Nanotecnology, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

One of today's most-sought goals in semiconductor technology is the monolithic integration of microelectronics and photonics on Si. Optical gain is, in general, not expected for Si and Ge or its alloys due to the indirect nature of the band gap in this material system. Here, we show that Ge/SiGe QWs show transient optical gain and may thus be used as an optically-pumped amplifier at room temperature [1]. Further, the nonequilibrium effects which govern the relaxation dynamics of the optically injected carrier distributions in this material were observed and analyzed using a microscopic many-body theory. Strong non-equilibrium gain was obtained on a sub-100 fs time scale. Long-lived gain arising from Γ-point transitions is overcompensated by a process bearing the character of free carrier absorption.

[1] C. Lange et al., Phys. Rev. B **79**, 201306(R) (2009)

15 Min. Coffee Break

HL 36.7 Wed 11:15 H14

Identification of localized states on Si/SiGe quantum dots by means of ESR — •F. Lipps, F. Pezzoli, M. Stoffel, C. Deneke, J. Thomas, A. Rastelli, V. Kataev, O. G. Schmidt, and B. Büchner — Leibniz Institute for Solid State and Materials Research IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

We performed electron spin resonance (ESR) measurements at 9.56 GHz on a series of heterostructures containing Si/SiGe quantum dots. The samples were characterized by means of transmission electron microscopy, atomic force microscopy and photoluminescence. Two distinct ESR peaks associated with electrons confined on the quantum dots were observed, characterized by different g-factors, anisotropies of the linewidth and g-factors as well as sensitivity to the illumination with sub-band gap light. Based on the structural information the electronic structure of the studied heterostructures was calculated. The single band calculations allow us to attribute the observed ESR peaks to the s- and p-like-electronic states on the quantum dots.

HL 36.8 Wed 11:30 H14

Towards efficient Silicon-based light sources using tailored photonic materials — •Norman Hauke[1], Thomas Zabel[1], Dominique Bougeard[1], Gerhard Abstreiter[1], Yasuhiko Arakawa[2], and Jonathan Finley[1] — [1]Walter Schottky Institut, Garching — [2]University of Tokyo, Japan

We present optical investigations of two-dimensional (2D) silicon (Si) photonic crystal (PhC) defect nanocavities. Temperature dependent spatially resolved μ-photoluminescence (μPL) measurements in the range 20K-300K show that the emission in the cavity mode stems mainly from the bulk Si phonon satellites. Unlike in bulk and nanopatterned Si, emission from the cavity can be observed up to room-temperature. Moreover, quantitative analysis of the temperature stability spectrally in- and out-of-resonance with the cavity mode suggests that the enhanced emission at the cavity reflects enhanced internal quantum efficiency due to the Purcell-effect.
We also present temperature dependent μPL studies on 2D Si PhC slabs with epitaxial grown high-density ($10^{11} cm^{-2}$) Ge-islands acting as an internal light source. We demonstrate strong enhancement of the quantum dot emission at cavity mode resonance and interpret our findings as being due to a combination of spatial redistribution of the emitted light and Purcell-effect. We also present first time-resolved μPL measurements that compare the radiative lifetime when detecting on the PhC with the unpatterned region of our devices.
Supported financially by the DFG via NIM, TUM IGSSE and TUM IAS.

HL 36.9 Wed 11:45 H14

Electrically active dopant profiles in individual silicon nanowires — •Pratyush Das Kanungo[1], Xin Ou[1,2], Reinhard Kögler[2], Peter Werner[1], Ulrich Gösele[1], and Wolfgang Skorupa[2] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, Halle D-06120, Germany — [2]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf e.V., P.O. Box 510119, 01314 Dresden, Germany

This contribution will be presented as Poster HL 31.47.

HL 36.10 Wed 12:00 H14

Influence of oxide layer thickness on thermal properties of single silicon nanowires: a Raman study — •Asmus Vierck, Sevak Khachadorian, Janina Maultzsch, and Christian Thomsen — Institut für Festkörperphysik, TU-Berlin, EW 5-4, Hardenbergstr. 36, 10623 Berlin, Germany

The Raman spectra of single silicon nanowires (SiNWs) varying SiO_2 layer thickness were studied as a function of laser excitation power using combined atomic force microscopy (AFM) and Raman spectroscopy. Since silicon nanowires grown by chemical vapour deposition (CVD) are inevitably oxidized during fabrication, a modification in shape and size of the crystalline core can be observed, dependent on oxidation time. To determine the impact of different oxide shells on the silicon core properties, we used Raman spectroscopy to study possible alterations in phonon confinement of samples oxidized for different durations. By separating the SiNWs from their original silicon substrate, we were able to compare the spectra of single NWs with distinct width, determined by AFM. While varying the incident laser power we investigated the downshift of the transverse optical phonon in different oxidized NWs as compared to that of bulk silicon.

HL 36.11 Wed 12:15 H14

Isotope Effect on the Spin Resonance of Boron in Silicon — •Andre R. Stegner[1], Hiroyuki Tezuka[2], Till Andlauer[1], Christoph Pellinger[1], Kohei M. Itoh[2], Martin Stutzmann[1], and Martin S. Brandt[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]School of Fundamental Science and Technology, Keio University, Yokohama 223-8522, Japan

The fourfold degeneracy of the Boron acceptor ground state in silicon, which is easily lifted by any symmetry breaking perturbation, allows for a strong inhomogeneous broadening of the B-related electron paramagnetic resonance (EPR) lines, e.g. by randomly distributed, defect-induced local strain. In previous studies a number of fundamental questions concerning the line shape, the magnitude of the residual broadening, and the substructure of the B resonances have remained unsolved. We show that local fluctuations of the valence band edge due to the presence of different Si isotopes in the vicinity of the B acceptors can quantitatively account for all inhomogeneous broadening effects in high purity Si with a natural isotope composition. A comparison of our calculations with previous work investigating the B acceptor ground state in the absence of an external magnetic field, provides an independent verification of the energy offsets between the valence bands of ^{28}Si, ^{29}Si, and ^{30}Si. Moreover, our calculations show that the isotopic perturbation also leads to a shift in the g-value of different B-related resonance lines, which could be verified in our experiments.

HL 36.12 Wed 12:30 H14

A theoretical study of hyperfine parameters in amorphous silicon — •Gernot Pfanner, Christoph Freysoldt, and Jörg Neugebauer — Department for Computational Material Design, Max-Planck-Institute for Iron Research, Max-Planck-Strasse 1, D-40237 Düsseldorf

Thin-film silicon solar cells are considered as low-cost alternatives to bulk crystalline silicon (c-Si) solar cells. A disadvantage of these devices is that their efficiency is severely limited by defects. The nature of the so-called 'Staebler-Wronski' effect, i.e. light-induced metastable changes in the properties of hydrogenated amorphous silicon (a-Si:H), is not yet fully understood and remains challenging. In this context, electron-paramagnetic resonance (EPR) is a key technique to probe for the local atomic structure of defects with unpaired spins such as the silicon dangling bond. However, the interpretation of the EPR spectrum requires comparison to theoretical calculations. Here, we focus on the hyperfine coupling of the unpaired electron to the nuclear spins. We present ab-initio calculations for a variety of dangling bond models in a-Si:H and consider the results in the light of systematic investigations for the c-Si dangling bond. We show that structural disorder in a-Si:H significantly modifies the trends found for c-Si and discuss whether the model Hamiltonians presently used to extract hyperfine parameters from EPR spectra can capture all relevant effects.

HL 36.13 Wed 12:45 H14

Solid-phase crystallization of amorphous silicon films by in-situ postannealing using RPCVD — •Oliver Skibitzki, Yuji Yamamoto, Klaus Köpke, Andreas Schubert, Günter Weidner, Bernd Heinemann, and Bernd Tillack — IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

Solid-phase crystallization of amorphous Silicon (a-Si) layer by in-situ postannealing using a single wafer Reduced Pressure Chemical Vapor Deposition (RPCVD) system was investigated for next generation high performance SiGe:C HBTs. The a-Si layers were deposited using H_2-Si_2H_6 gas mixture on SiO_2/Si_3N_4 patterned wafers. As-doped a-Si and non-doped a-Si were studied for emitter and base applications, respectively. After deposition process, epitaxial Si and a-Si were deposited on Si and on SiO_2/Si_3N_4 mask, correspondingly. By in-situ postannealing at 700 to 1000°C, the a-Si part was crystallized and polycrystalline Si was formed. Near the sidewall of the window, the a-Si was crystallized epitaxially. At higher postannealing temperatures, the grain size of crystallized poly-Si and the epitaxial domain near the sidewall became larger. Otherwise, by annealing at 575°C, direct polycrystalline formation from a-Si seems to be suppressed and the epitaxial domain near the sidewall grew with increasing annealing time. For both 700-1000°C and 575°C annealing conditions, the crystallization is inhibited if As concentration in a-Si layer raises. One possible explanation could be that the migration mobility of Si atoms during crystallization is reduced by As. These results may offer new process integration concepts for further SiGe:C HBT performance improvement.

HL 37: Quantum Dots and Wires: Optical Properties III

Time: Wednesday 9:30–12:45 Location: H15

HL 37.1 Wed 9:30 H15

Vanishing Excitonic Fine Structure Splitting in In(Ga)As/GaAs Quantum Dots Grown on (111) GaAs Substrates — •Murat Öztürk[1], Erik Stock[1], Jan A. Töfflinger[1], Till Warming[1], Irina Ostapenko[1], Sven Rodt[1], Andrei Schliwa[1], Aleksandr I. Toropov[2], Sergej A. Moschenko[2], Dimitry V. Dmitriev[2], Vladimir A. Haisler[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, Lavrenteva av 13, Novosibirsk 630090, Russia

Non-classical correlated photons are of largest importance for quantum key distribution. A source of entangled photon pairs can be based on the biexciton (XX)→ exciton (X)→ 0 recombination cascade, if the fine structure splitting (FSS) of the exciton bright states is below the homogeneous linewidth. Symmetrically shaped In(Ga)As/GaAs quantum dots (QDs) grown on GaAs (111) substrates are expected to exhibit zero FSS due to the C_{3V} symmetry of the confinement potential. Here, we present In(Ga)As/GaAs QDs grown on GaAs (111) substrates with a low spatial density ($<10^9\,cm^{-2}$). Single photon emission is proved with a $g^2(0) \leq 0.3$. Micro-photoluminescence from a number of single QDs reveals similar luminescence line patterns for several QDs and therefore allows the assignment to transitions of specific excitonic complexes. Polarization dependent measurements reveal the FSS down to less than 10 μeV, limited by the spectral resolution of our setup. The nonzero splitting is understood in terms of shape and strain as symmetry of the QDs. This work is partly funded by the SFB 787.

HL 37.2 Wed 9:45 H15

Fine Structure Splitting of Neutral Excitons in GaAs/AlGaAs Quantum Dots — •Johannes D. Plumhof[1], Vlastimil Krapek[1,2], Lijuan Wang[1,3], Andrei Schliwa[4], Armando Rastelli[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden — [2]Institute of Condensed Matter Physics, Masaryk University, Kotlarska 2, 61137 Brno, Czech Republic — [3]Max Planck Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart — [4]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, D-10623 Berlin

For the generation of polarization entangled photon pairs using self-assembled semiconductor quantum dots (QDs) it is important to decrease the fine structure splitting (FSS) energy of the neutral exciton to values lower than the emission linewidth. We study here the behaviour of the FSS of strain-free, molecular beam epitaxy grown GaAs/AlGaAs QDs. We use polarization-dependent photoluminescence spectroscopy to investigate the FSS of a large number of QDs. Based on AFM images of QDs grown under nominally same conditions we demonstrate the statistic interrelation of QD-shape and FSS. Due to the well known shape and composition profile of the QDs we are able to reproduce the experimental results with 8 band kp-simulations using the realistic structure as input. We also study the polarization of the light emitted by excitons confined in quantum well thickness fluctuations with not well defined shape to estimate the possible influence of effects on FSS other than shape, such as alloy ordering.

HL 37.3 Wed 10:00 H15

Remote pumping of self-assembled InGaAs Quantum Posts — •F. Knall[1], S. Völk[1], F. J. R. Schülein[1], H. Kim[2], T. A. Truong[3], J. He[3], P. M. Petroff[3], A. Wixforth[1], and H. J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, 86159 Augsburg, Germany — [2]Physics Department, UC Santa Barbara, Santa Barbara CA 93106, United States — [3]Materials Department, UC Santa Barbara, Santa Barbara CA 93106, United States

Oscillating electric fields in piezoelectric semiconductors such as GaAs can be induced by using surface acoustic waves (SAW). These fields modulate the band edges of a quantum well (QW) and thus, spatially separate excitons into electrons and holes, which propagate along the SAW direction. Therefore, recombination will be suppressed and the photogenerated charge carriers are transported to a quantum post (QP) located away from the point of excitation. The carriers relax into the confined states of the QP where they radiatively recombine. Using a spatially resolved detection we demonstrate remote pumping of individual QPs by the SAW. QPs are ideal candidates for acoustic charge conveyance driven single photon generation since they combine the superior optical quality of conventional self-assembled quantum dots and direct lateral embedding within a wide quantum well.

HL 37.4 Wed 10:15 H15

Quantum efficiency and oscillator strength of site-controlled InGaAs quantum dots — •Ferdinand Albert[1], Christian Schneider[1], Søren Stobbe[2], Sven Höfling[1], Stephan Reitzenstein[1], Peter Lodahl[2], Lukas Worschech[1], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørsteds Plads 343, DK-2800 Kgs, Lyngby, Denmark

Quantum dots (QDs) are fascinating nanoscopic structures for future quantum information technology. Even though tremendous progress has been achieved in understanding their properties and integrating them into devices like single photon sources, their random position inhibits a large scale fabrication. Thus a great challenge is the precise control of their position. Recently several groups succeeded in the growth of site-controlled quantum dots (SCQDs), but a complete characterization of their intrinsic parameters is still missing. In the present work we apply a recently developed method of determining the oscillator strength and the quantum efficiency of QDs on In(Ga)As SCQDs by means of time resolved spectroscopy on samples with varying thickness of the capping layer [1]. The modification of the local density of optical states as a function of the distance between the SCQDs and the GaAs-air interface enables us to extract the radiative and nonradiative decay rates, from which we calculate a quantum efficiency of 47% and the oscillator strength of 10 for the excitonic transition in SCQDs.

[1] J. Johansen et al., Phys. Rev. B 77, 073303 (2008)

HL 37.5 Wed 10:30 H15

Intraband resonances of GaAs/InAs quantum dots detected via photo induced current changes — •Boris Eichenberg[1], Heiko Wunderlich[1], Sabine Dobmann[1], Alois Seilmeier[1], Vadim Yu. Panevin[2], Leonid E. Vorobjev[2], Dmitry A. Firsov[2], and Alexander A. Tonkikh[3] — [1]Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Deutschland — [2]St. Petersburg State Polytechnic University, St. Petersburg 195251, Russia — [3]Ioffe Physico-Technical Institute, St. Petersburg 194021, Russia

The investigation of intraband (IB) transitions in semiconductor quantum dots (QD) via fourier transform infrared (FTIR) spectroscopy often suffers from very low absorption signals due to moderate absorption cross sections and a low dot sheet density. In this contribution we discuss a photocurrent method, which provides clear signals at the frequency positions of IB absorption lines. The QD sample is laterally contacted at the processed surface and biased by several 10V. Current changes due to excitation by intense picosecond mid infrared laser pulses monitor the IB transitions. Enhanced current signals are observed at frequencies of both bound to bound and bound to continuum IB transitions. Data taken at 77K and at 300K on highly doped GaAs/InAs QD samples, in which up to five QD levels are occupied, are presented. This technique provides interlevel spectra of QDs in the mid infrared with a considerably improved signal to noise ratio compared to FTIR measurements. The experimentally observed IB transition frequencies nicely agree with those from calculated QD levels.

HL 37.6 Wed 10:45 H15

Dependence of spectral diffusion on excitation mechanisms in InGaAs/GaAs quantum dots — •Irina Ostapenko[1], Jan Amaru Töfflinger[1], Murat Öztürk[1], Erik Stock[1], Sven Rodt[1], Till Warming[1], Paola Atkinson[2,3], Oliver G. Schmidt[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

The discrete energy levels and sharp luminescence lines of self organized quantum dots (QDs) allow the development of new nanophotonic devices such as emitters of entangled or single photons. Fluc-

tuating fields in the sample may cause a spectral diffusion (jitter) of the lines: their energetic positions shift and the intensities vary. If the characteristic jitter timescale is smaller than the integration time of a given application, the luminescence line is inhomogeneously broadened which might hinder the use of single QD-based devises. Therefore the understanding of the intrinsic mechanisms of jitter is essential for the realization of such devices. Here we compare the spectral diffusion of the same QDs under optical and, what is more substantial for real applications, electrical excitation conditions in electro-, cathode- and micro-photoluminescence experiments. The key element is an electrically driven device with a low density of QDs and the possibility to probe the same QD with different excitation methods.

15 Min. Coffee Break

HL 37.7 Wed 11:15 H15

Single As-grown $Al_xGa_{1-x}As$ Nanowires Probed by Raman Spectroscopy — •Benjamin Buick[1], Eugen Speiser[1,2], Paola Prete[3], Pasquale Paiano[4], Nicola Lovergine[4], and Wolfgang Richter[1] — [1]Università di Roma Tor Vergata, Rome, Italy — [2]ISAS Department Berlin, Berlin, Germany — [3]IMM-CNR di Lecce, Lecce, Italy — [4]CNISM di Lecce and Università del Salento, Lecce, Italy

III-V compounds nanowires (NWs) are of central interest due to their innovative physical properties and potential applications in electronic and photo-electronic devices. Freestanding AlGaAs NWs were grown by MOVPE by the Vapor Liquid Solid method along the (111) direction on GaAs(111) substrates.

Raman measurements were performed on single as-grown NWs with a scanning confocal micro-Raman spectrometer. Rayleigh imaging, was applied to locate individual NWs and define their position for Raman measurements.

The spectra of the AlGaAs NWs exhibit two-mode behavior: GaAs- and AlAs-like modes which were exploited to determine the stoichiometry. Its dependence on the growth temperature was determined. The Raman spectra show two sets of GaAs- and AlAs-like modes indicating regions with different stoichiometries within a single NW. The composition gradient oft the NWs can be understood as the unintentional formation of a core-shell structure. Furthermore, the presence of coupled plasmon-LO phonon peaks in the spectra was related to (unintentional) doping of the NWs.

HL 37.8 Wed 11:30 H15

Tunable exciton g-factor in height and composition engineered quantum dots — •Vase Jovanov[1], Florian Klotz[1], Emily Clark[1], Daniel Rudolph[1], Johannes Kierig[1], Paul M. Koenraad[2], Max Bichler[1], Martin S. Brandt[1], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, TU München, Am Coulombwall 3, 85748 Garching, Germany — [2]Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

We present experimental and theoretical investigations of the influence of static electric and magnetic fields on the exciton g-factor ($g_{ex,zz}$) of self-assembled InGaAs-GaAs quantum dots. The use of a novel growth procedure allows us to precisely control the dot height (h=2-6 nm) by partially capping the dots with GaAs before introducing a growth interruption and annealing step to remove Indium from the growth surface ("In-flush" method). By performing single quantum dot photoluminescence and photocurrent absorption measurements with magnetic fields up to 15T applied parallel to the quantum dot growth axis we show that the $g_{ex,zz}$ can be tuned from 0.4 to -0.4 by applying static electric fields$\leq$70kV/cm. Microscopically, the effect is caused by pushing the electron and hole components of the exciton wavefunction into different regions of the dot, with differing local In-Ga composition. For the tallest dots (h=6nm) we find that $|g_{ex,zz}|$ is also influenced by the static magnetic field. Our experimental findings are in good qualitative agreement with detailed 3D eight-band k·p calculations that incorporates the magnetic field in a fully gauge invariant manner.

HL 37.9 Wed 11:45 H15

Electrically controllable g-factor of single quantum dots and quantum dot molecules — •Thomas Eissfeller, Till Andlauer, and Peter Vogl — Walter Schottky Institut, TU München, 85748 Garching

We predict the exciton g-tensor of single self-assembled InAs/GaAs quantum dots and molecules of vertically coupled quantum dot pairs in an external magnetic and electric field. The calculations are carried out in terms of a detailed 3D electronic structure theory that includes strain, piezoelectric charges and an eight-band k.p envelope function model. The magnetic field is incorporated in a manifestly gauge-invariant manner. For zero effective electric field, we find a linear dependence of the exciton g-factor on the exciton energy for single quantum dots. Importantly, we predict a giant bias controlled exciton g-factor tunability for certain quantum dot shapes and compositions. This is in excellent agreement with recent experiments. Secondly, we present quantitative theoretical results for the bias controlled anisotropic exciton g-tensor of vertically coupled quantum dot pairs. We find a giant g-factor tunability for vertical magnetic fields and a very pronounced g-tensor anisotropy for horizontal magnetic fields. This g-tensor tunability is more robust for quantum dot molecules than for single quantum dots. These results indicate that quantum dot molecules are promising candidates for the realization of g-factor engineered qubit gates.

HL 37.10 Wed 12:00 H15

Exciton mediated dynamic nuclear polarzation in an individual self-assembled quantum dot — Florian Klotz, Vase Jovanov, •Johannes Kierig, Emily C. Clark, Daniel Rudolph, Dominik Heiss, Max Bichler, Gerhard Abstreiter, Martin S. Brandt, and Jonathan J. Finley — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

We present investigations of dynamic nuclear polarization (DNP) in a single self-assembled InGaAs/GaAs quantum dot subject to an external magnetic field (B_0) and electric field parallel to B_0. Resonant excitation of the neutral exciton (X^0) is shown to lead to a buildup of nuclear spin orientation due to tunneling escape of photoexcited carriers that serves to recycle dark states formed by hyperfine-mediated electron-nuclear spin flip-flop processes. DNP was achieved by tuning one Zeeman level of X^0 into resonance with a single frequency laser to optically pump spin-polarized carriers. We estimated the resulting Overhauser field B_N by locating both Zeeman branches relative to a measurement where DNP was inhibited. The saturation value of B_N depends on whether sweeps are performed from low to high electric fields or vice versa, B_0 and the timescale over which the sweeps are performed. B_N is always found to be oriented parallel to B_0 with magnitude $B_N \sim 3-5$ T. In addition, we also performed time resolved measurements of the nuclear spin orientation dynamics and found B_N to increase over timescales ranging from a few seconds to several minutes depending on the excitation intensity, electric field and detuning from resonance.

HL 37.11 Wed 12:15 H15

Magnetic field controlled interaction strength of a strongly coupled quantum dot-micropillar system — •Steffen Münch, Stephan Reitzenstein, Philipp Franeck, Andreas Löffler, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

So far most experimental studies of strong coupling in QD-microcavity systems have relied on temperature tuning or electro-optical resonance tuning based on the quantum confined Stark effect. In this work we demonstrate that an external magnetic field provides a further degree of freedom to fully explore the potential of coherently coupled QD-microcavity system. We investigated magneto-optical resonance tuning of a laterally extended $In_{0.3}Ga_{0.7}As$ QD embedded in the active layer of a micropillar cavity with a Q-Factor of 11000 which corresponds to a cavity mode linewidth of γ_C=120 μeV. Strong coupling with a QD exciton was observed at zero magnetic field exhibiting a Vacuum Rabi splitting (VRS) of 105 μeV. Magnetic field dependent studies show that the VRS and the associated coupling strength g decrease when magnetic confinement becomes significant above 3 T. This effect is explained in terms of a magnetic field dependent oscillator strength of the extended QDs. In this sense the magnetic field not only acts as a tuning parameter but also opens a way of in situ modifying the coupling strength of the interacting system. In a further approach we demonstrated spin-selective strong coupling by tuning Zeeman-split exciton lines sequentially through the cavity resonance.

HL 37.12 Wed 12:30 H15

Excited state spectroscopy of single lateral InGaAs quantum dot molecules — •Matthias Heldmaier[1], Claus Hermannstädter[1], Marcus Witzany[1], Jie Peng[2], Gabriel Bester[2], Lijuan Wang[3], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und

Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [3]Institut für Integrative Nanowissenschaften IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

The investigated structures contain self-assembled laterally coupled InGaAs quantum dots embedded in a planar microcavity, which are grown using a combination of metal-organic vapor phase and molecular beam epitaxy. The individual quantum dot molecules (QDMs) consist of two single dots that are coupled along the [1-10] crystal direction via electron tunneling. The coupling strength and the ground and excited state energies of the QDMs can be manipulated by applying a lateral electric field. A change in the relative intensities of the excitonic emission lines is observed in the photoluminesence (PL) spectra. PL excitation measurements were conducted using a wide-range tunable Ti:Sapphire laser to obtain information about excited states confined in the QDM. The results of these measurements are compared with the energies of the single-particle and correlated exciton states in the system obtained by an empirical pseudo-potential calculations using a random composition of the QDMs.

HL 38: ZnO and Related Semiconductors

Time: Wednesday 9:30–13:00 Location: H17

HL 38.1 Wed 9:30 H17

Surface structure and excitonic transitions of ZnO single crystals for homoepitaxy — •Daniel Fritsch[1], Olga Roshupkina[2], Jörg Grenzer[2], and Heidemarie Schmidt[2] — [1]School of Physics, Trinity College Dublin, Ireland — [2]FZD, Institute of ion beam physics and materials research, Germany

The surface quality and mosaicity of as received ZnO single crystals strongly depends on the applied crystal growth and subsequent surface polishing techniques. As a result single crystallite ZnO substrates are very often build up as a complex of single crystallite columnar structures. This microcrystalline substrate structure strongly influences the preparation of high-quality homoepitaxial ZnO films [1].

The columnar vs. mosaicity structure of as received Zn- and O-polar polished surfaces and unpolished backsides of (0001) ZnO substrates has been evidenced from high-resolution x-ray diffraction of the (0004) and ($11\bar{2}4$) reflections and from atomic force microscopy analyses. It was shown that there is a weak increase of the c-lattice parameter due to the polishing. The strain, induced by polishing, is evaluated from the probed c-and a-lattice parameter and used as an input parameter for emipirical pseudopotential (EPM) [2] calculations including excitonic effects near the direct bandgap. The calculated strain-dependent optical absorption near the direct band gap of ZnO has been related with the optical properties of the polished surfaces of ZnO single crystals probed in the spectral region from 1 to 4 eV using a VASE spectral ellipsometer. [1] H. von Wenckstern et al., phys. stat. sol. (RRL) 1, 129-131 (2007). [2] D. Fritsch, PhD thesis, Engelsdorfer Verlag, 2007.

HL 38.2 Wed 9:45 H17

Patterned growth of ZnO nanopillars — •Manfred Madel, Yong Xie, Martin Feneberg, Thilo Zoberbier, Benjamin Neuschl, Uwe Röder, and Klaus Thonke — Institut für Halbleiterphysik, Universität Ulm

To get a regular hexagonal arrangement of ZnO nanopillars on sapphire substrate, self-assembling monolayers of polystyrene (PS) spheres are used to cover a-plane sapphire substrates on which gold or nickel catalysts are deposited. We employ wet-chemical etching to remove the catalyst regions not protected by the PS. After lift-off of the colloid spheres a well prepatterned catalyst structure is obtained as confirmed by atomic force measurements. After optimizing the growth conditions ZnO nanopillars with diameters between 200 and 500 nm and lengths up to 5 μm are grown in hexagonal arrays on areas larger than 1 mm^2. Photoluminescence measurements show a perfect crystal quality with a full width at half maximum below 250 μeV for donor bound exciton lines in ZnO.

HL 38.3 Wed 10:00 H17

Gain dynamics of single ZnO nanowires — •Jan-Peter Richters, Jürgen Gutowski, and Tobias Voss — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Nanostructures of large band-gap semiconductors like ZnO are of great interest as light emitting and lasing media in the blue-UV spectral range. In order to use ZnO nanowires as lasing devices it is important to understand the spectral and temporal characteristics of their material and modal gain. Theoretical calculations predict a very high modal gain close to the material gain for semiconductor nanowires which is due to the very high confinement of the light for such nanostructures.

We investigate the gain of single ZnO nanowires under excitation with fs-laser pulses from a frequency tripled regenerative amplifier (800 nm, pulse duration less than 100fs, repetition rate 1kHz, pulse power 3 mJ) using the variable-stripe-length method allowing for the investigation of the profile of their modal gain. The measurements are carried out at room temperature on a glas substrate. We ammount the modal gain to 6000 - 8000 cm^{-1} for nanowires with diameters larger than 200 nm. These results are in good agreement with theoretical predictions from the literature where a values of up to 2500 cm^{-1} for GaN nanowires with a diameter of 105nm has been calculated.

HL 38.4 Wed 10:15 H17

Light-emitting devices based on ZnO-nanowire arrays coated with p-conductive polymers — Abdelhamid Elshaer, Apurba Dev, Jan-Peter Richters, and •Tobias Voss — Institut für Festkörperphysik, Universität Bremen

Due to their large surface-to-volume ratio and high crystalline quality, ZnO nanowires are promising candidates for optoelectronic applications in the blue-UV spectral region. Especially low-temperature grown ZnO nanowires offer interesting properties for the large-scale and low-cost production of environmentally friendly solar cells and light-emitting diodes. When a p-conductive polymer is used to form a hybrid junction, stable UV emission from such a heterojunction has also been observed. We have employed a wet-chemical synthesis method to fabricate ZnO nanowire arrays on conductive glass substrates. The typical dimensions of the nanowires are about 100 nm in diameter and 2 μm in length. A thin layer of the polymer PEDOT:PSS was spin-coated onto the nanowires to fabricate compound structures acting as light emitting diodes. We studied the electroluminescence and the I-V-characteristics of the devices for different polymers and processing parameters. An additional insulating polymer layer (polystyrene) coated directly onto the nanowires was found to significantly improve the device characteristics. This is in agreement with our previous investigations of n-ZnO nanowire/p-silicon light emitting diodes where an insulating silicon dioxide layer between the n-ZnO and the p-silicon is needed to allow for tunnel injection of holes into the ZnO valence band.

HL 38.5 Wed 10:30 H17

Stable enhancement of near band edge emission of ZnO nanowires by hydrogen incorporation — •Apurba Dev[1], Raphael Niepelt[2], Jan Peter Richters[1], Carsten Ronning[2], and Tobias Voss[1] — [1]Institute of Solid State Physics, University of Bremen, Germany — [2]Institute of Solid State Physics, University of Jena, Germany

ZnO nanowires have drawn considerable interest as efficient nanoscale UV light emitting device. However, due to the presence of defect states in the band gap, most of the radiative transitions take place via defect channels giving rise to a strong visible luminescence. At the same time, the near-band-edge emission is reduced. Several attempts have been made to increase the internal quantum efficiency of the UV emission by means of efficient energy transfer between surface plasmons of attached metal nanoparticles and the excitons in ZnO. In addition, passivation of the defect centers by incorporation of hydrogen impurities was also found to be a very effective way.

We performed a mild Ar plasma treatment on ZnO nanowires. The plasma-treated nanowires showed a stable and strong enhancement of the near-band-edge emission and a quenching of the deep-level emission. Photoluminescence studies at 4 K revealed a strong hydrogen

donor-bound-exciton line in the plasma treated samples indicating unintentional incorporation of hydrogen. To confirm the results, hydrogen was implanted into the ZnO nanowires with a low ion energy of 600 eV and with different fluences. The observed result can be related to the passivation of deep centers by hydrogen.

HL 38.6 Wed 10:45 H17

Synthesis of different ZnO and other nanostructures by modified-VLS approach — •Yogendra Kumar Mishra[1], Sören Kaps[1], V S K Chakravadhanula[2], Seid Jebril[1], Lorenz Kienle[2], and Rainer Adelung[1] — [1]Functional Nanomaterials, Institute for Materials Science, Faculty of Engineering, Christian-Albrechts-University, Kaiserstrasse 2, 24143 Kiel, Germany — [2]Synthesis and Real Structures, Institute for Materials Science, Faculty of Engineering, Christian-Albrechts-University, Kaiserstrasse 2, 24143 Kiel, Germany

Nanostructures of zinc oxide which are a member of II-VI wide direct bandgap biocompatible semiconductor family, have been of immense fundamental and technological research investigation due to their unqiue optical, electrical and mechanical properties. Several methods have been used for controlled synthesis of different ZnO nanostructures but the fundamental growth mechanism is still an open issue. In present work we report a very simple modified-vapour liquid solid approach for the synthesis of ZnO nanorods, nanoseaurchins and nanocups. Growth mechanism in terms of concentration, temperature and environment will be discussed. Structural evolution of ZnO nanorods and their elemental mapping using high resolution transmission electron microscopy will be presented. Formation of triangular, pentagonal, hexagonal gold nanoparticles and Au nanorods in ZnO matrix will also be presented. Modified vapour liquid solid approach in our group offers a very simple way to synthesize nanostructures of other metals and polymers and some of them will be shown and discussed.

15 Min. Coffee Break

HL 38.7 Wed 11:15 H17

Dynamics of the deep-level emission in ZnO nanowires — •Dongchao Hou, Ilja Rückmann, and Tobias Voss — Institut für Festkörperphysik, Universität Bremen

Due to its wide direct band gap and large exciton binding energy (60 meV), ZnO nanowires possess an efficient near band-edge emission (NBE) in UV range. Additional energy levels in the band gap of ZnO, commonly introduced by point defects such as oxygen or zinc vacancies and Cu impurities, can largely weaken the UV emission by providing extra recombination routes for the electrons in conduction band. In ZnO nanowires this deep-level emission band (DLE) is expected to be largely activated by tunneling processes of holes trapped in the surface depletion layer after optical excitation.

We studied the dependence of the DLE and NBE intensities of ZnO nanowires on the excitation power at different temperatures. For the experiments, the fundamental (1064 nm) and frequency-tripled (355 nm) pulses of an Nd:YAG microchip laser were used. The additional infrared laser radiation was used to directly populate the defect levels with electrons from the valence band. Our results show that the additional infrared photons lead to a reduction of the DLE while the NBE is enhanced. We will discuss the implications of our results for the models of DLE in ZnO nanowires.

HL 38.8 Wed 11:30 H17

First-principles DFT study of dopant elements at grain boundaries in ZnO — •Christian Elsässer and Wolfgang Körner — Fraunhofer Institut für Werkstoffmechanik, IWM, Freiburg, Germany

We present a first-principles density-functional-theory study of doped ZnO with focus on its application as a transparent conducting oxide (TCO). TCOs with high optical transparency and high electrical conductivity are for example applied in low emissivity windows, as transparent electrodes in photovoltaic cells or light emitting diodes. We investigated the impact of grain boundaries on the physics of atomic defects, and especially the formation energies of oxygen vacancies, cation dopants Al and Ga and anion dopants N and P are determined. The main goal is to obtain information about the positions of the defect levels generated by the different dopants in the electronic band gap. Because of the known deficiency of the local density approximation (LDA) to yield accurate values for band gap energies for insulators like ZnO a self-interaction correction (SIC) to the LDA is employed,which merely increase the computational costs. The main result of our study is that grain boundaries do affect the formation energies for substitutional dopants significantly. Furthermore the position and shape of dopant-induced electronic energy levels at the grain boundaries are changed considerably with respect to the single crystal. This may help to explain for example why N-doping can lead to p-conductivity at room temperature.

HL 38.9 Wed 11:45 H17

Excitons and their excitation channels in a-plane and c-plane ZnO — •Martin Kaiser[1], Markus R. Wagner[1], Gordon Callsen[1], Axel Hoffmann[1], S. Lautenschläger[2], S. Eisermann[2], and Bruno K. Meyer[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin Germany — [2]Physikalisches Institut , Justus-Liebig-Universität Gießen, Germany

In the last decade ZnO inspired an experimental revival due to improvements in growth techniques and its potential for future devices like polariton lasers and spintronic materials. However, the growth of high quality ZnO and p-doping is still a big challenge. Optical characterizations of defects and excitons assist in the understanding of energy transfer processes and provide indications for the optimization of the growth parameters. We report on studies for a-plane and c-plane grown bulk ZnO. Compared to non-polar a-plane material [1120], ZnO has a strong piezoelectric field for polar growth along the c-direction [0001]. In this contribution, we present polarization dependent photoluminescence (PL) spectra in order to study the influence of the polarity on the radiative free and bound exciton recombinations. Through photoluminescence excitation (PLE) measurements excitation channels of the various bound excitons are obtained. In addition, the excitation channels for the free A-excitions are studied. These results yield new insight into the energy transfer processes. Finally, we present infrared (IR) transmission data indicating the presence of deep impurities which may trap carriers and also affect the bandgap luminescence.

HL 38.10 Wed 12:00 H17

Donator-Akzeptor-Komplexbildung in ZnO — •Muhammed Türker, Peter Reichert, Manfred Deicher, Herbert Wolf und Thomas Wichert — Technische Physik, Universität des Saarlandes, 66123 Saarbrücken

Nach wie vor bereitet im Gegensatz zur n-Dotierung die p-Dotierung von ZnO große Schwierigkeiten. Als Möglichkeit für eine verbesserte p-Dotierung werden nach theoretischen Überlegungen die Donator-Akzeptor-Kodotierung [1] oder die Cluster-Dotierung [2] vorgeschlagen. Dabei führt die Bildung von Donator-Akzeptor-Komplexen zur Steigerung der p-Leitfähigkeit. Experimentell wurde dieser Ansatz für die In-N-Kodotierung durch elektrische Messungen bestätigt [3]. Auf atomarer Ebene sind solche Defektkomplexe durch elektrische Feldgradienten (EFG) am Ort des Donators charakterisiert, die mit Hilfe der gestörten $\gamma\gamma$-Winkelkorrelation (PAC) und des radioaktiven Donators ^{111}In bestimmt werden können. Für verschiedene Verfahren der In-Akzeptor-Kodotierung (Implantation und/oder Diffusion) wurden neben dem EFG des ungestörten ZnO-Gitters ($\nu_{QGitter}$ = 31 MHz) durch weitere EFG charakterisierte Defekte beobachtet, die auf eine Bildung von In-N- und In-P-Komplexen hinweisen. Unter Berücksichtigung von druckabhängigen PAC-Messungen und ergänzenden Diffusionsprofilmessungen werden die Messergebnisse diskutiert.

Gefördert durch das BMBF, Projekt 05KK7TS1.

[1] T. Yamamoto *et al.*, Physica B **302-303** (2001) 155
[2] L.G. Wang *et al.*, Phys. Rev. Lett. **90** (2003) 256401
[3] L.L. Chen *et al.*, Appl. Phys. Lett **87** (2005) 252106

HL 38.11 Wed 12:15 H17

Electrical characterization of single-crystal ZnO grown by different techniques. — •Vladimir Kolkovsky, Leopold Wolff, Xi Zhang, and Joerg Weber — Technische Universität Dresden, 01062 Dresden

In the present study single-crystal ZnO grown by different techniques (hydrothermal technology, melting-grown crystals and crystals from the vapor phase) have been investigated with electrical measurements such as current-voltage (IV), capacitance-voltage (CV) and deep level transient spectroscopy (DLTS). Properties of Schottky contacts formed on ZnO grown with these techniques have been also analysed and compared. In DLTS studies dominant peaks appear in the range of 120-170 K in all materials studied. However, the properties of the DLTS lines are different and depend on the growth procedure of ZnO. The origin of these lines will be discussed in the present work.

HL 38.12 Wed 12:30 H17

A novel method to determine optical emission rates of defect-trapped electrons with high precision — •Martin Ellguth, Florian Schmidt, Matthias Schmidt, Holger v. Wenckstern, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II

The properties of defects as the primary factor influencing the electrical behaviour of a semiconductor are one of the most important targets of semiconductor research, especially in novel materials like ZnO where the causes of unintended electrical behaviour in fabricated samples are often unknown. Existing publications on defects in ZnO report the activation energy and the carrier capture cross-section as well as occurence of defects in specially prepared samples. We extend this data set by providing photo cross-section spectra with the high accuracy necessary to determine meaningful values for the Franck-Condon parameter. A novel technique to reliably determine the emission rates of defect-trapped electrons excited by photon absorption ("optical" emission) is presented. It is similar to isothermal DLTS. Long transients (up to 1 hour) are digitally recorded while the sample is illuminated with monochromatic light and transformed into a rate spectrum. Varying the photon energy, the rates of optical emission processes can be determined from each spectrum to enable the calculation of the photo cross-section spectra with excellent precision. The thermal binding energy of a very deep defect not accessible in standard DLTS has been estimated from such a spectrum by applying a model from [1].

[1] A. Chantre, G. Vincent, D. Bois, Phys. Rev.˜B 23, 5335 (1981)

HL 38.13 Wed 12:45 H17

Temperature-dependent time-resolved photoluminescence on MgZnO — •Alexander Müller, Marko Stölzel, Christof Dietrich, Gabriele Benndorf, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Exp. Physik II, Abteilung Halbleiterphysik, Linnéstraße 5, 04103 Leipzig

ZnO is a promising material for optoelectronic applications in the UV spectral range. By alloying it with MgO, the band gap of the resulting MgZnO can be increased, making it a suitable barrier layer for ZnO-based quantum wells. To investigate the dynamic carrier properties in this material, we have performed time-resolved photoluminescence (TRPL) measurements on PLD-grown $Mg_xZn_{1-x}O$ thin films with $x \leq 0.33$. Carrier thermalization and localization effects have been investigated by temperature-dependent TRPL measurements. At low temperatures, the excitons in this alloy are strongly localized. For samples with low Mg concentration, the spectrum is dominated by impurity-bound excitons exhibiting a fast decay. For large Mg contents, the excitons are mainly localized in randomly distributed alloy-potential minima, showing a slow, non-exponential decay process. With increasing temperatures, the decay time strongly decreases, indicating a transfer of the excitons to non-localized, free states. This explanation will be supported by Monte Carlo simulations.

HL 39: Photovoltaics II

Time: Wednesday 9:30–11:45 Location: H3

HL 39.1 Wed 9:30 H3

Sputter deposition of Cu_2O thin films, nitrogen-doping and formation of $Cu_2O - ZnO$ p/n junctions — •Swen Graubner, Achim Kronenberger, Julian Benz, Daniel Reppin, Martin Fischer, Angelika Polity, Detlef Hofmann, Torsten Henning, Peter Klar, and Bruno K. Meyer — I. Physikalisches Institut, JLU Giessen

Cu_2O is one of the rare intrinsically p-type conducting semiconductors, in addition the energy of its band gap is in the visible spectral range. Thus it is considered to be a promising material for thin-film-solar cell applications. Metallic and ceramic sputtering processes can be used for the thin-film deposition. Depending on the oxygen partial-pressure, the stoichiometric properties of Cu_xO are adjustable from $x = 2$ to $x = 1$. The electrical properties change considerably depending on the copper-to-oxygen-ratio. It is commonly assumed that copper-vacancies are the dominant intrinsic acceptors in Cu_2O, thus high carrier concentrations come along with a reduced crystalline quality. Using nitrogen-gas for doping allows carrier concentrations of $p = 10^{15} - 10^{17} cm^{-3}$ without significantly reducing the structural properties of the Cu_2O-thin-films. By using ZnO as n-type semiconductor, first p/n hetero-junctions were realized. The mesa etched structures show rectifying behaviour and its electrical properties will be discussed on the conference.

HL 39.2 Wed 9:45 H3

3D photonic crystal interlayers for mircomorph thin film silicon tandem cell — •Johannes Üpping[1], Andreas Bielawny[1], Martin Otto[1], Ralf B. Wehrspohn[1], Lorenz Steidl[2], Rudolf Zentel[2], Seung-Mo Lee[3], Mato Knez[3], Thomas Beckers[4], and Reinhard Carius[4] — [1]Institute of Physics, mikroMD, University of Halle Wittenberg — [2]Dept. of Chemistry, University of Mainz — [3]Max Planck Institute of Microstructure Physics Halle — [4]Institute of Energy Research, IEF-5 Photovoltaics, Forschungszentrum Jülich GmbH

A 3D photonic intermediate reflector for textured micromorph silicon tandem solar cells has been investigated. In thin-film silicon tandem solar cells consisting of amorphous and microcrystalline silicon with two junctions of a-Si/μc-Si, efficiency enhancements can be achieved by increasing the current density in the a-Si top cell. It is one goal to provide an optimized current matching at high current densities. For an ideal photon-management between top and bottom cell, a spectrally selective intermediate reflective layer (IRL) is necessary. We show results toward the first fully integrated 3D photonic thin-film IRL device incorporated in a state-of-the-art textured tandem solar cell. The design and the preparation of a 3D self organized inverted opal photonic crystal structure in a textured micromorph tandem solar cell is presented.

HL 39.3 Wed 10:00 H3

Defect reduction in silicon nanocrystals by low-temperature annealing — •Sabrina Niesar[1], Nadine Erhard[1], Andre R. Stegner[1], Rui N. Pereira[2], Hartmut Wiggers[3], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, 85748 Garching — [2]University of Aveiro, 3810-193 Aveiro, Portugal — [3]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, 47057 Duisburg

Due to the potential of low-cost solution processing, freestanding silicon nanocrystals (Si-ncs) are a promising base material for application e.g. in photovoltaics, thermoelectric and printable electronics. They can be synthesized in macroscopic amounts with diameters tunable between 4 and 50 nm by microwave-induced decomposition of silane in a low-pressure plasma reactor. In this work, we investigate different cost-efficient post-growth methods to reduce the number of silicon dangling bond defects (Si-dbs) which are a limiting factor for many electronic applications. Using electron paramagnetic resonance measurements, it is found that an etching step with hydrofluoric (HF) acid combined with a low-temperature vacuum annealing at 200°C leads to a reduction of the Si-dbs density by a factor of 10. Furthermore, conductivity measurements performed on thin Si-ncs films show that HF etching and annealing also improves the electronic properties. For highly doped Si-ncs, we observe a significant and persistent increase of the room-temperature conductivity. Moreover, current-voltage measurements on Si-ncs/organic semiconductor heterojunction solar cells will be presented.

HL 39.4 Wed 10:15 H3

Thin film solar cells prepared on polycrystalline seed layers using low temperatures — •C. Jaeger[1], T. Matsui[2], M. Takeuchi[2], M. Karasawa[2], D. Wozniak[1], M. Kondo[2], and M. Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Garching, Germany — [2]Research Center for Photovoltaics, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

High costs and large material consumption are the main drawbacks of single crystalline Si wafer-based solar cells. Therefore, alternative methods using thin films are heavily investigated today. In this work, we present data from solar cells with PECVD-Si as the absorber material prepared on polycrystalline seed layers. For

the seed layer preparation, the reverse aluminum-induced layer exchange (R-ALILE) process is used. In a R-ALILE process, a substrate/amorphous silicon/oxide/Al layer stack is annealed at temperatures below 570°C, leading to a layer exchange and the crystallization of the silicon. After the layer exchange is completed, a substrate/Al (+Si)/oxide/polycrystalline silicon film structure is formed.

We found that the proper treatment of the seed layers prior to the absorber layer deposition is crucial for a good solar cell performance. We studied different wet chemical methods (HF-solution, Al-etch) and the influence of an hydrogen plasma treatment. Furthermore, we investigated the influence of an additional Ag/ITO-back contact on the solar cell performance. We found that solar cell efficiencies over 5% can be obtained using the presented seed layer concept.

15 Min. Coffee Break

HL 39.5 Wed 10:45 H3

Interface recombination in heterojunction solar cells: influence of buffer layer thickness and interface charge — •Helena Wilhelm, Roland Scheer, and Hans-Werner Schock — Helmholtz Zentrum Berlin für Materialien und Energie, 14109 Berlin

In window/buffer/absorber type heterojunction solar cells the buffer/absorber interface is a very sensitive part. Due to the lattice mismatch there may be a high density of defects that can lead to a dominant recombination at the buffer/absorber interface. The recombination current depends on the carrier densities and thus on doping ratios, buffer layer thickness and interface charge.

The recombination current is characterized by two parameters - the diode quality factor and activation energy of saturation current density. These two parameters help to determine the recombination process and its location and can be extracted from the data of the temperature dependent current/voltage measurements.

The goal of this work was to investigate the influence of the buffer layer thickness and the interface charge on the diode quality factor and activation energy in cells with inverted buffer/absorber interface and to develop appropriate analytical expressions that include this influence. The analytical equations are verified by numerical device simulation. They describe that the diode quality factor largely depends on the buffer layer thickness and only to a minor extent on the interface charge.

HL 39.6 Wed 11:00 H3

Shunts in Thin-Film Photovoltaics — •Stephanie Malek[1], Uli F. Wischnath[1], Juan Rechid[2], Ingo Riedel[1], and Jürgen Parisi[1] — [1]Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany — [2]CIS Solartechnik GmbH & Co. KG, 20539 Hamburg, Germany

Shunts can lead to severe performance reductions in thin film solar cells. This work aims to look in more detail at the shunts in order to find their microscopic causes.

Localization of hot spots is commonly addressed by infrared thermography via visualization of the Joule heating. The resolution of this method is restricted to the μm-range. We use Lock-In-Thermography (LIT) for the fast localization of imperfections in order to identify positions of interest. For more detailed analysis of hot spots we use high resolution microscopy like Scanning Electron Microscopy (SEM) and AFM-based Scanning Thermal Microscopy (SThM). These small-scale investigations can for example reveal if areas of high heat dissipation are rather related to the inner structure of the involved thin films or to accidentally incorporated imperfections.

HL 39.7 Wed 11:15 H3

Synthesis and Characterization of Cu_2ZnSnS_4 (CZTS) Nanoparticles for Application in Printed Solar Cells — •Folker Zutz, Christine Chory, Jörg Ohland, Ingo Riedel, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, 26111 Oldenburg, Germany

Cu_2ZnSnS_4 (CZTS) is a novel compound semiconductor based on abundant and non-toxic precursor elements. The material has a high potential for photovoltaic application and exhibits a direct optical band gap of 1.5 eV and an absorption coefficient $> 10^4 cm^{-1}$. CZTS nanoparticles (NP) are derived from colloidal synthesis presenting high yields of the CZTS nanopowder. The material is intended for development of solar cells with printed light absorber which stochiometry is already established in the nanoparticles prior to thin film formation.

We report on the structural and photoelectrical characterization of printed CZTS thin films and CZTS nanopowders. The crystal structure of CZTS NPs was investigated by XRD analysis of dried powders while the internal structure of the thin films was studied by AFM, SEM in combination with EDX spectroscopy. Absorption and photoluminescence (PL) spectroscopy were applied for analysis of the general optical properties while time-resolved PL was used for estimation of the minority carrier lifetime in thin films. Photoconductance of the thin films was studied for derivation of the threshold absorption and activation energy of charge transport.

HL 39.8 Wed 11:30 H3

Entwicklung von Lift-off Techniken zur Herstellung von hocheffizienten invertierten III-V-Mehrfachsolarzellen — •Karen Dreyer, Tobias Roesener, Vera Klinger, Eduard Oliva, Frank Dimroth und Andreas W. Bett — Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg

Die Kombination von Solarzellen verschiedener Bandlücken, sogenannte Mehrfachsolarzellen, führt zu einer besseren Ausnutzung des Sonnenspektrums und somit zu einem höheren Wirkungsgrad. So wurden am Fraunhofer ISE bereits Effizienzen von bis zu 41% bei $454 kW/m^2$ mit einer Struktur aus GaInP, GaInAs und Ge erreicht. Die drei pn-Übergänge werden in einem Epitaxieverfahren (MOVPE) auf Ge aufgewachsen und anschließend mit Kontakten und Antireflexschicht versehen. Neue Konzepte arbeiten teilweise mit invertiert gewachsenen Strukturen, in denen die Teilzellen in umgekehrter Reihenfolge auf einem GaAs Substrat abgeschieden werden.

Grundlegend für diese invertierten Solarzellenkonzepte ist die Entwicklung eines Ablöseprozesses (Lift-off) zur Trennung der nur wenigen μm dicken Epitaxiestruktur vom GaAs Substrat, um dieses in späteren Prozesse wiederzuverwenden. Hierfür wurden insbesondere nasschemische Lift-off Prozesse untersucht. Dazu wird zwischen der Zellstruktur und dem Substrat eine selektiv ätzbare AlGaAs Schicht epitaktisch aufgewachsen. Verschiedene Konzepte zur Erhöhung der Ätzgeschwindigkeit wurden untersucht und auf ihre Anwendbarkeit in einem Standardprozess geprüft. Prozessdauern von weniger als 10 Stunden für das Ablösen eines 4-Zoll Substrats wurden erreicht.

HL 40: Plasmonics and nanooptics III

Time: Wednesday 10:30–13:15 Location: H32

HL 40.1 Wed 10:30 H32

3D optical Yagi-Uda nanoantenna array — •Daniel Dregely, Richard Taubert, and Harald Giessen — University of Stuttgart, Germany

Optical nanoantennas have gained a lot of interest in the past few years [1,2]. They are able to link propagating radiation and confined optical fields. Only little work has been done on complex antenna geometries on the nanoscale. In our experiments, we investigate a 3D optical Yagi-Uda nanoantenna array. Due to the high directivity of the array structure the incoming light is received efficiently at resonant wavelengths in the near-infrared (around $\lambda = 1.3$ μm).

Our 3D gold nanoantenna structure was fabricated with electron beam lithography using layer-by-layer stacking. We measured the transmission and reflection spectra of the nanoantenna array from both directions in order to examine the directive behavior of the structure. FIT-calculations agree very well with our experimental findings and confirm the concentration of the incoming plane-wave radiation to the feeding points of the antenna array.

References: [1] P. Mühlschlegel, H.-J. Eisler, O. J. F. Martin, B. Hecht, and D. W. Pohl, Science 308, 1607 (2005). [2] T. H. Taminiau, F. D. Stefani, F. B. Segerink, and N. F. van Hulst, Nature Photon. 2, 234 (2008).

HL 40.2 Wed 10:45 H32

Few-cycle nonlinear optics of single plasmonic nanoantennae

— •Tobias Hanke, Günther Krauss, Daniel Träutlein, Barbara Wild, Rudolf Bratschitsch, and Alfred Leitenstorfer — Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz, Germany

We have studied the nonlinear optical properties of single gold nanoantennae driven with few-cycle laser pulses in the near infrared [1]. Intense third harmonic emission is obtained when exciting with fundamental spectra below 1.1 eV. At higher photon energies frequency doubling and two-photon induced luminescence are observed. We relate these findings to the band structure of bulk gold, especially a two-photon resonance with the d-band transitions.

The intense third-harmonic emission enables precise detection of frequency-resolved interferometric autocorrelation traces of individual nanoantennae. We find an enhancement up to 3 orders of magnitude when driving on resonance with the fundamental plasmon mode. A sub-cycle dephasing time as short as 2 fs is measured directly in the time domain, highlighting the strong radiation coupling and ultrabroadband response of these efficient nanodevices.

[1] Hanke et al., Phys. Rev. Lett., accepted for publication.

HL 40.3 Wed 11:00 H32

plasmon-enhanced high-order harmonic generation in the vicinity of metal nanostructures — •song-jin im, anton husakou, and joachim herrmann — Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2a, D-12489 Berlin, Germany

Generation of high harmonics in noble gases is one of key topics of nonlinear optics, which is of a critical importance in many disciplines, for example in attosecond physics. Recently, plasmon-enhanced high-order harmonic generation became possible in the vicinity of bow-tie shaped nanostructures by pulses directly from an oscillator with MHz repetition rate. In this contribution, we simulate high-order harmonic generation by sub-TW/cm^2 pulses using large plasmon field enhancement near metallic nanostructures such as bowtie-shaped antennas or nanocones. Our simulations using a commercial software JCMwave predict intensity enhancement of 3 orders of magnitude near the surface of silver nanocones. The generation of the high harmonics was modeled using a modified Lewenstein approach taking into account the inhomogeneity of the field and the electron absorption by the metal. Our results are consistent with experimental observations for bowtie elements. Considering the generation of high harmonics in argon in the vicinity of silver nanocones, we show that harmonics numbers up to 50, corresponding to 15 nm wavelength, can be achieved using relatively low input intensity of 300 GW/cm^2, characteristic for nJ laser pulses directly from a laser oscillator with MHz repetition rate.

HL 40.4 Wed 11:15 H32

Analytic photoemission localization and switching in plasmonic nanoantennas by laser pulse shaping — Martin Aeschlimann[1], Michael Bauer[2], Daniela Bayer[1], Tobias Brixner[3], Stefan Cunovic[4], Alexander Fischer[1], Pascal Melchior[1], Walter Pfeiffer[4], Martin Rohmer[1], Christian Schneider[1], Christian Strüber[4], •Philip Tuchscherer[3], and Dmitri V. Voronine[3] — [1]Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Kiel, Leibnizstr. 19, 24118 Kiel, Germany — [3]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [4]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Germany

We experimentally achieve two-photon photoemission localization and switching on a subwavelength scale in plasmonic nanoantennas. Complex polarization-shaped laser pulses which are found in adaptive optimizations control the linear response of the nanostructure. We consider previous analytic investigations to identify the interference of two excited modes in the nanostructure as the main control mechanism. The optimal pulse shapes for switching are then found deterministically. Adaptive and analytic control schemes are compared, and agreement between both approaches is demonstrated.

HL 40.5 Wed 11:30 H32

Swichable Hot Spots in Bipyramid-Nanoresonators — •Siji Wu, Calin Hrelescu, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and Center for Nano Science (CeNS), Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 München, Germany

Highly enhanced and strongly localized electromagnetic fields, so-called hot spots, are attractive for imaging applications, based on raman scattering or fluorescence enhancement.[1,2] Hot spots can be provided by nonspherical gold nanoparticles or nanoparticles aggregates. Here, we report on nanoresonators consisting of two bipyramidal gold nanoparticles prepared by AFM manipulation. Applying a force with the AFM allows switching between the two possible adsorption geometries of an individual bipyramid on the substrate. The plasmonic coupling between two bipyramids is different in the two configurations. Consequently, the hot spot in the nanoresonator can be switched mechanically. Furthermore, the hot spot can be located within 1nm above the substrate surface in contrast to dimer nanoresonators from spheres, rods or ellipsoids.

[1] C. Hrelescu, T.K. Sau, A.L. Rogach, F. Jäckel, J. Feldmann Appl. Phys. Lett., 94, 153113 (2009)

[2] A. Bek, R. Jansen, M. Ringler, S. Mayilo, T. A. Klar, J. Feldmann Nano Lett., 8 (2), 485 (2008)

HL 40.6 Wed 11:45 H32

Near-field measurements on nanoscopic sphere-on-plane-systems by means of PEEM — •Florian Schertz[1], Marcus Schmelzeisen[2], Hans-Joachim Elmers[1], Gerd Schönhense[1], and Max Kreiter[2] — [1]Inst. f. Physik, Johannes Gutenberg-Universität, 55099 Mainz — [2]Max-Planck-Inst. f. Polymerforschung, 55128 Mainz

Surface immobilized gold nano-spheres above a gold surface with a gap distance in the order of a nanometer act as sphere-on-plane (SOP) optical resonator systems showing unique optical properties. In the vicinity of a flat metal surface, a second resonance band red-shifted with respect to the isolated particle resonance occurs, understandable on the basis of multipole interactions of the sphere with its own mirror image in the gold film. Several theoretical and optical far-field studies of SOP resonators were performed, investigating the dependence of the resonance wavelength on the resonator geometry and dielectric properties of the spacer material [1]. The optical near-field of the system under fs-laser-radiation causes highly non-linear (n=3-5) photoemission processes strongly varying depending on the particle properties. Photoelectron microscopy turned out to be a valuable tool for the investigation of the optical near-field of individual SOPs (cf.[2]). We present the gap-resonance-induced photoemission characteristics of several SOPs (individually characterized by SEM), excited by fs-laser radiation in the range from 750nm to 850nm. This work was supported by DFG (EL172-16) and MWFZ, Univ. Mainz. [1] A. Rueda et al., J. Phys. Chem. C 112 (2008) 14801, and Refs. therein. [2] M. Cinchetti et al., Phys. Rev. Lett. 95 (2005) 047601

HL 40.7 Wed 12:00 H32

Strong-field photoelectron emission from metal nanotips — •Max Gulde, Reiner Bormann, Alexander Weismann, Sergey Yalunin, and Claus Ropers — University of Göttingen, Courant Research Center Nano-Spectroscopy and X-Ray Imaging, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

The generation of ultrashort, localized electron pulses is of fundamental interest for future applications in time-resolved electron imaging and diffraction. Femtosecond electron sources of great spatial coherence make use of a combination of local field enhancement at metal nanotips and nonlinear photoelectric effects. Previous studies have resulted in a controversial debate about the underlying physical processes.

Here, we present our most recent theoretical and experimental results regarding ultrafast photoelectron emission from nanometric gold tips. For the first time, we conclusively show the transition between the multiphoton and the optical field emission (i.e. tunneling) regimes. Direct evidence for this transition is found from both the power dependence of the total current and the spatial characteristics of the resulting electron beam. The results are supported by theoretical modeling.

HL 40.8 Wed 12:15 H32

Dark-Mode Plasmonic Nanorod Cavity — •Johannes Kern, Swen Grossmann, Jer-Shing Huang, Paolo Biagioni, and Bert Hecht — Experimental Physics 5, University of Würzburg, Germany

We report ultra-small nanoplasmonic cavities consisting of a self-assembled, side-by-side aligned gold nanorod dimer. The rods are 50-70 nm long and are separated by a 3 nm gap. The structure corresponds to a finite piece of a two-wire transmission line with two highly reflective open ends which supports a quasi-TE fundamental

mode which propagates along the transmission line. Reflection at the end caps leads to length-dependent Eigenmodes, whose energies are determined by the cavity length and the phaseshift introduced upon reflection. Unlike the dipolar longitudinal and transverse plasmon resonances that are also supported by the structure, the fundamental cavity mode is a dark quadrupol mode.

Nevertheless the cavity mode is experimentally accessible by excitation of electron-hole pairs in the gold bandstructure, which act as local dipole sources. The ultra-small mode volume and comparatively high Q-factor leads to a high selectivity of the cavity and the electron-hole pairs preferentially decay into the cavity resonance. Therefore luminescence spectra of the cavities clearly show the peak of the cavity mode. The wavelength of the cavity mode depends on the cavity length and lies in the VIS region, consistent with FDTD simulations and analytical modeling.

The ultra-small mode volume and high Q-factor make our cavities promising candidates to study lasing and/or strong coupling effects.

HL 40.9 Wed 12:30 H32

Temperature related nanoantenna extinction in infrared range — •Chung Hoang, Frank Neubrech, Makus Klevenz, Robert Lovrincic, Olaf Skibbe, and Annemarie Pucci — Kirchhoff-Institut für Physik der Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We present important progress in the experimental studies of single-crystalline lead nanorods grown on Si(557) vicinal surfaces by self-assembling process in ultra-high vacuum. The growth of such nanorod arrays is governed by four experimental parameters: substrate temperature, surface energy, deposition rate, and amount of deposited lead. Upon cooling, strong enhancement of the infrared signal at resonance is observed, indicating the increase of extinction-cross section. This scenario can be attributed to the reduction of electron scattering events where electron - phonon scattering is the main factor that is involved in this process. Below half of the Debye temperature, the maximum resonant antenna extinction is nearly temperature independent, indicating residual electron scattering at surfaces.

HL 40.10 Wed 12:45 H32

Polarization-independent chiral split-ring resonator arrays with colossal optical activity — •Max Wunderlich, Sebastian Engelbrecht, Alexey Shuvaev, and Andrei Pimenov — Experimentelle Physik IV, Universität Würzburg

We have studied the optical activity of bi-layered split-ring resonator arrays. They form chiral quasi-molecules due to inductive coupling. We have examined these structures with the instruments of quasioptical terahertz-spectroscopy. Our investigation shows that such systems can produce a colossal optical activity of 600 degree per wavelength. This results might lead to negative refraction due to chirality. Furthermore we present a way to effectively suppress polarization-dependent behavior of split-ring resonator arrays by introducing C_n symmetries. Thus we have demonstrated a way to realize a ultra-thin orientation-independent polarization rotator.

HL 40.11 Wed 13:00 H32

Efficient surface-plasmon-polariton excitation on nanoparticle structures by inclined incident light — •Andreas Seidel, Wei Cheng, Andrey Evlyukhin, Carsten Reinhardt, and Boris Chichkov — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

We study the features of local surface plasmon polariton (SPP) excitation on single and chains of gold nanoparticles positioned near a gold surface using a light beam under inclined incidence. It is shown that by tuning the incident angle and the parameters of the surface nanoparticle structure one could obtain symmetric or asymmetric excitations of SPP beams propagating along certain directions depending on the particle/chain distances. The reasons and conditions for this behaviour and efficiency of SPP excitation as a function of the incident angle are studied. It is demonstrate that the SPP excitation efficiency strongly depends on the incident angle. Adjusting the incident angle to the maximum field component perpendicular to the metal dielectric interface can lead to a large increase of SPP excitation efficiency. In the case of nanoparticle chains the symmetric or asymmetric patterns of the SPP distributions are the result of the interference of the scattered waves generated by each nanoparticle in a structure. The theoretical consideration is based on the Green*s function technique for the Maxwell equations of the total electric field and on the point-dipole approximation. Experimental investigation is realized by leakage radiation microscopy in real and reciprocal space.

HL 41: Quantum Dots and Wires: Preparation and Characterization II

Time: Wednesday 11:00–12:45 Location: H13

HL 41.1 Wed 11:00 H13

Selective MBE-growth of GaN nanowires on patterned substrates — •Timo Schumann, Tobias Gotschke, Toma Stoica, Friedrich Limbach, and Raffaella Calarco — Institute of Bio- and Nanosystems (IBN-1), Research Center Jülich GmbH, D-52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology

Self assembled III-nitride nanowires are promising candidates for optoelectronic devices. The precise control of size and position of the nanowires is crucial for further applications.

We demonstrate the selective growth of arranged GaN nanowires by plasma-assisted molecular beam epitaxy on an AlN buffer. The position of each nanowire is controlled by a thin silicon oxide mask, patterned by electron beam lithography.

The dependence of selectivity and nanowire morphology on the growth parameters and mask properties are investigated. We change the substrate temperature and the Ga-flux, retaining nitrogen rich conditions, which are suitable for self-assembled nanowire growth. Samples with different masks are produced, varying the thickness and the layout. The diameter of the holes and their distance from each other vary across the pattern. We discuss the influence of these parameters on the nanowire growth and morphology.

HL 41.2 Wed 11:15 H13

Electrochemical analysis of Si and Mg doped GaN nanowires — •Jens Wallys[1], Sascha Hoffmann[1], Florian Furtmayr[1,2], Markus Schäfer[1], Jörg Teubert[1], Jörg Schörmann[1], and Martin Eickhoff[1] — [1]I. Physikalisches Intstitut, Justus-Liebig-Universität Gießen, Germany — [2]Walter Schottky Institut, Garching, Germany

Due to their high electrochemical stability and the large surface-to-volume ratio, GaN nanowires are promising candidates for applications in the field of photocatalytic water splitting and electrochemical sensors. We have analyzed the electrochemical properties of non intentionally doped, Si-doped and Mg-doped GaN nanowires grown on Si (111) substrates by plasma assisted molecular beam epitaxy.

Bias dependent electrochemical impedance spectroscopy measurements and comparison to an equivalent circuit model allowed extraction of the nanowire electronic properties. The influence of doping on the carrier type and density in the nanowires is discussed.

HL 41.3 Wed 11:30 H13

Vertical and lateral heterostructure of GaN/InGaN within nanowires — •Friederich Limbach[1], Tobias Gotschke[1], Toma Stoica[1], Raffaella Calarco[1], Eli Sutter[2], Ramon Cusco[3], and Luis Artus[3] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Center Jülich GmbH, D-52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology — [2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973, USA — [3]Institut Jaume Almera, Consell Superior d'Investigacions Cientifiques (CSIC), 08028 Barcelona, Catalonia, Spain

A vertical and lateral GaN/InGaN heterostructure within a nanowire has been grown by plasma assisted molecular beam epitaxy. The resulting wires have a complex morphology which results from a combination of vertical and lateral heterostructure interfaces. Photoluminescence indicates Indium content in the InGaN alloy of approximately 30 % and evidences in addition a high quality of the GaN nanowire. Raman investigation based on the analysis of the LO peak position and its shape reveal a composition variation between 20 % and 30 %.

XRD measurements show a peak with an onset at 17.26° that extends to 16.6° also suggesting a spread in compositions. Transmission electron microscopy analysis indicates composition variations along the wire growth direction. In addition insight is gained about the position of the heterointerfaces. This allows an understanding of the complex shape of the nanowire.

HL 41.4 Wed 11:45 H13

MBE grown InN nanowires: Doping effects of Si and Mg — •Tobias Gotschke[1], Friederich Limbach[1], Roberta Caterino[1], Toma Stoica[1], Eike Oliver Schäfer-Nolte[1], Raffaella Calarco[1], and Elli Sutter[2] — [1]Institute of Bio- and Nanosystems (IBN-1) Research Centre Jülich GmbH, D-52425 Jülich, and JARA- Fundamentals of Future Information Technology, Germany — [2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973, USA

Si and Mg doped InN nanowires (NWs) were grown by plasma assisted molecular beam epitaxy on Si(111) substrates under nitrogen rich conditions. Influence of dopant flux, substrate temperature and In flux were investigated by means of SEM, PL and Raman. We can show that Si doped InN nanowires can be grown at higher substrate temperatures than the undoped once. By carefully choosing growth parameters the fabricated Si doped nanowires can be optimized in terms of morphology yielding to well separate nanowires with high aspect ratio and smooth sidewalls. The growth parameters chosen for the realization of Mg doped nanowires are very similar to that of undoped InN NWs. Photoluminescence measurements on Si doped nanowires show a band filling effect, which indicates a successful n-doping. PL intensity, peak energy and broadening of the peaks are fluctuating by doping with Mg. An intense LO mode in Raman measurements on InN nanowires has been observed. Mg doped NWs show a narrowing of the Raman peaks. A low energy tail emerges for the LO mode upon high doping with Si.

HL 41.5 Wed 12:00 H13

MOVPE overgrowth of InN quantum dot like structures — •Christian Meissner[1,2], Michael Högele[1], Raimund Kremzow[1], Markus Pristovsek[1], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Straße 9, 12489 Berlin

Indium nitride (InN) quantum dots could be used an alternative material for applications at the standard telecommunication wavelength of 1.55 μm. We showed that the density and size of InN quantum dots grown in Volmer-Weber growth mode can be controlled by growth temperature and total amount of InN on the surface. For light emitting devices those quantum dot like structures need to be overgrown. Therefore, we studied systematically the overgrowth process by MOVPE of InN quantum dots on GaN/sapphire with a density of $10^{10}\,\mathrm{cm}^{-2}$. Different capping strategies were monitored by in-situ ellipsometry which allows investigations on a submonolayer scale of the InN/GaN system with 11% lattice mismatch. Additional characterisation was done by atomic force microscopy, x-ray and photoluminescence measurements.

The main problem of indium segregation from InN QDs into the first capping layers and the formation of InGaN is observed by XRD with a gallium content of less than 20%. Thus for overgrowth a high growth rate is needed, but the material quality must still be maintained. Further investigations with InGaN capping layers to reduce the strain during overgrowth have been done.

HL 41.6 Wed 12:15 H13

DLTS measurements on GaSb/GaAs quantum dots — •Annika Högner[1], Tobias Nowozin[1], Andreas Marent[1], Dieter Bimberg[1], Chi-Che Tseng[2], and Shih-Yen Lin[3] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Institute of Photonics Technologies, NTHU, Taiwan — [3]Institute of Optoelectronic Sciences, NTOU, Taiwan

Memory devices based on hole storage in self-organized quantum dots offer significant advantages with respect to storage time and scalability. Recently, we demonstrated a first prototype based on InAs/GaAs quantum dots at low temperatures [1]. To enable feasible storage times at room temperature the localisation energy of the quantum dots has to be increased by using other material systems. A first step in this direction is the use of GaSb quantum dots within a GaAs matrix.
We have characterized self-organized GaSb/GaAs quantum dots embedded into a n^+p-diode structure. DLTS measurements on hole emission were conducted and yield a strong peak from which a mean emission energy of about 400 meV can be extracted. The reference sample without the quantum dots (containing only the wetting layer) shows no such peak.

[1] A. Marent, T. Nowozin, J. Gelze, F. Luckert, and D. Bimberg, "Hole-based memory operation in an InAs/GaAs heterostructure", Appl. Phys. Lett. (in press).

HL 41.7 Wed 12:30 H13

Investigating Axial Zinc Doping Profile in Galliumarsenide Nanowires with Kelvin Force Microscopy and Scanning Microwave Microscopy — •Matthias Fenner[1], Hassan Tanbakuchi[1], C. Gutsche[2], A. Lysov[2], I. Rgolin[2], W. Prost[2], and F.-J. Tegude[2] — [1]Agilent Technologies, Campus Kronberg, 61476 Kronberg, Germany — [2]Center for Nanointegration, University of Duisburg-Essen, Duisburg, Germany

Nanowires with a nominal change of the doping along the nanowire axis were grown. Fabrication of high quality doping and material transitions is well established in bulk semiconductors. This is callenging especially for III-V nanowires, where a complete model of the vapour-liquid-solid (VLS) growth mechanism is still pending. We employed two atomic force microscopy (AFM) methods for dopant profiling of GaAs nano wires: Kelvin Force Microscopy (KFM) and Scanning Microwave Microscopy (SMM). KFM indirectly measures the dopant density via the surface potential [1, 2]. SMM measures the capacitance of the tip sample junction with resolutions in the attofarad and nanometer range. By means of a local capacitance spectroscopy method (dC/dV) SMM directly maps the dopant density in semiconductors [3]. The two methods show transitions from undoped to doped regions in the nanowires as well as gradients along the axis of the wires.

[1] C. Baumgart, M. Helm, H. Schmidt, Phys. Rev. B 80, 085305 (2009). [2] S. Vinaji et al., Nanotechnology 20 (2009) [3] F. Michael Serry, Agilent Application Note 5989-8818EN, http://cp.literature.agilent.com/litweb/pdf/5989-8818EN.pdf, 2008.

HL 42: Focussed Session: Silicon Photonics

Time: Wednesday 14:00–17:45 Location: H13

Invited Talk HL 42.1 Wed 14:00 H13

Recent advances in silicon-based photonic devices — •Delphine Marris-Morini[1], Laurent Vivien[1], Gilles Rasigade[1], Papichaya Chaisakul[1], Xavier Le Roux[1], Eric Cassan[1], Jean-Marc Fedeli[2], Daniel Chrastina[3], and Giovanni Isella[3] — [1]Institut d'Electronique Fondamentale, Université Paris Sud - CNRS, bât. 220, 91405 Orsay, France — [2]CEA, LETI, Minatec 17 rue des Martyrs, 38054 Grenoble cedex 9, France — [3]L-NESS Politecnico di Milano, Polo Regionale di Como, Via Anzani 42, 22100 Como, Italy

In the past few years, the interest in silicon photonics has greatly increased. Silicon on insulator (SOI) guiding structures have been successfully demonstrated and research focuses now on active devices. The state of the art in optical modulators and photodetectors will be presented, and recent results obtained in the group will be detailed. For optical modulation, both electro-refraction and electro-absorption can be used. In silicon, free-carrier concentration variation is the most efficient way to achieve refractive index variation. We have experimentally demonstrated a 15 GHz modulator with low insertion loss and large modulation contrast. We are also investigating electro-absorption mechanisms, especially the quantum confined Stark effect (QCSE), in SiGe/Ge multiple quantum well (MQW) heterostructures. For high performance integrated photodetectors, we have chosen to use pure germanium grown on silicon. 40 Gbit/s data transmission has been achieved with a responsivity of 1 A/W in the 1.3 1.6 um wavelength range.

Topical Talk HL 42.2 Wed 14:30 H13

3D silicon photonic crystals — •Georg von Freymann — Institut für Nanotechnologie, KIT, Karlsruhe, Germany

We report on our recent progress in the fabrication and characterization of three-dimensional silicon photonic crystals. Structures are fabricated by direct laser writing (DLW) and subsequent silicon inversion or silicon double inversion.

DLW is a very versatile technique and allows for a variety of structures ranging from woodpile photonic crystals over chiral photonic crystals to photonic quasicrystals. We will present a novel resonator design for woodpile photonic crystals and discuss future developments.

Topical Talk HL 42.3 Wed 15:00 H13

Miniband-related IR luminescence of Ge/Si quantum dot superlattices — •Peter Werner — MPI für Mikrostrukturphysik, Weinberg 2, Halle (Saale)

Highly strained Si/Ge multi-layer heterostructures incorporating Ge quantum dots may show strong IR luminescence even at room temperature. Calculations of the electronic band structure and luminescence measurements prove the existence of an electron miniband within the columns of the QDs. Such a miniband formation results in a conversion of the indirect to quasi-direct excitons. The optical transitions between electron states within the miniband and hole states within QDs are responsible for an intense photoluminescence in the 1.4 - 1.8 micrometer range. The talk will present basics of the crystal growth of such staked multi-layers as well as the analysis of their luminescence properties. Such multi-layers can be applied for LED concepts including etched nanostructures.

Topical Talk HL 42.4 Wed 15:30 H13

Transient optical gain in Germanium quantum wells — •Christoph Lange[1,2], Niko Köster[1], Martin Schäfer[1], Mackillo Kira[1], Stephan Koch[1], Danny Chrastina[4], Giovanni Isella[4], Hans von Känel[4], Hans Sigg[3], and Sangam Chatterjee[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität, Renthof 5, D-35032 Marburg, Germany — [2]Department of Physics University of Toronto 60 St. George St. Toronto ON, M5S 1A7 Canada — [3]Laboratory for Micro and Nanotechnology, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [4]CNISM and L-NESS, Dipartimento di Fisica del Politecnico di Milano, Polo di Como, via Anzani 42, I-22100 Como, Italy

One of today's most-sought goals in semiconductor technology is the monolithic integration of microelectronics and photonics on Si. Optical gain is, in general, not expected for Si and Ge or its alloys due to the indirect nature of the band gap in this material system. Here, we show that Ge/SiGe QWs show transient optical gain and may thus be used as an optically-pumped amplifier at room temperature [1]. Further, the nonequilibrium effects which govern the relaxation dynamics of the optically injected carrier distributions in this material were observed and analyzed using a microscopic many-body theory. Strong non-equilibrium gain was obtained on a sub-100 fs time scale. Longlived gain arising from Γ-point transitions is overcompensated by a process bearing the character of free carrier absorption.

[1] C. Lange et al., Phys. Rev. B **79**, 201306(R) (2009)

15 Min. Coffee Break

Invited Talk HL 42.5 Wed 16:15 H13

SiGe based quantum cascade systems: 10 years after. — •Hans Sigg — Paul Scherrer Institut, Villigen PSI, Switzerland

The exploration of a Si-technology based long-wavelength laser for gas sensing, medical screening and airport security monitoring etc., started ten years ago, with the demonstration of electro-luminescence in SiGe based quantum cascade structures [Dehlinger, Diehl et al. Science 290, 2277 (2000)]. At the beginning, most activities focused on the development of a relaxed buffer substrate, and the implementation of intersubband systems in the valence band, i.e. cascade emitters based on hole-transport. Recently, despite the reduced band offsets, intersubband systems in the conduction band have come into the focus, because of their simpler bandstructure. Alternative approaches, such as optical pumping and intersubband Raman lasing have also been investigated. The present outline of these basic developments allows the remaining significant technological and fundamental problems to be brought into perspective.

Invited Talk HL 42.6 Wed 16:45 H13

A Germanium Laser on Silicon — •Jurgen Michel, Jifeng Liu, Lionel C. Kimerling, Xiaochen Sun, and Rodolfo Camacho — Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Lasers on silicon are one of the most crucial components for silicon-based electronic-photonic integration. Epitaxial Ge-on-Si is a particularly interesting candidate due to its pseudo-direct band gap behavior and its compatibility with advanced electronic devices on Si. Integrated photonic devices such as waveguide-coupled photodetectors and electro-absorption modulators have already been demonstrated based on the direct band gap transition of Ge. Our theoretical analysis has shown that Ge can be band-engineered by tensile strain and n-type doping to achieve efficient light emission and optical gain from its direct gap transition. Indeed, direct gap photoluminescence (PL) and electroluminescence (EL) at room temperature have already been demonstrated from these band engineered Ge-on-Si materials. We will present the experimental observation of optical gain and lasing in epitaxial tensile strained n+ Ge-on-Si at room temperature. Lasing has been achieved by pumping a Ge waveguide with nanosecond pulses from an NdYAG laser at 1064nm.

Topical Talk HL 42.7 Wed 17:15 H13

Monolithic integration of lattice-matched Ga(NAsP)-based laser device structures on (001) Silicon — •Kerstin Volz and Wolfgang Stolz — Philipps University Marburg, Materials Science Center and Faculty of Physics, Marburg, Germany

The novel, direct band gap, dilute nitride Ga(NAsP)-material system allows for the first time for the monolithic integration of a III/V-based active laser material lattice matched to exact (001) Si substrates. This lattice-matched approach results in a high-quality, low defect density integration leading to long-term stable laser devices on Si-substrates.

Broad area laser structures consist of pseudomorphically strained active Ga(NAsP)/(BGa)(AsP) multi-quantum-well heterostructures embedded in thick doped (BGa)P waveguide layers, grown by a specific low-temperature metal organic vapour phase epitaxy (MOVPE) process on (001) Si-substrate. The optimization of the laser properties focus on improvements in material quality based on MOVPE growth and nucleation conditions as well as the design parameters such as optimal carrier and light field confinement, doping levels and post-growth annealing treatments.

This paper will present and discuss the current status to realise electrical injection laser diodes as a basis for Si-photonics.

HL 43: Electronic Structure and Atomistic Modeling

Time: Wednesday 14:00–15:45 Location: H14

HL 43.1 Wed 14:00 H14

Does the KLI approximation work for current-density-functional theory? — •Marc Siegmund and Oleg Pankratov — Lehrstuhl für Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen, Germany

Orbital exchange-correlation functionals which depend explicitly on the Kohn-Sham orbitals but only implicitly on the density became popular in the last years. These functionals systematically improve the description of many-body effects within density-functional theory. Among those, the optimized effective potential (OEP) method is often employed which expresses the exchange-correlation potential as a solution of complicated integral equations. Due to the complexity of these equations, a simplification known as the Krieger-Li-Iafrate (KLI) approximation is widely used in practice.

Recently, the OEP integral equations and the KLI approximation have been derived for current-density-functional theory (CDFT) [1]. Using a one-dimensional model system, we discuss the applicability of the KLI approximation in this case. A numerical example shows, that the solution of the CDFT-KLI equations may produce the exchange-correlation vector potential which leads to violation of the continuity

equation. On the contrary, the solution of the full CDFT-OEP equations does not suffer from this shortcoming.

[1] S. Pittalis, S. Kurth, N. Helbig, and E.K.U. Gross, Physical Review A **74**, 062511 (2006)

HL 43.2 Wed 14:15 H14

Electronic properties of rolled-up materials — •Carmine Ortix and Jeroen van den Brink — Leibniz-Institute for Solid State and Materials Research Dresden, D-01171 Dresden, Germany

The success achieved in modern nanotechnology has made it possible to develop systems having fairly complex geometrical shapes. Typical examples are the so-called rolled-up nanotubes which mimic the cylindrical geometry of a radial crystal. In this talk we will discuss the electronic properties of a rolled-up two-dimensional electron gas. The nature and energy dispersion of the quantum states reflect the interplay between the typical length scales of the problem. In addition we will show that the effect of an external magnetic field adds a new degree of freedom to manipulate the quantum states of the carriers.

HL 43.3 Wed 14:30 H14

Exploring the unusual diffusion of N adatoms on GaAs(001) using first principles calculations — •Hazem Abu-Farsakh and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany

The large band-gap bowing resulting from the incorporation of N in GaAs has attracted a considerable interest recently for various applications including e.g. infrared laser diodes. However, epitaxial growth of dilute nitride alloys is hampered by several challenges. A key issue is the low solubility of N in this material system, which requires growth conditions far away from equilibrium. To optimize such conditions it is crucial to employ accurate simulation techniques. Key input quantities include diffusion paths and barriers on the growing surface. To determine these parameters we first employed *ab-initio* calculations to map the potential energy surface (PES) of N on GaAs(001) surface. Our results reveal that the energy landscape is highly complex and multivalued in nature. A detailed analysis showed that this is a consequence of the high reactivity of the N adatoms causing large surface relaxations. A consequence of this finding is that the conventional PES mapping approach dramatically fails. We therefore propose an alternative approach that allows us to identify the diffusion coefficients and the activation barriers over the entire relevant temperature range. Our results show a completely unexpected interplay of localization within the reconstructed surface unit cell that prevents equilibration and high mobility inside it guaranteeing the incorporation on the desired substitutional sites.

HL 43.4 Wed 14:45 H14

Tight-binding theory of $Cd_xZn_{1-x}Se$ semiconductor alloy nanocrystals — •Daniel Mourad and Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen

For a wide class of semiconductor materials alloys of the type A_xB_{1-x} can be realized, e.g. $Cd_xZn_{1-x}Se$, Si_xGe_{1-x}, $Al_xGa_{1-x}N$, $Ga_xIn_{1-x}N$, and many others. These substitutional alloys find widespread applications, in particular in nanoelectronic devices like quantum wells, quantum wires and quantum dots, as the band gap varies continuously with x, and therefore a band structure tayloring is possible by variation of the concentration. To calculate the electronic properties of such semiconductor alloys we start from multiband (sp^3) tight-binding (TB) models for the pure bulk semiconductor materials A and B and perform ensemble averaged finite supercell calculations. Alternatively, we apply the coherent potential approximation (CPA) to calculate and compare the configurationally averaged electronic density of states and effective band structure. These treatments allow for an intrinsic reproduction of band bowing effects as a function of the concentration x and lead to finite lifetime effects due to the loss of translational invariance, contrary to much simpler mean-field approaches like the virtual crystal approximation (VCA). As an up-to-date application, we have in particular investigated $Cd_xZn_{1-x}Se$ nanocrystals. We compare our results to experimental ones by combining these treatments with the recently developed TB models of nanostructures. Finally, we discuss the proper choice of material parameters for these systems.

HL 43.5 Wed 15:00 H14

The Atomistic-Continuum Modeling of Short Pulse Laser Interaction with Semiconductors — •Dmitriy Ivanov, Baerbel Rethfeld, and Vladimir Lipp — Physics Department, Technical University of Kaiserslautern, Kaiserslautern, Germany

The understanding of fundamental mechanisms behind the sub-wave length surface modification on semiconductors is of a great importance for Information Technologies. However, strong laser-induced phase perturbations, occurring under conditions of nonequilibrium between free laser-generated carriers and phonons, make the experimental and theoretical study of short pulse laser nanostructuring on semiconductors difficult. Previously, the atomistic-continuum approach for modeling of short-pulse laser interactions with metals have been proven as an efficient tool when studying processes of laser melting, ablation, and nanostructuring on metals.

In present work, a computational technique that combines the advantages of different approaches into the atomistic-continuum model for semiconductors is developing on the example of Si. In the combined model, 1) the kinetics of fast non equilibrium phase transformations is treated at atomic level with Molecular Dynamics method, and 2) the description of laser light absorption by free carriers, their transport dynamics, and strong laser-induced non equilibrium between free carriers and phonons are accounted for in the continuum part by means of free carrier dynamics model.

HL 43.6 Wed 15:15 H14

Intrinsic n-type Behavior in Transparent Conducting Oxides: A Comparative Hybrid-Functional Study of In_2O_3, SnO_2, and ZnO — •Péter Ágoston[1], Karsten Albe[1], Risto M. Nieminen[2], and Martti J. Puska[2] — [1]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 32, 64287 Darmstadt — [2]Department of Applied Physics, Helsinki University of Technology, FIN-02015 TKK, Finland

We present a comparative study of point defects in In_2O_3, SnO_2 and ZnO based on the hybrid-functional method within the density functional theory (DFT). For In_2O_3 and SnO_2, our results provide strong evidence of shallow donor states at oxygen vacancies. The formation energies of oxygen vacancies are low both for the doubly positive and neutral charge states. In comparison with the semilocal exchange-correlation approximations in DFT the hybrid-functional method lowers strongly the formation energy of the positive charge state and keeps that of the neutral state nearly intact. The trend is analyzed in terms of changes in the lattice relaxation energy and the electron energy levels near the band gap. The existence of shallow donor states at oxygen vacancies and the consequent n-type conductivity are in line with experimental findings. The results invalidate some former theoretical interpretations.

HL 43.7 Wed 15:30 H14

Semiconductors and oxides studied using relativistic exact-exchange implemented within the multiple scattering KKR formalism — •Diemo Ködderitzsch and Hubert Ebert — Ludwig-Maximilians-Universität München, Department Chemie und Biochemie, Physikalische Chemie, Butenandtstraße 11, D-81377 München, Germany

In the *systematic* development of new exchange-correlation (xc) functionals in density functional theory the so called orbital dependent xc-functionals have emerged and are now extensively studied. Here we give a formulation of relativistic exact-exchange (REXX) as an approximation to the xc-functional subsequently used in a multiple-scattering KKR Green's function implementation. Both core and valence states are treated on the same footing in an all electron approach. The REXX used for the valence states is reformulated in terms of the electronic Green's function. Numerical four-component wave functions for the description of the ingredients of the REEX integral equation are employed. We present and discuss the application of the formalism to semiconductors and oxides.

HL 44: Invited talk: S. Krischok

Time: Wednesday 14:00–14:30 Location: H15

Invited Talk HL 44.1 Wed 14:00 H15

Surface characterisation and reactivity of clean GaN(000±1) surfaces — Pierre Lorenz[1], Richard Gutt[2], Marcel Himmerlich[1], Juergen A. Schaefer[1], and •Stefan Krischok[1] — [1]Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastr. 72, 79108 Freiburg, Germany

This contribution summarises our present understanding of the surface properties of reconstructed GaN(000±1) thin films grown by plasma assisted molecular beam epitaxy and the early stages of the interaction with selected small molecules. The intrinsic properties of the pure GaN samples have been analysed in-situ following the epitaxial growth mainly utilizing photoelectron spectroscopy (XPS and angular resolved UPS). Special attention is paid to the presence of reconstruction-induced surface states and their influence on surface band bending and electronic properties as well as the angular dependence of the valence band spectra. The initial surface-adsorbate-interaction and the related changes of surface electronic properties are discussed for the model molecules O_2 and H_2O. The observed surface states reveal a high reactivity and vanish upon the initial stages of oxidation. Furthermore, adsorbate-related electron states are formed which will be discussed in terms of changes in surface dipole, bend bending and work function. A comparison of the reactivity towards O_2 and H_2O between different GaN surface modifications will be made.

HL 45: Group-III-Nitrides: Optical Properties II

Time: Wednesday 14:30–17:45 Location: H15

HL 45.1 Wed 14:30 H15

Determination of the Faust-Henry Coefficient of GaN by Raman Scattering — •Christian Röder, Gert Irmer, and Cameliu Himcinschi — TU Bergakademie Freiberg, Institute for Theoretical Physics, Leipziger Str. 23, 09596 Freiberg, Germany

In order to specify the charge carrier concentration n and mobility μ in GaN by Raman spectroscopy the Faust-Henry coefficient C should be determined with good precision. Unfortunately, the values for this parameter found in literature differ significantly. Using the standard dielectric approach we calculated the Raman lineshape of coupled phonon-plasmon modes (CPPM) depending on the Faust-Henry coefficient and scattering mechanisms respectively.
Raman intensity measurements on the A1(TO) and A1(LO) phonons of undoped GaN specimen were carried out from room temperature down to 77 K to determine the Faust-Henry coefficient. Additionally we investigated several doped GaN samples with the goal to compare the ascertained free-carrier concentrations with those derived from the Raman lineshape fitting using the previously determined value of C. The comparison gives good agreement confirming the determined Faust-Henry coefficient. Furthermore the analysis of the lineshape reveals the deformation-potential and electro-optic mechanisms as dominant scattering mechanisms in gallium nitride.
The authors would like to thank the European Union (EFRE) as well as the Free State of Saxony for financial support.

HL 45.2 Wed 14:45 H15

Auger Coefficient in GaInN-based Laser Structures — •Alexander Daniel Dräger, Carsten Netzel, Moritz Brendel, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

Todays GaInN-based light emitting devices such as LEDs and laser diodes show excellent properties in terms of quantum efficiency or threshold current in the violet-blue spectral region. With increasing wavelength towards the green this performance decreases strongly. In particular at longer wavelengths, the quantum efficiency decreases for higher current densities, called the efficiency droop. This phenomenon is still subject to intensive research and different mechanisms such as Auger recombination, losses due to dislocations and carrier escape have been named as possible explanations. We combine optical gain measurements using the variable stripe length technique with model calculations of the optical gain spectra to derive the carrier lifetime. From the dependence of the inverse effective lifetime on carrier density we determine the recombination coefficients for radiative, nonradiative and Auger recombination. The Auger coefficients we obtained are about 1-2×10^{-31} cm^6/s for GaInN quantum wells with 2.5eV< E_g <3.1eV which is more than an order of magnitude lower than estimated from photoluminescence [1] and thus too low to explain the LED droop. Nevertheless, Auger recombination seems to contribute to laser threshold.

[1] Shen et. al. APL **91**, 141101(2007)

HL 45.3 Wed 15:00 H15

Exciton enhancement of recombination mechanisms in GaInN/GaN quantum well structures — •T. Langer, A. D. Dräger, H. Jönen, D. Fuhrmann, H. Bremers, U. Rossow, and A. Hangleiter — Institute of Applied Physics, TU Braunschweig

Temperature-dependent and time-resolved photoluminescence spectroscopy on highly efficient GaInN/GaN quantum well structures with low excitation power reveal the nature of radiative recombination being free exciton dominated up to room temperature. This implies a strong enhancement of radiative recombination rates of free excitons compared to free carriers, due to a higher probability of electrons and holes being at the same place simultaneously. In the low excitation regime, where screening of excitons is not important, we therefore observe a linear rather than a quadratic carrier concentration (n) dependence of radiative recombination rates. This observation, as well as the radiative rates in the whole temperature and carrier concentration range, can be described using a n-dependent correlation function g_{eh} of electrons and holes in a many body system. The radiative recombination rate turns to $Bg_{eh}(n)n^2$ in case of optical excitation ($n = p$).

We also discuss the effect of excitons on Auger recombination, whose rate is known to be proportional to n^3 for free carriers. For GaInN/GaN quantum well structures, the Auger coefficient is about $1 \cdot 10^{-31} cm^6 s^{-1}$ which appears to be too low to let Auger recombination become a significant recombination process in such structures. Nevertheless, excitonic enhancement might increase the importance of Auger recombination in these materials.

HL 45.4 Wed 15:15 H15

Excitonic dielectric function of hexagonal GaN — •Steve Lenk and Erich Runge — Institut für Physik und Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, 98693 Ilmenau, Germany

We calculate the dielectric function of hexagonal GaN including the A-, B-, and C-excitons using a multi-valence band formalism. The importance of excitons for the interpretation of reflectance spectroscopy of GaN was emphasized by several experimental groups, but only recently theoretical calculations were presented [1]. We derive the dielectric function from a numerical solution of an initial value problem [2] via an exponential split-operator method, taking into account the full 6x6 valence band structures of several parametrizations. We present the complex dielectric function as well as the deduced reflectivity spectra of the excitons in GaN. These results show qualitative and quantitative agreement with recent experimental studies.

[1] A. T. Winzer, G. Gobsch, and R. Goldhahn, Phys. Rev. B **74**, 125207 (2006).

[2] S. Glutsch, *Excitons in Low−Dimensional Semiconductors*, Springer Heidelberg (2004).

[3] S. L. Chuang and C. S. Chang, Phys. Rev. B **54**, 2491 (1996).

HL 45.5 Wed 15:30 H15

Ortsaufgelöste Photolumineszenz- (PL), Elektrolumineszenz- (EL) und LBIC- (Light Beam Induced Current) Messungen an einer InGaN/GaN-LED auf Silizium(111)-Substrat — •Martin Thunert, Thomas Hempel, Armin Dadgar und Jürgen Christen — Otto-von-Guericke-Universität Magdeburg, Germany

Eine mittels MOVPE gewachsene InGaN/GaN-LED wurde anhand ortsaufgelöster EL-, PL- und LBIC-Messungen untersucht. Das Lumineszenzspektrum zeigt einen breiten Peak um 477 nm mit einer Halbwertsbreite von 0,14 eV. Durch auftretende Fabry-Perot-Interferenzen wurde die Schichtdicke der LED berechnet. Die EL-Messungen ergeben bei Stromstärkeerhöhung eine stärkere Intensitätszunahme des höherenergetischen Spektralbereiches relativ zum niederenergetischen.

Der Vergleich zwischen der EL- und der PL-Messung zeigt die unterschiedlichen Einflüsse der Ladungsträgerinjektion und -verteilung, sowie der Absorption auf die Lumineszenz der LED. Aus der Temperaturabhängigkeit der PL-Spektren wurden die Aktivierungsenergien zweier Prozesse berechnet, welche zu einem Abfall der PL-Intensität bei Temperaturerhöhung führen. Bei tiefen Temperaturen (4 K) wurde ein linearer Zusammenhang zwischen PL-Intensität und Anregungsdichte nachgewiesen.

Anhand der LBIC-Messung wurden elektrische Eigenschaften der LED in der Nähe des p-n-Übergangs untersucht. Vergleichende Messungen zeigen, dass Fehler in der Metallkontaktierung hohe Einbrüche der EL-Intensität verursachen, wohingegen sie das LBIC-Signal nicht beeinflussen.

15 Min. Coffee Break

HL 45.6 Wed 16:00 H15

Untersuchungen von gezielt belasteten, blauen InGaN-MQW-LEDs mittels EL, μ-EL, simultanem μ-PL/Raster-LBIC und FE-REM — •T. Fey, T. Hempel und J. Christen — Institut für Experimentelle Physik, Otto-von-Guericke-Universität, 39106 Magdeburg

Es wurden sowohl mechanisch als auch elektrisch belastete, kommerzielle, blaue InGaN-MQW-LEDs mittels EL, μ-EL, simultanem μ-PL/Raster-LBIC(Light Beam Induced Current) sowie FE-REM untersucht. Bei den mechanisch belasteten LEDs konnte sowohl im FE-REM als auch in der μ-EL kein eindeutiger Einfluss auf die Bauelemente nachgewiesen werden. Im Gegensatz dazu zeigten viele der elektrisch belasteten Proben eine inhomogene Intensitätsverteilung und ein Ansteigen des Sperrstromes. Bei diesen geschädigten LEDs konnte in Sperrrichtung Lumineszenz detektiert werden. Diese Lumineszenz in Sperrrichtung steht in örtlicher Korrelation zu dunklen Bereichen in Durchlassrichtung. In Übereinstimmung dazu zeigen die simultanen μ-PL/LBIC Messungen ein deutliches Ansteigen des LBIC und ein Einbruch der MQW-Lumineszenz in diesen defekten Bereichen. Bei Untersuchungen einer defekten LED konnte ebenfalls Lumineszenz in Sperrrichtung mit gleicher spektraler Verteilung detektiert werden. Wir danken der Firma PerkinElmer Elcos GmbH für die freundliche Unterstützung.

HL 45.7 Wed 16:15 H15

Optical and structural investigations of pendeo-epitaxial AlGaN layers by spectrally resolved cathodoluminescence microscopy — •G. Schmidt[1], B. Bastek[1], T. Hempel[1], F. Bertram[1], J. Christen[1], V. Küller[2], A. Knauer[2], F. Brunner[2], H. Rodriguez[2], M. Weyers[2], and M. Kneissl[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin, Germany

The ternary alloy AlGaN is a promising candidate for optoelectronic devices emitting in the deep UV. However, due to the large lattice and thermal mismatch, AlGaN layers grown on sapphire exhibit a high density of dislocations. In order to reduce this density AlGaN layers have been grown by pendeo-epitaxy. For this approach an AlN layer is directly grown on sapphire and subsequently patterned, resulting in a stripe structure parallel to [10$\underline{1}$0] with a trench width of 1.9μm and a ridge width of 1.1μm. The pattern was overgrown by a fully coalesced MOVPE AlGaN layer. We present the microscopic optical properties of the pendeo-epitaxial AlGaN layers. The spatially integrated cathodoluminescence (CL) spectrum exhibits two dominant peaks at 3.939eV and 4.326eV, respectively. Spatially resolved CL proved a correlation between the wavelength distribution and the trench pattern. The high energetic luminescence originates from the areas above the AlN ridges and the low energetic intensity from the area above the trenches, suggesting local different Al incorporation. Furthermore, the strain relaxation in growth direction is imaged by cross-sectional CL.

HL 45.8 Wed 16:30 H15

Dielectric function of AlInN nearly lattice-matched to GaN — •Egidijus Sakalauskas[1], Pascal Schley[1], Georg Rossbach[1], Rüdiger Goldhahn[1], Hannes Behmenburg[2,3], Christoph Giesen[2], Michael Heuken[2,3], Christoph Hums[4], and Alois Krost[4] — [1]Institut für Physik, TU Ilmenau — [2]Aixtron AG — [3]Institut für Theoretische Elektrotechnik, RWTH Aachen — [4]Institut für Experimentalphysik, Otto-von-Guericke Universität Magdeburg

$Al_{1-x}In_xN$ material with ∼18 % indium content is lattice matched to GaN and has lot of potential applications for photonic and electronic devices. In our work we carry out a comprehensive study of high-quality MOCVD-grown c-plane $Al_{1-x}In_xN$ films with In content ranging from 14 to 22 %. High resolution X-ray diffraction measurements revealed that AlInN films are pseudomorphically grown to GaN. Ellipsometry studies were conducted on the AlInN samples in the photon energy range from 1 to 10 eV. For the first time, complex effective ordinary dielectric function (DF) of AlInN nearly lattice-matched (LM) to GaN was extracted and the critical points of the band structure were determined. The pronounced optical transitions in the high-photon energy part of the DF indicate already promising optical quality of the AlInN films. The sharp onset of the imaginary part of the DF defines the direct absorption edge which is red-shifted for the AlInN samples with higher In content. High frequency dielectric constants were estimated from the real part of the DF in the transparent region. The band gap values are evaluated including the influence of strain.

HL 45.9 Wed 16:45 H15

Phase separation in AlGaN layers grown on SiN interlayers — •Kim Juliane Fujan[1], Benjamin Neuschl[1], Ingo Tischer[1], Martin Feneberg[1], Klaus Thonke[1], Martin Klein[2], Kamran Forghani[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

For high quality AlGaN templates *in-situ* SiN interlayers are a possible method to decrease the dislocation density effectively. Immediately after such a SiN layer, the growth re-starts in a 3D-like mode, before the layers smoothen again. We report on a low temperature photoluminescence and cathodoluminescence study with high spatial resolution on a series of such AlGaN layer structures. We find signatures of anisotropic aluminum incorporation efficiency for different facets especially immediately after the interlayer deposition. In cathodoluminescence we directly can spatially resolve this phase separation, which vanishes for layer thicknesses of $\sim 1\,\mu$m and more. Influence of layer homogeneity (roughness) and possible growth mechanisms are discussed in detail.

HL 45.10 Wed 17:00 H15

Optical properties of homoepitaxial AlN — •Martin Feneberg[1], Benjamin Neuschl[1], Ramon Collazo[2], Anthony Rice[2], Zlatko Sitar[2], Jinqiao Xie[3], Seiji Mita[3], Georg Rossbach[4], Rüdiger Goldhahn[4], Marcus Roeppischer[5], Christoph Cobet[5], Norbert Esser[5], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm — [2]Dept. of Mat. Sci. Engr., North Carolina State University, USA — [3]HexaTech, Inc., Morrisville, NC, USA — [4]Institut für Physik, TU Ilmenau — [5]ISAS, Berlin

Homoepitaxial c- and m-plane AlN layers, deposited by MOCVD on bulk PVT AlN are investigated by means of high resolution photoluminescence and spetroscopic ellipsometry. We find donor bound exciton lines with a full width at half maximum below 500μeV at T = 10 K. The exciton binding energy amounts to 52 meV in the c-plane sample leading to a bandgap energy of 6.092 eV (at 10 K). By spectroscopic ellipsometry we access both the ordinary and the extraordinary dielectric functions. The analysis of the sharp free exciton resonance found in the extraordinary tensor components yields a transition energy being in excellent agreement with the emission studies. The ordinary component exhibits a feature which indicates a strong contribution of exciton-phonon interaction to the absorption process.

HL 45.11 Wed 17:15 H15

Impact of stress on the optical properties of AlN layers — •Georg Rossbach[1], Pascal Schley[1], Gerhard Gobsch[1], Rüdiger Goldhahn[1], Marcus Röppischer[2], Christoph Werner[2], Christoph Cobet[2], Norbert Esser[2], Armin Dadgar[3], Matthias Wieneke[3], and Alois Krost[3] — [1]Technische Universität Ilmenau,

Institut für Physik, PF 100565, 98684 Ilmenau — [2]Institute for Analytical Sciences (ISAS), 12489 Berlin — [3]Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, 39106 Magdeburg

The reversed valence-band (VB) ordering of wurtzite AlN with respect to GaN causes a strong dependence of the free excitonic transition energies on stress and a strong polarization anisotropy around the absorption edge. Here, we show that spectroscopic ellipsometry (0.9-9.8eV) is a powerful tool to determine both the ordinary and the extraordinary part of the dielectric function around the band edge of C-plane AlN layers. The investigations of films experiencing either tensile or compressive in-plane stress due to the growth on different substrates (Si, SiC and sapphire) allows us to demonstrate experimentally the stress dependence and anisotropy. The energy spacing of the three VBs at the center of the Brillouin zone is obtained from the analysis. The extracted shifts in energy are compared with the results of strain-dependent k*p calculations yielding in addition experimental values for the deformation potentials. Temperature-dependent studies reveal a strong influence of exciton-phonon interaction on the absorption.

HL 45.12 Wed 17:30 H15

Broadening mechanism of excitonic transitions in GaN nanowire ensembles — •Carsten Pfüller, Oliver Brandt, Caroline Chèze, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Nanowires (NWs) offer the possibility to integrate III/V and II/IV semiconductors of high crystalline quality even on lattice mismatched substrates such as silicon.

We investigate the photoluminescence (PL) of GaN NWs grown by plasma-assisted molecular beam epitaxy on a Si(111) substrate. The energy of the donor-bound exciton emission at 3.472 eV confirms the NWs to be unstrained. Its linewidth is typically of the order of 3 meV, which is much broader than expected for a strain-free semiconductor.

PL spectra of single NWs dispersed onto a Si(111) vary widely from wire to wire and differ significantly from ensemble spectra. While the majority of dispersed NWs experiences strain from interaction with the substrate, a few NWs exhibit sharper excitonic lines than the ensemble. These lines comprise the donor-bound exciton and free exciton emission of strainfree GaN as well as a set of sharp transitions at 3.475-3.476 eV. The same transitions are observed for as-grown, low density NW ensembles. We attribute these high-energy lines to recombination of excitons bound to surface donors. The statistically distributed distances of these donors to the surface determines the spectral energy of the related exciton recombination and thus provide a natural explanation for the unusual broad luminescence of the unstrained NW ensemble.

HL 46: Quantum Dots and Wires: Transport

Time: Wednesday 14:00–17:45 Location: H17

HL 46.1 Wed 14:00 H17

Study of two-Kondo impurities coupled via an open conducting reservoir — •Daniel Tutuc[1], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Feskörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We present measurements on a structure consisting of two quantum dots connected via an open conducting region, in Kondo regime. The sample is created by Local Anodic Oxidation with an AFM on a GaAs/AlGaAs heterostructure with a 2DEG 37nm beneath the surface. The measurements have been performed with the standard lock-in technique, in a dilution refrigerator, at about 200 mK electron temperature. At finite magnetic fields both dots exibit the so-called Kondo chessboard pattern and we investigate the effective interaction between the dots as a function of edge states direction and tunnel coupling to the central region.

[1] N. J. Craig et al., Science 304, 565 (2004)
[2] P. Simon, et al., Phys. Rev. Lett. 94, 086602 (2005)
[3] M. G. Vavilov and L. I. Glazman, Phys. Rev. Lett. 94, 086805 (2005)

HL 46.2 Wed 14:15 H17

Interaction-induced spin selection in quantum dots — •Maximilian C. Rogge[1], Esa Räsänen[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover, Germany — [2]Nanoscience Center, Department of Physics,University of Jyväskylä, FI-40014 Jyväskylä, Finland

We present a combined work of theory and experiment concerning the spectrum of electronic states of a many-electron lateral quantum dot in high magnetic fields. We performed magnetotransport measurements on a quantum dot made with local anodic oxidation and electron beam lithography. Several Coulomb blockade peaks are analyzed in terms of the energetic properties of the involved states. In the $4 > \nu > 2$ regime with two Landau levels (LL), with ν being the filling factor of the dot, a pronounced zig-zag pattern is found. This can roughly be understood with the constant interaction model, that uses the single electron excitation spectrum (Fock-Darwin) plus a constant Coulomb repulsion energy. However, detailed analysis reveals, that this model can only be applied to the data from the zeroth LL with a spin-dependent bimodal structure. Data from the first LL show different behavior without bimodality. To understand this phenomenon, many-electron calculations within spin-density-functional theory were performed. As a result, interaction-induced spin polarization is found in the first LL.

HL 46.3 Wed 14:30 H17

Adiabatic pumping through an interacting quantum dot with spin-orbit coupling — •Stephan Rojek and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CeNIDE, 47048 Duisburg, Germany

We study adiabatic pumping through a two-level quantum dot coupled to two normal leads in the presence of spin-orbit coupling. Varying the two energy levels of the dot periodically in time can generate finite charge and spin currents. To calculate the pumped charge and spin we use a generalization of Brouwer's formula for interacting systems relates the pumped charge to the instantaneous Green's functions of the dot [1]. We calculate the latter by means of an equation-of-motion technique. In order to investigate the influence of Coulomb interaction we study the limits of noninteracting and strongly interacting electrons on the quantum dot. We find that the sign of the pumped charge and spin can change with regard to the spin-orbit coupling strength and we discuss differences between the charge and spin transport characteristics.

[1] J. Splettstoesser *et al.*, Phys. Rev. Lett. **95**, 246803 (2005).

HL 46.4 Wed 14:45 H17

Electron-phonon interaction in a triple quantum dot interferometer — •Fernando Dominguez and Gloria Platero — Instituto de ciencia de materiales de Madrid (ICMM)

In this work we analyze the effect of electron-phonon interaction on the electronic transport through a triple quantum dot in closed loop configuration. We consider that one of the quantum dots contains a mechanical degree of freedom, while the rest are fixed to the electronic leads. Under appropriate energetic conditions and in the absence of the electron-phonon interaction, an electron becomes coherently trapped in the system. As the electron-phonon interaction is switched on, the mechanical degree of freedom interacts with the electronic charge in the oscillating quantum dot. Thus, the interaction acts on the system as a "which path" detector, leading to the destruction of the coherent superposition, i.e., of the dark state, giving rise to current. By means of the Generalized Density Matrix formalism, we calculate the current density and the shot noise.

HL 46.5 Wed 15:00 H17

Electronic and transport properties of Ge nanoparticle pellets structured by focused ion beam — •Andreas Gondorf, Martin Geller, and Axel Lorke — Universität Duisburg-Essen, Duisburg

Semiconductor nanoparticles are of interest for future electronic and optoelectronic devices, especially low cost, flexible, printable electronics. We investigate here the transport properties (charge carrier concentration and mobility) of Ge nanoparticles, which were synthesized in

the gasphase and pressed into pellets. The nanoparticles inside these pellets sinter into a sponge-like structure, that may exhibit unusual magneto-transport properties similar to the strong magnetoresistance observed in nanoporous gold [Fujita, PRL 101, 166601 (2008)]. The measurements are made on directly contacted macroscopic pellets and on Hallbar-microstructures fabricated by a focused ion beam (FIB). In the FIB fabrication process, a lamella is cut out of a pellet and positioned onto a prestructured substrate with metal contacts. The sample is connected with the contacts by deposition of platinum. Finally the disk is etched by FIB into a Hallbar shape. We use I-V and Hall-measurements and find a very weak but measurable Hall-effect and a negative magnetoresistance of about 0.01% at 2.5T. At room temperature, Ge nanoparticles show a charge carrier concentration of about $4{\cdot}10^{14}$ cm^{-3}, comparable to the intrinsic charge carrier concentration in bulk germanium. Ge nanoparticles have a very low mobility of 0.1 cm^2/Vs at 25°C, which is comparable to the mobility of organic semiconductors, so that Ge nanoparticles may be suitable in some applications which are presently based on organic semiconductors.

HL 46.6 Wed 15:15 H17

Spatially resolved flow of ballistic electrons measured by quantized photocurrent spectroscopy — Klaus-Dieter Hof[1], Franz J. Kaiser[2], •Markus Stallhofer[3], Dieter Schuh[4], Werner Wegscheider[4,5], Peter Hänggi[2], Sigmund Kohler[2,6], Jörg P. Kotthaus[1], and Alexander W. Holleitner[1,3] — [1]Fakultät für Physik and Center for NanoScience (CeNS), LMU München — [2]Institut für Physik, Universität Augsburg — [3]Walter Schottky Institut and Physik Department, TUM Garching — [4]Institut für Experimentelle und Angewandte Physik, Universität Regensburg — [5]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland — [6]Instituto de Ciencia de Materiales de Madrid, CSIC, Spain

Quantum point contacts (QPCs) have recently been exploited in very sensitive detection schemes to quantify charge and spin states in nanoscale circuits and to monitor the coherent charge flow in two-dimensional electron gases (2DEGs). Here, we demonstrate the use of GaAs-based QPCs to laterally resolve the ballistic flow of photo-generated electrons in a 2DEG. To this end, electron-hole pairs are optically created in a 2DEG, and the resulting current through an adjacent QPC is measured as a function of the laser spot position. The transmission of photo-generated electrons through the QPC is governed by the quantized energy and momentum values of the electron modes in the QPC. Hereby, the measured photocurrent across the QPC exhibits quantization steps. We observe that photo-generated electrons can ballistically propagate across several micrometers, before they tunnel through the QPC.

HL 46.7 Wed 15:30 H17

Spectroscopy of non-equilibrium charging states of self-assembled quantum dots — •Bastian Marquardt[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimental Physics and CeNIDE, University Duisburg-Essen — [2]Chair of Applied Physics, Ruhr University Bochum

Electron-electron (or hole-hole) interaction in confined electron systems like self-assembled quantum dots (QD) has been a topic of continuing interest for roughly 15 years [1, 2]. The Coulomb repulsion between the charge carriers has dramatic effects on the conductance through a QD, as evidenced, by the so called Coulomb blockade. However, measurements of the QD states without the influence of Coulomb repulsion has not been studied yet. Using, for instance, pulsed time-resolved measurement to prepare a non-equilibrium situation between the QD states and the chemical potential enables us to study dot states in transport measurements without Coulomb blockade. We study charge tunneling of self-assembled InAs QDs through large tunneling barriers resulting in charging times between 1 ms and 100 s. These long times allow us to adjust the chemical potential on time scales much faster than the average charge tunneling time of the dots. This way, non-equilibrium situations can be realized where the chemical potential in the reservoir is higher than all states in the dot. On the basis of the measured transients non-equilibrium dot states can be identified for different applied magnetic fields.

[1] D. Bimberg et al., Quantum Dot Heterostructures (Wiley, Chichester, 1998). [2] D. Reuter et al., Phys. Rev. Lett. 94, 026808 (2005).

15 Min. Coffee Break

HL 46.8 Wed 16:00 H17

High-order cumulants in the counting statistics of asymmetric quantum dots — •Christian Fricke, Frank Hohls, Nandhavel Sethubalasubramanian, Lukas Fricke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Current fluctuations in mesoscopic systems allow to obtain information on transport that is not accessible from the average current alone. Further understanding in electron transport can be gained from higher moments of the transport statistics. With the use of a quantum point contact as a non-invasive charge detector the full counting statistic (FCS) is now experimentally accessible in quantum dot physics. These techniques made the extraction of high-order cumulants possible, revealing an oscillating behavior as function of integration time. The theoretical treatment has shown that these oscillations are a universally expected phenomenon for most physical systems and that in quantum dots they should show up prominently as function of the barrier asymmetry. We carried out FCS measurements on a quantum dot with tunable barrier asymmetry and present the asymmetry dependence of high-order cumulants up to the 15^{th} order.

HL 46.9 Wed 16:15 H17

Quantum Jitter of a single electron source — Adrien Mahé[1], François Parmentier[1], Erwann Bocquillon[1], Jean-Marc Berroir[1], Christian Glattli[1,2], Takis Kontos[1], •Bernard Placais[1], and Gwendal Fève[1] — [1]Laboratoire Pierre Aigrain, ENS, 24 rue Lhomond 75005 Paris, France — [2]Service de Physique de l'Etat Condensé, CEA, 91192 Gif-sur-Yvette, France

Coherent ballistic electronic transport along the quantum Hall edge states of two dimensional electron gases bears strong analogies with the propagation of photons, well illustrated in electronic Mach-Zehnder interferometers. The quantum optic variant would be the realization of Hanbury-Brown and Twiss or Hong Ou Mandel experiments where one or few electrons would be coherently manipulated.

The first step toward this goal has been the realization of a single electron emitter based on fast gating of single quantum dot states [1]. This work addresses the second step by demonstrating measurement of the output correlations in the current generated by the source. The first result is the qualification of the single electron source by the absence of multiple events in the shot noise. The second one is the revealing of quantum fluctuations in the emission time. This "quantum jitter" is a high frequency noise that dominates in single electron sources, and constitutes the basic limitation for a future coherent single electronics.

[1] G. Fève, A. Mahé, J.-M. Berroir, T. Kontos, B. Plaçais, D. C. Glattli, A. Cavanna, B. Etienne, Y. Jin, Science 316, 1169 (2007).

HL 46.10 Wed 16:30 H17

A Single-Electron-Transistor with current gain — Armin C. Welker[1] and •Jürgen Weis[2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergtraße 1, 70569 Stuttgart

Quantum-dot systems are model systems for single-molecule experiments. Here, a new application of a quantum-dot system in electrical transport measurements is presented. The model system, a quantum dot with three leads, is used as a new type of current-gain transistor by using excited states of electron systems inside the quantum dot. We are able to prove experimentally and theoretically for certain cases that with each single-electron exchange with the base lead in fact more than one single-electron transfer is possible from source to drain (current gain).

HL 46.11 Wed 16:45 H17

Electronic Transport in Fully Oxidized Silicon Nanowires — •Mohammad Koleini[1], Lucio Colombi Ciacchi[1], and Marivi Fernandez-Serra[2] — [1]Hybrid Materials Interfaces (HMI), Faculty of Production Engineering and Bremen Center for Computational Materials Science, University of Bremen, 28359 Bremen, Germany — [2]Department of Physics and Astronomy and New York Center for Computational Science, Stony Brook University, Stony Brook, New York 11794-3800, USA

We present the first realistic model of an ulta-thin Silicon Nanowire (SiNW) grown along the <100> crystallographic direction with a natively fully oxidized surface. Ballistic transport in such SiNW has been studied by ab initio modeling, combining density functional theory and nonequilibrium Green's function techniques. A comparison with the pristine SiNW reveals the effect of oxidation on the electronic properties of the wire. The effect of p- and n-type dopants on the conductance

of the oxidized SiNW has been studied extensively. The results indicate a strong coupling between the electronic properties of the dopants and the wire oxide shell, showing the need to explicitly consider the core-shell structure of SiNWs in theoretical transport studies.

HL 46.12 Wed 17:00 H17

Electronic phase coherence in InAs nanowires — •Christian Blömers, Mihail Ion Lepsa, Steffi Lenk, Hans Lüth, Thomas Schäpers, and Detlev Grützmacher — Institute of Bio- and Nanosystems (IBN-1) and JARA - Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich

We report on magnetotransport measurements on InAs nanowires grown by molecular beam epitaxy. Among the III-V semiconductor materials, InAs is particularly interesting because of its low direct band gap and its low effective mass. Additionally InAs is known to show a strong quantum confinement in devices of mesoscopic dimensions. A well known quantum effect revealed by magnetotransport measurements at low temperatures are the universal conductance fluctuations (UCF), resulting from electron interference. By analyzing the UCFs it is possible to draw conclusions about the phase coherence length of the electrons in the device. In the special case of a magnetic field in parallel to the wire, Altshuler-Aronov-Spivak oscillations were found in lithographically defined InAs columns. These oscillations are known to result from the surface 2DEG, which is present in those columns. In contrast the present InAs wires do not show this behavior. The explanation is given in terms of the high density of stacking faults, which were observed in transmission electron microscopy. The stacking faults are due to transitions between wurtzite and zincblende structure. The wurtzite segments are origins of polarization charges which most probably mask the effect of surface states, being the reason for the surface 2DEG.

HL 46.13 Wed 17:15 H17

Aharonov-Bohm phase shift in an asymmetric quantum ring — •S.S. Buchholz[1], S.F. Fischer[1], U. Kunze[1], D. Reuter[2], and A.D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

The phase evolution of the electron wave function can be used to study fundamental interaction effects in quantum coherent transport. Therefore, we investigate a multi-terminal quantum ring which allows phase shift measurements in Aharonov-Bohm (AB) experiments. We focus on non-local measurements in an asymmetric four-terminal electron wave guide geometry [1].

The device was fabricated from a GaAs/AlGaAs heterostructure and is covered with a global Au gate. The quantum ring is linked to two-dimensional reservoirs via quantum wire leads. Transport measurements were performed at 23 mK with lock-in technique. AB resistance oscillations prove coherence in two- and four-terminal probe configurations [1] and obey time reversal symmetry: Two-probe measurements show phase rigidity. The ring's asymmetry allows modulating the phase of the interference pattern electrostatically: Via the gate voltage we can tune the electrons' Fermi wavelength along the unequally long paths and observe a gradual phase shift in the non-local measurement configuration. Numerical results from a time-dependent wave packet approach (see contribution by Ch. Kreisbeck) qualitatively reproduce our results in phase shift, phase jumps and the observation of higher harmonics.

[1] S.S. Buchholz et al., Appl. Phys. Lett. 94, 022107 (2009).

HL 46.14 Wed 17:30 H17

Phase Behavior of Aharonov-Bohm Oscillations in Four-Terminal Nanodevices — •Christoph Kreisbeck[1] and Tobias Kramer[1,2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We discuss recent experiments on four terminal Aharonov-Bohm rings, based on GaAs/AlGaAs heterostructures. The phase of the AB oscillation shows a rich structure with variation of the top gate voltage. Even though the phase should be continuously adjustable in a four terminal setup, strong phase rigidity prevails in the local setup.

To explain this behavior within the Landauer-Büttiker formalism requires to go beyond simplified 1D-models and the scattering matrix in a realistic 2D-setup has to be computed. Provided that we include depletion effects and rounded crossings, we reproduce the experimental observed phase changes and explain the underlying mechanism. As a consequence the phase behavior fundamentally relies on the device geometry. Finite temperature and finite bias voltage does break symmetry in the local setup and the phase rigidity is slightly lifted. We computed the scattering matrix by an efficient time-dependent approach, based on wave packet propagation. Hence, simulation of complicated 4-terminal geometries for a large range of gate voltages have become accessible for the first time.

HL 47: New Materials: mainly thermoelectric and nanomechanical Properties

Time: Wednesday 16:00–17:15 Location: H14

HL 47.1 Wed 16:00 H14

Coulomb gap variable range hopping in graphitized polymer surfaces — •Yuri Koval, Irina Lazareva, and Paul Müller — Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany

Polymer surfaces were graphitized by low-energy ion irradiation. We show that the conductance of the graphitized surfaces gradually increases with the energy of ions and the temperature of irradiation. At rather modest ion energies (∼1000) eV and irradiation temperatures (∼400°C) the transition to a metallic state was observed. We investigated electric transport on the insulating side of metal-insulator transition (MIT). Temperature dependences of conductance and current-voltage characteristics (IVs) at low temperatures were measured and analyzed. We found that electric transport in the graphitized surfaces can be described by 2D Coulomb gap variable range hopping. Similar to low-temperature results in crystalline 2D systems, the pre-factor is temperature independent and has a unique value e^2/h. In the activationless regime of hopping, the pre-factor of IVs has a significantly smaller but also unique value $\sim e^2/5h$. We show that the localization length is constant for all samples. The dielectric constant gradually increases approaching MIT from the insulating side. Due to an extremely high bare density of states, the Coulomb gap persists up to high temperatures. We explain this by a strong inhomogeneity of density of states in the graphitized surfaces.

HL 47.2 Wed 16:15 H14

Type-I clathrate compounds as thermoelectric materials — •Christophe Candolfi, Umut Aydemir, Niels Oeschler, Michael Baitinger, Yuri Grin, and Frank Steglich — Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

In the last decade, huge efforts were devoted to improve the thermoelectric properties of intermetallic clathrates. Their crystal structures are composed of face-condensed polyhedral cages in which metal cations are situated. Cage compounds represent a promising class of material for thermoelectric applications at high temperatures since they usually feature a low thermal conductivity and chemical stability up to 900 K. By changing the chemical composition, the charge carrier concentration can be tuned with the aim at achieving high thermoelectric figure of merits. Here, we present and discuss how this can be realized in some type-I clathrates in the system $Ba_8M_xGe_{46-y}$ (where M is a transition metal) both in the high and low temperature ranges (2 - 700 K).

HL 47.3 Wed 16:30 H14

Thermoelectric properties and electronic structure of NiTSn(T = Ti, Zr, Hf) Heusler compounds. — •S. Ouardi[1], G. H. Fecher[1], B. Balke[1], G. Stryganyuk[1], C. Felser[1], and E. Ikenaga[2] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan

Heusler compounds with 1:1:1 composition attracted attention as potential candidates for thermoelectric applications. Complex $C1_b$ compounds such as NiTiSn are promising n-type thermoelectrical materials. In the present study we have used stoichiometric doping of such compounds to investigate its influence on the transport properties. Our

work focuses on a systematic investigation of pure NiTSn systems and the substituted derivates Ni$T_{1-x}T'_x$Sn (T, T'= Ti, Zr, and Hf). The $C1_b$ structure was verified for all compounds by powder X-ray diffraction. The effect of electron- or hole- doping was studies by electrical conductivity, Seebeck coefficient, and thermal conductivity measurement in the temperature range from 2 K to 300 K using a physical properties measurement system (PPMS). The electronic structure - in particular of the valence band - was studied by photoelectron spectroscopy excited by hard X-ray synchrotron radiation at BL-47XU of SPring-8 (Japan). All experimental findings are well supported by first principle calculations of the electronic structure.

This work was financially supported by the Stiftung für Inovation Rheinland Pfalz.

HL 47.4 Wed 16:45 H14

Modeling Nanomechanical Quality Factors — •Quirin Unterreithmeier, Thomas Faust, and Jörg Kotthaus — Fakultät für Physik and Center for NanoScience (Cens), Ludwig-Maximillians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany

The study of nanomechanical resonant motion is a rapidly advancing field of science with prospects in fundamental science and application. For many aspects, a low mechanical friction (or equally high quality factor) is advantageous. However, the dominant damping mechanism is yet to be known. We present studies on silicon nitride resonators under high tensile stress having high mechanical quality factors. Applying a damping model based on continuum mechanics that assumes a homogeneous friction throughout volume of the resonator, we are able to quantitatively model the quality factors observed in the (room-temperature) experiments.

HL 47.5 Wed 17:00 H14

Crossover between Type II and Type I Alignment in Layered Hybrid Assemblies of CdSe and CdTe Nanocrystals — •Andreas Pöschl[1], Dieter Gross[1], Christian Mauser[1], Andrei Susha[2], Andrey Rogach[2], Enrico Da Como[1], and Jochen Feldmann[1] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität, München, Germany — [2]Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong

Semiconductor nanocrystals (NCs) feature variable band gaps controlled by the quantum confinement. Reducing the size of the NCs increases the band gap. This effect is used to tune layered assemblies of CdSe and CdTe NCs between charge separation and energy transfer processes. Considering the bulk energy levels, CdSe and CdTe exhibit a type II interfaces alignment. Previously, we have shown that assemblies of large CdSe NCs and CdTe NCs provide charge separation processes, investigated by photoluminescence (PL) quenching. In this work the size of the CdSe NCs is varied. Increasing the band gap of the CdSe NCs from 2.4 to 2.7 eV yields a transition from type II to type I interface with CdTe NCs of 2.1 eV band gap. Because of the unfavorable alignment for charge transfer, energy transfer processes from the CdSe to the CdTe NCs are observed by PL spectroscopy. The use of smaller CdTe NCs with 2.2 eV band gap restores the type II alignment. These optical investigations demonstrate a facile method to probe the crossover form type II to type I in NCs assemblies and therefore the relative band alignment.

HL 48: Semiconductor Lasers

Time: Thursday 9:30–12:45 Location: H13

HL 48.1 Thu 9:30 H13

Dynamic Properties of Quantum Dot Semiconductor Optical Amplifiers — •Niels Majer, Miriam Wegert, Kathy Lüdge, and Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate the dynamic properties of quantum dot semiconductor optical amplifiers (QD-SOAs) on the basis of Bloch equations for the coupled interband polarization and carrier dynamics of the QDs along with a travelling wave type field equation for the electric field within the device. The model includes microscopically calculated Coulomb scattering rates in the dynamic equations for the carrier populations of the quantum dots.

Pump-probe simulations using ultrashort input pulses (∼150 fs) give insight into the (ultra-) fast gain recovery dynamics of QD-SOAs, whereas the propagation dynamics of ultrashort input pulses reveals coherent effects such as pulse breakup.

HL 48.2 Thu 9:45 H13

Quantum Dot Based Electro Absorption Waveguide Modulator — •Mirko Stubenrauch, Christian Meuer, Gerrit Fiol, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, EW 5-2, Hardenbergstr. 36, 10623 Berlin, Germany

InAs quantum dot (QD) based electro absorption ridge waveguide modulators (EAM) having different length and layer number are fabricated and tested. The operation wavelength of the devices is around 1.3 μm and the fast change of electro absorption is induced by the Quantum Confined Stark Effect (QCSE). Transmission spectra simulations based on kp-calculations including charge carrier Coulomb interaction predict a QCS shift of 20 nm and an extinction ratio of maximum 35 dB at 10 V reverse bias. These results are compared to experimentally achieved values for maximum absorption edge shift of 15 nm at an applied field of 240 kV/cm, corresponding to 9 V reverse voltage. Transmission power measurements show the highest extinction ratio of 18 dB reached so far for QD devices at a wavelength of 1315 nm. First dynamic scattering parameter measurements using a completely calibrated network analyzer show a maximum 3dB bandwidth of 17 GHz at a wavelength of 1310 nm with an applied reverse bias of 1.5 V. These are promising results for monolithic integration with single mode emitting lasers, e.g. distributed feedback lasers.

HL 48.3 Thu 10:00 H13

Effects of 1st order Coulomb Interaction on the Turn-on Dynamics of Quantum Dot Lasers — •Benjamin Lingnau[1], Kathy Lüdge[1], Eckehard Schöll[1], and Weng Chow[2] — [1]Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Sandia National Laboratories, Albuquerque, New Mexico 87185-1086, USA

We investigate the influence of many-body and nonequilibrium effects on the turn-on dynamics of a quantum dot laser. The interplay of bandgap renormalization, population hole-burning and inhomogeneous broadening is crucial for understanding the dynamics of the turn-on process and gives rise to modifications in relaxation oscillation behaviour. The theory used in the simulations is based on a semiclassical approach, where the laser field and active medium are described by the Maxwell-semiconductor-Bloch equations. Many-body Coulomb effects are described in the screened Hartree-Fock approximation. Carrier-carrier and carrier-phonon collisions are treated within the effective relaxation rate approximation. Inhomogeneous broadenening of the quantum-dot distribution is taken into account. Many-body effects were found to have a large effect on the turn-on dynamics of the laser device and especially on the relaxation oscillations after turn-on. We observe a noticeable increase in oscillation frequency and a stronger damping due to the bandgap renormalization. Furthermore, when changing the width of the inhomogeneously broadened quantum dot distribution, increasing frequencies and more pronounced oscillations for smaller broadening widths are observed.

HL 48.4 Thu 10:15 H13

Charaterization of red VCSELs via S-Parameter Analysis — •Hendrik Niederbracht[1], Marcus Eichfelder[1], Wolfgang Vogel[2], Michael Wiesner[1], Sandra Klinger[2], Robert Rossbach[1], Michael Jetter[1], Manfred Berroth[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, 70550 Stuttgart, Germany — [2]Institut für Elektrische und Optische Nachrichtentechnik, 70550 Stuttgart, Germany

The future optical data transmission via Polymer Optical Fibre needs devices which are able to achieve high modulation frequencies. The ideal candidates for this task are vertical-cavity surface-emitting laser (VCSEL) due to their splendid properties. In this presentation we show small signal modulation measurements examined by the method of scattering (S)–parameter analysis to characterize 660 nm AlGaInP–based VCSELs. Based on S_{11} measurements and an equivalent circuit

model for the VCSEL geometry, device values are revealed. First steps of optimization are shown, allowing a higher modulation frequency, mainly by reducing parasitic pad capacitance. The area surrounding the mesa was reduced and the spatial distance between p– and n–contacts was increased by a thick layer of high dielectric material. The intrinsic response is evaluated through the simulated low pass and the measurement of the $|S_{21}|$–parameter. The difference between single and multiple apertures for current confinement reducing intrinsic capacitance is also part of the presentation.

HL 48.5 Thu 10:30 H13

40 GHz hybrid mode-locking in a monolithic quantum dot laser — •Dejan Arsenijevic, Gerrit Fiol, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, EW 5-2, Hardenbergstr. 36, 10623 Berlin, Germany

The quantum dot mode-locked lasers presented here are processed into ridge waveguide structure from material grown by molecular beam epitaxy and contain 15 stacks of InGaAs/GaAs quantum dots emitting at 1.3 μm. To enhance temperature stability the material is p-doped. The lasers having an overall length of 1 mm are separated into two sections (900 μm gain, 100 μm absorber). For hybrid mode-locking in addition to the DC-biasing of these two sections a RF signal was applied to the absorber. The emitted optical pulses for varying frequency and power of the RF source as well as different heat sink temperatures are analyzed by auto-correlation and electrical spectra measurements. The pulse width ranges from below 2 ps to about 8 ps. Although no change in pulse width is found by switching the operation mode from passive to hybrid mode-locking a decrease in optical timing jitter is observed. The maximum locking range for one operating point is 30 MHz and in addition can be linked to the widths of the pulses. The dependence of the locking range on the RF power is found to be linear. Interestingly the region of hybrid mode locking is asymmetric compared to the passive mode-locked frequency.

HL 48.6 Thu 10:45 H13

Monolithic electro-optically modulated vertical cavity surface emitting laser — •Jan-Hindrik Schulze[1], Tim D. Germann[1], Alex Mutig[1], Alexey M. Nadtochy[1], James A. Lott[2], Sergey A. Blokhin[1], Vitaly A. Shchukin[2], Nikolay N. Ledentsov[2], Udo W. Pohl[1], and Dieter Bimberg[1] — [1]Inst. für Festkörperphysik, EW 5-2, Hardenbergstr. 36, TU-Berlin, 10623 Berlin — [2]VI-Systems GmbH, Hardenbergstr. 7, 10623 Berlin

The steadily growing data traffic requires high speed and low-cost laser diodes. Conventional current modulated vertical cavity surface emitting lasers (VCSEL) are limited in their bit rate due to a quadratic increase in the current density with the bit rate. Monolithically integrated electro-optic modulator (EOM) VCSEL promise to overcome this problem. In this work we demonstrate a GaAs-based 850 nm EOM-VCSEL. The VCSEL is driven continuously while the pulsed light output is generated by reflectivity modulation of the top DBR through an embedded EOM section. A very low modulation voltage ($<$ 2 V) is needed to reach -3 dB extinction ratio enabling the use of such EOM-VCSELs with low power consumption CMOS drivers. Excellent output stability at a significant extinction ratio is demonstrated up to 85°C. A similar extinction ratio was revealed in large-signal modulation experiments at frequencies presently up to 3 GHz. Thus the first high bit rate data transmission by an EOM-VCSEL is demonstrated.

15 Min. Coffee Break

HL 48.7 Thu 11:15 H13

Two-section DBR lasers based on surface defined gratings for high-speed applications — •Sohaib Afzal[1], Florian Schnabel[1], Wenzel Scholz[1], Johann Peter Reithmaier[1], Gadi Eisenstein[2], Amir Capua[2], Evgeny Shumakher[2], Petri Melanen[3], and Ville Vilokkinen[3] — [1]Technische Physik, Institute of Nanostructure Technologies and Analytics (INA), Universität Kassel, 34132, Kassel, Germany — [2]Technion, Electrical Engineering Department. Technion City Haifa 32000, Israel — [3]Modulight Inc. FIN-33720, Tampere, Finland

To realize low-cost high-performance lasers for high-speed optical transmission a new surface-defined grating etching process was developed based on a four gas ICP-RIE etching process, which allow high aspect ratios of $>$ 1:15. The gratings are lithogaphically defined on the sample surface by e-beam lithography, but could be easily adapted by low-cost large volume nanoimprint lithography. The gratings are formed lateral to the ridge in 1st and 2nd order with a trench width of about 120 nm and an etch depth of about 2 um. With this surface defined patterning techique two-section DBR lasers were fabricated on a 1.3 um InP laser material, which exhibit low cw threshold currents down to 8 mA by pumping the grating section at 50 mA (total device length = 900 um). The influence of the grating period and operation temperature on the threshold current and emission wavelength will be discussed. First small signal measurement results show a -3dB bandwidth of 10 GHz with an extrapolated max. bandwidth of about 40 GHz.

HL 48.8 Thu 11:30 H13

Time-resolved studies of a rolled-up semiconductor laser — •Christian Strelow[1], Michael Sauer[1], Sebastian Fehringer[2], Tobias Korn[2], Christian Schüller[2], Andrea Stemmann[1], Christian Heyn[1], Detlef Heitmann[1], and Tobias Kipp[1,3] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg — [3]Institut für Physikalische Chemie, Universität Hamburg

We report on lasing in microtube bottle resonators that are fabricated by the self-rolling mechanism of thin strained semiconductor bilayers. The optical modes are confined by total internal reflection inside the thin walls of the AlGaAs/InAlGaAs microtubes with typically 42 nm wall thickness and about 2.4 μm radius. Constructive interference after a round trip leads to the formation of ring modes. In axial direction a special modulation of the wall thickness, similar to a ridge waveguide, confines the modes on a length of about 1.4 μm. A GaAs quantum well as optical gain material is excited nearly resonantly by sub-picosecond laser pulses. Time-resolved studies on this novel kind of semiconductor laser reveal particularly fast turn-on times and short pulse emission above the threshold, as well as single-mode lasing. We observe a strong redshift of the laser mode during the pulse emission which is compared to the time evolution of the charge-carrier density calculated by rate equations.

HL 48.9 Thu 11:45 H13

InGaN-based greenish seperate confinement heterostructures — •Jakob Ebeling, Timo Aschenbrenner, Christian Tessarek, Stefan Figge, and Detlef Hommel — Institut für Festkörperphysik, Universität Bremen

For opto-electronic applications green laser diodes (LDs) are of great interest. The fabrication of such GaN-based light emitting diodes (LEDs) and LDs however faced different problems ranging from the lack of adequate homoepitaxial substrates to the miscibility gap of InGaN. Recently [1,2] there have been reports of laser diodes based on InGaN quantum wells (QWs) in the green spectral region. In this work the influence of InGaN quantum dots (QDs) on the opto-electronic properties of LDs is discussed in detail. All samples were grown by metal-organic vapour-phase epitaxy on free-standing GaN substrates from Lumilog and the number of QD stacks or QWs was varied. The samples were processed as ridge and deep ridge waveguide structures with different ridge widths and measured by high-resolution X-ray diffraction and electroluminescence, and light-current (L-I) and current-voltage (I-V) characteristics were recorded. A comparison of all different growths and process designs in respect of opto-electronic properties is presented.

[1] D. Queren et al., Appl. Phys. Lett. 94, 081119 (2009).
[2] T. Miyoshi et al., Appl. Phys. Express 2, 062201 (2009).

HL 48.10 Thu 12:00 H13

Exceeding 1 W output power of a red AlGaInP-VECSEL emitting at 665 nm — •Thomas Schwarzbäck, Marcus Eichfelder, Wolfgang-Michael Schulz, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Vertical external cavity surface-emitting lasers (VECSELs) have emerged recently as an important category of power-scalable semiconductor lasers in a wide range of applications in biophotonics, television or projectors and spectroscopy. With usage of external cavities and optical pumping, VECSELs achieve high continuous-wave output power and near-diffraction-limited beam quality with a TEM_{00} Gaussian beam profile.

We present a VECSEL system based on a multi-quantum-well structure with 20 compressively-strained GaInP quantum wells (QWs) for an operation wavelength of around 665 nm. Five QW packages are

placed in $(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}P$ cladding layers in a resonant periodic gain design. Each package consists of four QWs embedded in $(Al_{0.33}Ga_{0.67})_{0.51}In_{0.49}P$ barriers, respectively. The 3λ cavity is fabricated on an $Al_{0.50}Ga_{0.50}As$/AlAs distributed Bragg reflector. By bonding an intra-cavity diamond heatspreader on the chip, continuous-wave operation exceeding 1 W output power is achieved.

We show key parameters like power transfer characteristics, beam profile and spectra of the laser. The measurement of the beam propagation factor is also presented.

HL 48.11 Thu 12:15 H13

Tuning the emission wavelength of interband cascade lasers in the 3-4μm spectral range — •Matthias Dallner[1], Adam Bauer[1], Fabian Langer[1], Marcin Motyka[2], Grzegorz Sek[2], Krzysztof Ryczko[2], Jan Misiewicz[2], Martin Kamp[1], Sven Höfling[1], Lukas Worschech[1], and Alfred Forchel[1] — [1]Technische Physik, University of Würzburg, Röntgen Research Center for Complex Material Systems, Am Hubland, 97074 Würzburg, Germany — [2]Institute of Physics, Wrocław University of Technology, Wybrzeze Wyspiańskiego 27, 50-370 Wrocław, Poland

Interband cascade lasers (ICLs) are a unique type of semiconductor lasers, which is very promising to cover the mid-infrared wavelength range from 3-4μm. In contrast to conventional diode lasers, in ICLs only electrons are injected, although the laser operation is driven by interband transitions. The special broken gap alignment within the active quantum wells (QWs), combined with electronic band gap engineering, allows to achieve the needed population inversion. In addition, ICLs can make use of various active cascades to provide higher gain.

In this work we fabricated and investigated ICLs and reference QWs with regards to the dependence of active QW thickness on emission wavelength. Room temperature operation has been achieved and a emission range between 2.97 to 4.16μm could be covered. An average tuning rate of 0.55μm per monolayer was obtained from photoluminescence and electrically driven ICL device data. This was confirmed by theoretical band structure calculations. Furthermore, a temperature dependent tuning behavior of 1.88nm/K was found.

HL 48.12 Thu 12:30 H13

Efficient modeling of non-equilibrium quantum transport in 3D nanostructures — •Peter Greck, Christoph Schindler, and Peter Vogl — Technische Universität München, Germany

We present non-equilibrium Green's function (NEGF) alculations based on an extension of the standard Büttiker Probe model [1]. Büttiker Probes provide a phenomenological method to model incoherent scattering very efficiently. However, any effects of discrete energy coupling (e.g. by optical phonons) are not captured due to the simple structure of the model. Therefore, devices relying on resonant phonon effects such as THz quantum cascade lasers (QCLs) call for more sophisticated models for the scattering self energies. While the self-consistent Born approximation provides the required accuracy, it is extremely costly in terms of computational resources, especially for 3D nanostructures. We have extended the standard Büttiker Probe model in a way that accurately accounts for optical phonon scattering without losing the computational efficiency and simplicity of the Büttiker Probe model. The method allows one to control the scattering mechanisms individually. This renders realistic quantum transport calculations of 3D nanostructures feasible. We present detailed calculations of mid-infrared quantum cascade structures and compare the results with experimental data as well as with full NEGF results [2]. [1] M. Büttiker, Phys. Rev. Lett. 57, 1761 (1986) [2] T. Kubis, C. Yeh, P. Vogl, A. Benz, G. Fasching, and C. Deutsch, Phys. Rev. B 79, 195323 (2009)

HL 49: Optical Properties

Time: Thursday 9:30–13:00 Location: H14

HL 49.1 Thu 9:30 H14

Quantum confinement effect in prestine and oxygen covered silicon nanocrystals with surface states — •Sudip Chakraborty[1], Subhash V Ghaisas[1], Ch Rajesh[2], and Shailaja Mahamuni[2] — [1]Department of Electronic Science, University of Pune, Pune 411007, India — [2]Department of Physics, University of Pune, Pune 411007, India

Absorption spectra for prestine silicon and oxygen capped silicon nanocrystals (nc) are computed using Time Dependent Local Density Approximation (TDLDA) in the size range 1.0 to 1.5 nm. These clusters show very small Highest occupied Molecular Orbital (HOMO) - Lowest Unoccupied Molecular Orbital (LUMO) gaps. This indicates presence of surface states.The Partial Density Of States (PDOS) for these clusters confirm the presence of surface states when compared to the corresponding ncs with hydrogen passivation. The HOMO-LUMO gaps do not show any size dependence. However the optical absorption gaps show the quantum confinement effect(QCE) for both the types of clusters. The oxygen capped silicon ncs are prepared following the wet chemical route. The optical absorption spectrum of experimentally prepared ncs is compared with the computed one. Experimental results support the theoretical argument explaining the QCE in these clusters.

HL 49.2 Thu 9:45 H14

Finite-difference time-domain simulations of fabricated black silicon nanostructures: Optimal geometries for an antireflective coating — Adam Williamson[1,2] and •Andreas Voerckel[1] — [1]X-FAB Semiconductor Foundries AG, Haarbergstrasse 67 99097 Erfurt, Germany — [2]Technische Universität Ilmenau, Gustav-Kirchhoff-Str. 7, 98693 Ilmenau, Germany

Nano-structured silicon has received a growing and serious amount of interest in industrial technology and university research, particularly in regard to the possibility of such nanostructures in optics, with the primary interest here being black silicon as an anti-reflective coating (ARC) for photodiodes. Current literature now contains a wealth of morphological information to influence structure growth and shape in fluorine-based plasma etching in the presence of oxide-forming or fluorocarbon gas inhibitors [1, 2]. Using the computationally efficient grid-based differential time-domain numerical modeling of the finite-difference time-domain (FDTD) method, approximations to Maxwell's equations are solved to model the optical properties of crystalline black silicon. Multiple geometries, from pillars to more pyramid and needle-like structures, are considered and results are correlated to actual scanning electron microscope (SEM) pictures with corresponding reflection measurements taken in a Cary 5000 UV*VIS spectrophotometer with accompanying integrating (Ulbricht) sphere from 200nm to 800nm to evaluate both diffuse and specular reflection from the silicon surface. Optimal geometries are simulated and the consequences for photodiode applications are discussed.

HL 49.3 Thu 10:00 H14

Disorder in Ga(N,As,P)/GaP MQW structures — •Christian Karcher, Tobias Bertram, Bernardette Kunert, Kerstin Volz, Wolfgang Stolz, Kakhaber Jandieri, Sergei Baranovskii, and Wolfram Heimbrodt — Dept. Physics and Material Sciences Center, Philipps- University of Marburg, Germany

The incorporation of nitrogen into III-V semiconductors has an enormous impact onto the emission characteristics of the host material. We examine these features in pseudomorphically grown multiple-quantum-well heterostructures of the dilute nitride Ga(NAsP)/GaP material system by means of modulated reflectance, photoluminescence- (PL) and PL excitation-spectroscopy. By identifying both the absorption and emission characteristics of the system from 10K up to room temperature, we observe a large stokes shift originating from deep traps formed by nitrogen. The complex temperature behaviour of the resulting emission can be understood in detail by theoretically modelling hopping processes in an exponential distribution of localised states within the band gap. This model explains the s-like temperature shift and the linewidth broadening of the emission as well as the high stokes shift up to room temperature.

HL 49.4 Thu 10:15 H14

Confocal microscopy with cylindrical vector beams and spectroscopy of single silicon nanoparticles — •Anna Chizhik[1], Alexey Chizhik[1], Torsten Schmidt[2], Sebastian Baer[1], Friedrich Huisken[2], and Alfred Meixner[1] — [1]Inst. of physical and theor. Chem.., Univ. of Tuebingen — [2]Lab. Astrophys.,

Group of the MPI for Astronomy at the Inst. of Solid State Phys., Univ. of Jena

Being the paramount material silicon revealed new magnificent outlooks with the development of nanotechnology. During last years the research on silicon nanoparticles has been one of the hottest topics. However, many of their photoluminescence (PL) properties are still unclear. Combining the confocal microscopy, spectroscopy, and cylindrical vector beams (also known as higher order laser modes) we reveal new details of fundamental PL properties of Si/SiO2 core-shell systems and hollow SiO2 shells. We show that the emission from both systems may originate from defects of the SiO2 structure or at the Si-SiO2 interface. This result demonstrates the effect of *break-down* of the quantum confinement in small Si/SiO2 nanoparticles, which limits the PL tunability and thus, applications in Si optical nanostructures, especially in the short wavelength range. Using the technique of cylindrical vector beams we demonstrate that SiO2 nanoparticles and Si/SiO2 nanocrystals, where the PL originates from defects, possess linear transition dipole moment (TDM). Moreover, we precisely determine the 3-dimensional orientation of single nanoparticle TDM and show such dynamical effects as TDM sudden flipping.

HL 49.5 Thu 10:30 H14

Transmission and Reflection Measurements on Rolled-up Microtubes — •Stephan Schwaiger, Markus Bröll, Jochen Kerbst, Jens Ehlermann, Ricardo Costa, Andreas Rottler, Andrea Stemmann, Yuliya Stark, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Strained metal-semiconductor nano layers can be rolled-up into microtubes with a rolled-up carped like shape [1]. The walls of these microtubes represent effective media with anisotropic permittivity. Finite difference time domain simulations show that the microtubes can be used for imaging below the diffraction limit. To characterize the imaging behaviour of the microtubes we performed transmission and reflection measurements. The transmission through the walls of the tubes can be measured by placing a tapered optical single mode fiber inside the microtube. Holes which are prepared into the tip of the fiber by means of focused ion beams act as light emitters illuminating the microtube from the inside. Subsequently the transmitted light is detected by an optical microscope. Comparison of the measurements with calculations using the transfer matrix method show that the walls of the tubes can be described with an effective plasma frequency which can be tuned within the visible and near infrared regime by changing the metal and semiconductor layer thickness ratio [2]. We gratefully acknowledge support by the DFG through GrK 1286 and SFB 508.

[1] V. Ya. Prinz et al., Physica E 6, 828 (2000)
[2] S. Schwaiger et al., Physical Review Letters 102, 163903 (2009)

HL 49.6 Thu 10:45 H14

FIB implantation induced site-selectively grown self-assembled InAs QDs in a light emitting μ-diode — Minisha Mehta[1], •Cedrik Meier[1], Dirk Reuter[2], Andreas D. Wieck[2], Stefan Michaelis de Vasconcellos[2], Tim Baumgarten[1], and Artur Zrenner[1] — [1]Physics Department, University of Paderborn, Paderborn , Germany — [2]Applied Solid State Physics, Ruhr University of Bochum, Bochum, Germany

We present an approach for fabrication of intentionally positioned epitaxial InAs QDs in a micron sized light emitting diode. For site-selective growth, a combination of molecular beam epitaxy (MBE) and focused ion beam (FIB) implantation technology in an all-ultra-high-vacuum (UHV) setup has been employed. Single dot occupancy of almost 55 % on FIB patterned nano-depressions was successfully achieved. Thereafter, carrier injection and subsequent radiative recombination from the positioned InAs/GaAs self-assembled QDs was investigated by embedding these QDs in the intrinsic part of a GaAs-based micron sized p-i-n junction device. Few or single dot are expected to be electrically addressed in these devices. We report results from electroluminescence (EL) measurement which proves the single dot characteristics of our device. The EL spectra consist of sharp emission lines and their dependence on injection current shows linear behavior for exciton and quadratic behavior for biexciton recombination. Furthermore, estimation of built-in dipole moment in InAs quantum dots due to stark shift in EL spectra will be given. Financial support by the BMBF via the NanoFutur grant 03X5509-NanoPhox and the NanoQuit program.

15 Min. Coffee Break

HL 49.7 Thu 11:15 H14

Optical and electrical properties of metal-insulator-semiconductor devices with stepped insulator layer — •Wolfgang Brezna[1], Jürgen Smoliner[1], Kevin Stella[2], Domocos Kovacs[2], and Detlef Diesing[2] — [1]Institut für Festkörperelektronik, Technische Universität Wien — [2]Institut für Physikalische Chemie, Universität Duisburg Essen

A preparation procedure based on localized electrochemical oxidation unites multiple metal-insulator-semiconductor (MIS) junctions (also arrays) in a single device. The "stepped-MIS" enables a comparative study of several MIS junctions of different oxide thicknesses on one silicon wafer. We present a Si(n-type)-SiO_x-Au four-step device with oxide thicknesses of 0, 1, 2.5, and 4 nm. Each step is partially covered with a 20 nm thick Au-electrode. The samples are characterized by internal photoemission using variable wavelengths (300 -1600 nm) and capacitance - voltage experiments. The "1 nm" junction shows an increased photo-sensitivity compared to the "0 nm" junction (MS system). The internal photoemission drops by two orders of magnitude when increasing the oxide thickness from 1 to 4 nm. The photoemission is increased by two orders of magnitude, when the sample is biased by 1 Volt in the depletion region (reverse voltage direction).

HL 49.8 Thu 11:30 H14

Optical characterization of $AgGaSe_2$ thin films grown by Chemical Close Spaced Vapor Transport (CCSVT) — •Christoph Merschjann[1], Barys Korzun[1,2], Anastasia Karkatzinou[1,3], Thomas Schedel-Niedrig[1], and Martha Christina Lux-Steiner[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany — [2]Scientific-Practical Materials Research Centre of NAS of Belarus, Minsk, Belarus — [3]National Technical University of Athens, Athens, Greece

Thin films ($d \approx 3\,\mu$m) of n-type chalcopyrite $AgGaSe_2$ were successfully grown on glass and glass/molybdenum substrates using the technique of Chemical Close Spaced Vapor Transport (CCSVT). Scanning electron microscopy of the prepared layers shows a morphology typical for polycrystalline chalcopyrites. The electronic properties of the films are investigated by means of optical transmission/reflection and photoluminescence spectroscopy. While the absorption spectra of the films exhibit clear and distinct bandgaps, their photoluminescence comprises various unreported emission peaks, thus pointing to a rich intrinsic defect structure.

The results are compared to those published for single-crystalline $AgGaSe_2$, and possible consequences for the application of this material as thin-film solar cell absorber layer are discussed in the presentation.

HL 49.9 Thu 11:45 H14

Optical properties of high-quality cubic AlN, GaN, AlGaN and AlN/GaN MQWs grown on 3C-SiC — •Marcus Röppischer[1], Christoph Cobet[1], Norbert Esser[1], Georg Rossbach[2], Rüdiger Goldhahn[2], Martin Feneberg[3], Benjamin Neuschl[3], Klaus Thonke[3], Thorsten Schupp[4], Klaus Lischka[4], and Donat As[4] — [1]ISAS - Institute for Analytical Sciences, 12489 Berlin — [2]Institut für Physik, Technische Universität Ilmenau, 98684 Ilmenau — [3]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [4]Department Physik, Universität Paderborn, 33098 Paderborn

It was recently demonstrated, that the quality of zincblende group-III nitrides can be considerably improved if bulk 3C-SiC(001) is used as the substrate for the deposition of the films by molecular beam epitaxy. For example, phase-pure cubic GaN and AlN has been achieved, and intersubband absorption of short-period GaN/AlN MQWs in the infra-red was demonstrated. Despite this progress, fundamental optical properties of these materials have not been reported so far. In this contribution, we present a comprehensive characterization of cubic AlN, GaN, AlGaN and related MQWs. The shape of the dielectric functions (DF) from 0.56 eV up to 20 eV, as obtained by ellipsometry, as well as photoreflectance (PR), photo- (PL) and cathodoluminescence (CL) spectra will be discussed in detail.

HL 49.10 Thu 12:00 H14

Longitudinal-transverse splitting of individual excitonic polaritons in ZnO derived from ellipsometry — •Munise Cobet[1], Christoph Cobet[2], Markus R. Wagner[1], Norbert Esser[2], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin — [2]ISAS- Institute for

Analytical Sciences, 12489 Berlin

The complex dielectric tensor of ZnO in the regime of the excitonic transitions is determined with ellipsometry and analyzed concerning the quantization of the electromagnetic field in terms of coupled polariton-eigenmodes. Negative sections in the real part indicate the significant formation of polaritons for the dipole-allowed excitons of the three upper valence-bands $\Gamma_7, \Gamma_9, \Gamma_7$. The transverse-longitudinal splittings which separate the upper polariton branch from the lower branch are deduced precisely for each subband and for different strain levels. Mainly for $\mathbf{E}\|c$, additional absorption peaks are observed at the longitudinal B-exciton and closely above. One is considered to be a mixed-mode and the other is seen as a consequence of interference effects in an exciton free surface layer which is also visible in Reflectance Anisotropy Spectroscopy (RAS). Furthermore, the effect of d-level-hybridization on valence-band-symmetries is evaluated by the effective number of electrons n_{eff} in high energy data between 3 and 32 eV. CdS polaritonic spectra were also measured as a reference and further support the inversed ordering of valence bands (negative spin-orbit splitting) in ZnO.

HL 49.11 Thu 12:15 H14

Near band edge luminescence of ZnN thin layers — •Ronny Kirste[1], Jebreel M. Khoshman[2], Martin E. Kordesch[3], Markus R. Wagner[1], Jan-Hindrik Schulze[1], Gordon Callsen[1], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, TU Berlin, Berlin, Germany — [2]Al-Huessin Bin Talal University, Ma-an, Jordan — [3]Department of Physics and Astronomy, Ohio University, Athens, OH 45701, United States

The novel material ZnN may help to understand the nitrogen doping in ZnO. Additionally, ZnN is a possible candidate for optical devices like hot and cold mirrors. However, nearly none of the basic physical properties are known, so far. Even the band gap of ZnN is still under discussion. In this contribution we present PL measurements for 200nm thick ZnN samples grown on SiO2 via RF sputtering. The successful ZnN growth was confirmed by XRD. PL measurements in different ambient gases indicate that the low energy signal between 2.0 and 3.0 eV which sometimes is attributed to ZnN is indeed related to surface oxygen. On the other hand a high energy peak at 3.41 eV arises, which is attributed to the ZnN layer. Temperature dependent measurements were performed revealing a shift of this peak from 3.41 eV at 4.2 K to 3.44 eV at room temperature. Finally, time resolved measurements were performed in order to understand the origin of the high energy signal.

HL 49.12 Thu 12:30 H14

Spin induced second harmonic generation in europium chalcogenides — Benjamin Kaminski[1], •Marco Lafrentz[1], Roman V. Pisarev[2], Dmitri R. Yakovlev[1,2], Victor V. Pavlov[2], Volodya A. Lukoshkin[2], Andre Henriques[3], Gunther Springholz[4], Günther Bauer[4], Eduardo Abramof[5], Paulo H. O. Rappl[5], and Manfred Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Instituto de Fisica, Universidade de Sao Paulo, 05315-970 Sao Paulo, Brazil — [4]Institut für Halbleiter- und Festkörperphysik, Johannes Kepler Universität Linz, 4040 Linz, Austria — [5]LAS-INPE, 12227-010 Sao Jose dos Campos, Brazil

The second harmonic generation (SHG) in Europium chalcogenides EuX (X=O, S, Se, and Te) is fordbidden in the electric dipole and the electric quadrupole approximations due to the centrosymmetrical crystal lattice and the electronic band structure with an odd parity 4f-5d band gap transition. However we have found SHG signals in the vicinity of the band gap of 2.2-2.4eV in EuTe and EuSe in external magnetic fields. Further magnetic field and temperature investigations revealed that the SHG signals are induced by a ferromagnetic spin component, which strongly enhances the magnetic-dipole transition. This new type of spin induced susceptibility opens access to various classes of centrosymmetric magnetic materials by second harmonic generation spectroscopy.

HL 49.13 Thu 12:45 H14

Trionic Optical Potentials for Charge Carriers in Semiconductors — •Martin Schuetz, Michael G. Moore, and Carlo Piermarocchi — Michigan State University, East Lansing, Michigan, USA

Optical trapping of neutral particles has led to remarkable advances in precision measurement, quantum information, and addressing fundamental longstanding questions in condensed matter physics. Despite recent advances in the optical and electronic control in semiconductor systems, a similar laser-induced technique to trap and manipulate charged carriers in semiconductor devices has not yet been investigated. In this talk, we will propose analogues optical trapping potentials for charge carriers embedded in a semiconductor quantum well by driving the trion resonance with intense, detuned laser light. Accordingly, the Stark energy is modified in proportion to the light intensity at the carrier location, which serves as a source of mechanical potential energy for the carrier. We show that this novel trion-mediated potential exhibits a non-local character, but can confine carriers at the lengthscale of optical wavelengths.The model is extended to the new paradigm of a spin-selective carrier lattice in a true Solid State environment which is potentially much simpler to engineer and control than similar lattices in AMO physics. Our results suggest the possibility of new single-carrier semiconductor devices with promising applications in quantum information processing, and exploring the physics of interacting electrons in the presence of a periodic potential readily controllable in space and time.

HL 50: Graphene and Carbon Nanotubes

Time: Thursday 9:30–12:15 Location: H15

HL 50.1 Thu 9:30 H15

Electronic properties of twisted graphene monolayers — •Hennrik Schmidt, Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We investigate the transport properties of two stacked graphene monolayers with a rotational stacking fault in respect to Bernal stacking. Using micromechanical cleavage of graphite as preparation methode, flakes of different thickness, also including folded samples, are deposited on top of a silicon wafer with a 330 nm thick silicon oxide. This folded monolayer graphene forms a system of two very closely spaced layers, decoupled due to the misorientation. Magneto–transport measurements on this decoupled monolayers conducting in parallel are performed variing perpendicular applied magnetic field, backgate voltage and temperature. From the Shubnikov–de Haas oscillations, carrier densities are obtained, being different for the two layers due to screening. Mobilities and scattering times are calculated for both layers and exhibit significantly higher values in the top layer, indicating weaker substrate influence. From the temperature dependence of the Shubnikov–de Haas oscillations, the cyclotron masses are obtained, yielding higher values than for a single monolayer. These masses correspond to reduced Fermi velocities of down to $0.66{\cdot}10^6 m/s$, being consistent with theory.

[1] H. Schmidt, T. Lüdtke, P. Barthold, E. McCann, V. I. Fal'ko, and R. J. Haug, Appl. Phys. Lett. 93, 172108 (2008)

HL 50.2 Thu 9:45 H15

What's the color of graphene ? Black and dark or white and bright ? — •Rainer Stöhr[1], Roman Kolesov[1], Fedor Jelezko[1], Jens Pflaum[2], and Jörg Wrachtrup[1] — [1]3rd Physics Institute, Stuttgart University — [2]Julius-Maximilians-University of Würzburg, Experimental Physics VI and Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern)

In this contribution, we report on the first, to our knowledge, study of non-linear optical properties of graphene and thin graphite flakes. We particularly focus on graphene under picosecond pulsed infrared excitation yielding to a spectrally broad non-linear upconverted luminescence. Several key experiments are discussed to illustrate its characteristics and to clarify its nature. Comparing the effective non-linear coefficient d_{eff} of that process with that of other highly non-linear materials shows that graphene reveals extraordinary performance in terms of its non-linear optical properties. Through rigorous study of

this upconverted luminescence as a function of the number of graphite layers, incident laser power and substrate material we introduce a new and superior tool for imaging and quantifying single and multilayered graphene flakes. Comparing this new imaging method with standard techniques like atomic force microscopy and Raman spectroscopy will evidence its excellent properties in terms of imaging quality and the unambiguous thickness determination of multilayer graphene flakes up to twenty layers.

HL 50.3 Thu 10:00 H15

Photon helicity driven electric currents in graphene — •J. Karch[1], P. Olbrich[1], M. Schmalzbauer[1], Ch. Brinsteiner[1], J. Eroms[1], U. Wurstbauer[1], M.M. Glazov[2], S.A. Tarasenko[2], E.L. Ivchenko[2], D. Weiss[1], and S.D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

We report on the observation of photon helicity driven photocurrents in graphene. The currents are generated in single layer graphene by terahertz radiation from a cw molecular gas laser operating at a wavelength of 118mkm. The photocurrents are measured at normal incidence and reverse their signs upon reversing the radiation helicity. Besides a photon helicity dependent current we also observe a photocurrent in response to linearly polarized radiation. The microscopic mechanisms governing these effects are discussed. The in-plane photocurrents induced by normal incidence of radiation are forbidden by symmetry in an ideal infinite graphene structure. The appearance of such currents are an evidence for a symmetry reduction, for instance, caused by the shape asymmetry of the real finite-size sample, which results in the edge photogalvanic effect. The helicity-dependent and -independent signals demonstrate also a strong dependence on the light incidence angle, i.e. there are remarkable contributions to the photocurrent being odd in the incidence angle. These effects can be attributed to currents in the bulk of the sample and can be described by the circular photon drag effect stemming from the transfer of the photon momentum to the electron subsystem in graphene.

HL 50.4 Thu 10:15 H15

Electronic structures and screening effects in bilayer graphene nanoribbons — •Hengyi Xu[1], Thomas Heinzel[1], and Igor Zozoulenko[2] — [1]Heinrich-Heine-Universität, Düsseldorf — [2]Linköping University, Sweden

Graphene is considered as a promising material for future microelectronics in which the externally controllable of the resistance is crucial. To achieve this purpose, a number of mechanisms to induce an energy gap in single-layer graphene are proposed. Graphene bilayers, however, provide an alternative way to realize this task. Here, we study the electronic properties of bilayer graphene nanoribbons in the presence of a single gate using the tight-binding approach. The Coulomb interactions are incorporated in a self-consistent way within the Hartree approximation. We calculate the density and Hartree potential profiles and compare them with those of the single-layer graphene. It is shown that the fluctuations of the density and potential of bilayers are suppressed and their values decrease due to the Coulomb interaction between layers in contrast to the single-layer graphene. For sufficient thin dielectrics and high external voltages, the potentials of graphene layers diverge clearly and the differences grow linearly as gate voltages increases. This potential difference results in the electron-hole asymmetry of electronic spectrum and energy gaps around the neutrality point in the otherwise metallic graphene bilayers. The sizes of energy gaps are studied as a functions of external gate voltages. The relevant electrostatics of double- and single-gate geometries of bilayer is also discussed.

HL 50.5 Thu 10:30 H15

Inter-valley plasmons and local-field effects in graphene — •Sergey Mikhailov[1] and Timur Tudorovskiy[1,2] — [1]Institute of Physics, University of Augsburg, Germany — [2]Department of Physics, Philipps-University of Marburg, Germany

We develop a theory of the linear electromagnetic response of graphene to a scalar-potential field taking into account local field effects [1]. The electromagnetic properties of graphene are characterized by an infinite dielectric matrix over reciprocal lattice vectors. The spectrum of collective excitations (plasmons) is then determined by the determinant of this matrix. We have calculated the dielectric matrix and the spectrum of plasma waves in graphene using the tight binding approximation.

In the long-wavelength limit (the plasmon wavevector is small as compared to the inverse lattice constant) our results reproduce those obtained in the Dirac model [2]. For the wavevectors close to the corners of the hexagon-shaped Brillouin zone we have found (arXiv:0910.2163v1) new low-frequency two-dimensional plasmon modes with a linear spectrum. These intra-band inter-valley plasmons are related to the electronic transitions between the two nearest Dirac cones in the electronic Brillouin zone. Their group velocity exceeds the Fermi velocity of graphene electrons and their Landau damping vanishes at zero temperature.

This work was supported by the Deutsche Forschungsgemeinschaft.

[1] S. L. Adler, Phys. Rev. 126, 413 (1962)

[2] B. Wunsch et. al., New J. Phys. 8, 318 (2006); E. H. Hwang and S. Das Sarma, Phys. Rev. B 75, 205418 (2007)

15 Min. Coffee Break

HL 50.6 Thu 11:00 H15

Hysteresis in the Field Effect of Bilayer Graphene at Low Temperatures — •Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We present transport measurements on single crystal bilayer graphene at low temperatures down to 1.5 K. In the field effect a strong hysteresis is observed. The bilayer graphene is deposited via micromechanical cleavage on top of a 265 nm SiO_2/Si substrate. Using standard e-beam lithography the device is structured and leads are evaporated to the device (Ti/Au). As the field effect is measured at T=1.5 K in a four-terminal setup the neutrality point varies in dependence of the direction the back-gate voltage is swept. This splitting in the neutrality points (hysteresis) changes with different sweeping rates. At the lowest rate (6.6 mV/s) the splitting is almost zero, whereas it rises with faster rates. By applying a perpendicular magnetic field to the device the hysteresis changes dramatically. We attribute this behaviour to molecular adsorbates which act as charge traps.

HL 50.7 Thu 11:15 H15

Phase coherent transport in graphene nanoribbons — •Silvia Schmidmeier, Daniel Neumaier, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

Quantum interference effects result in quantum corrections of the conductivity. One of these corrections, which results from interference of electron waves that are scattered by disorder and form closed trajectories, cause a decrease of conductivity and is well-known as weak localization. Another correction of the conductivity is due to universal conductance fluctuations, which appear when the phase coherence length is comparable to the sample length.

Here we investigate electronic transport in graphene nanoribbons (GNR). The lateral confinement of the charge carriers in the quasi one-dimensional ribbons creates an energy gap near the charge neutrality point, where the gap depends on the width of the GNR. The GNRs were fabricated by electron beam lithography and plasma etching techniques. Widths of 50nm were achieved. We measured the magnetoconductance in a perpendicular magnetic field for different temperatures down to 20mK. These measurements allowed us to determine the phase coherence length both from weak localization as well as from the amplitude of the universal conductance fluctuations. At mK temperatures the phase coherence length exceeds the lateral dimensions of the GNR, indicating that etching does not destroy the phase coherent properties of the sample.

HL 50.8 Thu 11:30 H15

Magnetotransport behaviour of Graphene on GaAs — •Ulrich Wurstbauer, Ursula Wurstbauer, Jonathan Eroms, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

The influence of the substrate on the transport properties of graphene generated recently some interest. To clarify the role of the underlying substrate, we perform (magneto)-transport experiments of graphene and few-layer graphene on (001)-GaAs substrates, grown by molecular beam epitaxy. The graphitic flakes on GaAs were detected and their morphology was characterized by scanning electron and atomic force microscopy.

We found that graphene follows the curvature of the sustaining substrate very closely. Low-temperature transport measurements of graphene on these substrates reveal a conventional electric field dependence indicated by a resistance maximum at the charge neutrality

point. It turns out that the intrinsic doping on GaAs substrates is always hole like. Magnetotransport measurements in the low-field region display a superposition of universal conductance fluctuations and weak localization, both more pronounced on GaAs substrates than on SiO_2 and visible up to 75 K. Additionally, in the high field region Hall-effect and Shubnikov-de Haas oscillations were observed indicating quantized transport.

HL 50.9 Thu 11:45 H15

Time-resolved ultrafast photocurrent spectroscopy using THz stripline circuits on carbon nanotubes — •Leonhard Prechtel[1], Li Song[2], Stefan Manus[2], Dieter Schuh[3], Werner Wegscheider[3,4], and Alexander Holleitner[1,2] — [1]Walter Schottky Institut and Physik Department, TUM Garching, Germany — [2]Fakultät für Physik and Center for NanoScience (CeNS), LMU München, Germany — [3]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [4]Laboratorium für Festkörperphysik, HPF E 7, ETH Zürich, Switzerland

The exciton dynamics in carbon nanotube devices are typically detected in a time-resolved way by optical techniques such as the transient absorption technique and the time-resolved photoluminescence spectroscopy. Both methods focus mainly on the dynamics of charge carriers within carbon nanotubes. Many questions remain concerning the separation and the transport of photo-generated charge carriers to source and drain leads. We address these questions by a novel ultrafast photocurrent spectroscopy, which is based on a common pump-probe technique. The experimental setup with a picosecond time-resolution will be introduced, and first results of the time-resolved photocurrent of carbon nanotubes will be shown. We will discuss polarization and charge separation effects within the carbon nanotubes as well as the influence of hot phonons, the bath temperature, and the bias voltage on the photocurrent across carbon nanotubes.

HL 50.10 Thu 12:00 H15

Low-temperature transport through suspended single-wall nanotube resonators — •Daniel Schmid, Dominik Preusche, Christoph Strunk, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Suspended carbon nanotubes not only present fascinating electronic properties, but also provide excelling high-frequency and low-dissipation mechanical resonators. In addition, recent work has shown direct strong interaction between electronic tunneling and mechanical motion in the Coulomb blockade regime. We present results on transport through such nano-electromechanical devices at ultra-low temperature, using a recently developed technique to detect the nanomechanical motion in dc current signals. Different contact metals are discussed for their influence on electronic transport and their suitability.

HL 51: Invited Talk: F. Henneberger

Time: Thursday 9:30–10:00 Location: H17

Invited Talk HL 51.1 Thu 9:30 H17

All-epitaxial inorganic/organic semiconductor hybrid heterostructures — •Fritz Henneberger — Humboldt-Universität zu Berlin, Institut für Physik, Deutschland

This talk summarizes recent efforts to fabricate hetero- and nanostructures based on ZnO and various conjugated organic materials as well as to tailor their electronic and optical properties. Growth by molecular beam epitaxy of both material components ensures well-defined interfaces and highest structural quality. The relevant growth mechanisms up to the level of organic/inorganic superstructures and the interfacial energy structure including *band-gap* engineering through molecular morphology are discussed. Direct electronic coupling of the fundamental excitations (Frenkel and Wannier-Mott excitons) across the interface is achieved with coupling constants on the meV-energy scale. Efficient nonradiative energy transfer reducing, e.g., markedly the organic lasing threshold, charge separation at the interface, and inorganic/organic pn-junctions are also demonstrated.

HL 52: Heterostructures

Time: Thursday 10:00–13:00 Location: H17

HL 52.1 Thu 10:00 H17

THz Radiation Induced Ratchet Effects in Heterostructures with a Lateral Periodic Potential — •P. Olbrich[1], J. Karch[1], J. Kamann[1], E.L. Ivchenko[2], R. Ravash[1], T. Feil[1], S.N. Danilov[1], J. Allerdings[1], D. Weiss[1], D. Schuh[1], W. Wegscheider[1], and S.D. Ganichev[1] — [1]THz Center, University of Regensburg, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

We report on the observation of the Seebeck ratchet effect measured in semiconductor heterostructures with a one-dimensional lateral potential excited by terahertz (THz) radiation [1]. The one-dimensional grooves in the cap layer obtained by electron beam lithography and subsequent reactive ion etching result in a lateral periodic potential acting on the two dimensional electron gas (2DEG). The photocurrent generation is based on a phase shift which occurs due to the spatially periodic in-plane potential and the spatially modulated light, affecting the local temperature. In addition to the polarization-independent current known as the Seebeck ratchet effect [2], we observed two further contributions being sensitive to the helicity and to the linear polarization of the exciting THz radiation. The effects strongly depend on the symmetry of the one-dimensional lateral potential and its orientation in respect to the crystallographic axes. We show the experimental data described by a microscopic picture and the theoretical analysis, expanding the one of Ref. [2] to the case of polarized radiation.

[1] P. Olbrich et al., *Phys. Rev. Lett.* **103**, 090603 (2009)
[2] Y.M. Blanter, M. Buettiker, *Phys. Rev. Lett.* **81**, 4040 (1998)

HL 52.2 Thu 10:15 H17

Bandpass Switching in an Optical Microcavity by a Picosecond Acoustics — Thorsten Berstermann[1], •Christian Brüggemann[1], Michael Bombeck[1], Andrey V. Akimov[2,3], Dimitri R. Yakovlev[1,3], Carsten Kruse[4], Detlef Hommel[4] und Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44227 Dortmund, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [3]A. F. Ioffe Physical Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]Institut für Festkörperphysik, Abteilung Halbleiterepitaxie, Universität Bremen, D-28359 Bremen, Germany

We present a new experimental approach for the energy modulation of the cavity mode of a semiconductor optical Bragg microcavity, that can be considered as an optical bandpass. This is accomplished by the application of picosecond strain pulses. The strain pulses are excited in a 100 nm Al thermoelastic transducer, evaporated on the opposite site of 100 μm GaAs substrate, by 100 fs (800 nm) laser pulses. They get injected into the substrate and travel towards the cavity. When the strain pulse hits the bragg structure, the layers and interfaces are shown to be significantly altered by the displacement of the interfaces and the photoelastic effect. The resulting energy modulation of the confined cavity mode is detected in reflection geometry, by white laser pulses, generated by the same source as the excitation beam on the Al transducer. This modulation is shown to be in the order of the spectral width of the cavity mode.

HL 52.3 Thu 10:30 H17

Crystal structure and dielectric function of $BaTiO_3$/ZnO heterostructures with applied electric bias — •Tammo Böntgen, Stefan Schöche, Rüdiger Schmidt-Grund, Chris Sturm, Mathias Brandt, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universtät Leipzig, Institut für Experimentelle Physik

II, Linnestr. 5

The orientation of the ferroelectric polarization of $BaTiO_3$ (BTO) in heterostructures composed of a BTO layer and a conductive ZnO layer, exhibiting a non-switchable spontaneous polarization, can be controlled by an applied electrical bias giving rise to a persistent change in the complex dielectric function (DF). We present first measurements of the DF of epitaxial perovskite BTO/ZnO heterostructures and its change under the effect of an applied electric field. In addition we show detailed investigations of the structural quality and the surface morphology measured by X-Ray diffraction (XRD) and atomic force microscopy. The DF is determined by means of spectroscopic ellipsometry (SE). The SE data are analyzed by a layer-stack analysis. The DF of the different layers were modeled with parameterized model DF and the energies of band-to-band transitions as well as the refractive index spectra were derived.

The interest in the optical properties of BTO and BTO heterostructures is based on its switchable ferroelectric properties, which make it a suitable material for application in e.g. thin film capacitators, nonvolatile memory or electronic switchers for optical signals[1].

[1] V.M. Voora et al., App. Phys. Lett. **95**, 082902 (2009)

HL 52.4 Thu 10:45 H17

Extraordinary metastabilities in a magnetic two-dimensional hole systems — •Ursula Wurstbauer[1,2], Cesary Śliwa[3], Dieter Weiss[2], Wolfgang Hansen[1], Tomasz Dietl[3], and Werner Wegscheider[2,4] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [3]Institute of Physics, Polish Academy of Sciences, Poland — [4]Solid State Physics Laboratory, ETH Zurich, Switzerland

Magnetotransport experiments on inverted manganese modulation doped compressively strained InAs quantum well structures reveal strong localization effects in coexistence with typical quantized transport phenomena in a two-dimensional charge carrier system. Here, manganese plays a dual role: it acts as an acceptor and additionally provides a localized spin of 5/2. Peculiarities of the MBE growth lead to a broadening of the doping layer resulting in a certain amount of Mn inside the channel hosting the two-dimensional holes. This phenomenon causes a hysteretic magnetic field driven metal to insulator transition with abrupt resistance changes over several orders of magnitude. The novel metastable insulator phase is a non-polarized state and originates from a large magnetic anisotropy of the heavy holes, coupled to the parent Mn acceptors by strong p-d exchange interaction. As a result, the spin relaxation of individual bound holes is remarkably enhanced and exceeds several hundreds of seconds. The influences on field-induced delocalization and extended relaxation of the holes will be discussed.

15 Min. Coffee Break

HL 52.5 Thu 11:15 H17

Derivation of AlN/GaN band offsets from GW superlattice band structures — •Chandrima Mitra, Christoph Freysoldt, and Joerg Neugebauer — Max-Planck-Institut für Eisenforschung GmbH, Dusseldorf, Germany

Band offsets at heterojunctions are key parameters for the design of modern electronic devices. In calculating these parameters the standard approach is to use density functional theory (DFT). Since DFT is known to underestimate band gaps, a constant 'scissor' shift is added to match the experimental band gap. However, in doing so it is implicitly assumed that the valence band offsets can be accurately predicted within the framework of DFT. In this context a more reliable approach could be many body perturbation theory in the GW approximation which is known to produce band gaps in good agreement with experimental values. A straightforward approach would be to compare absolute GW corrections at the valence band position and add them on the DFT computed values. However, the reliability and transferability of absolute GW corrections is a delicate issue. In order to circumvent it, we perform a GW band structure calculation on a superlattice of two semiconductor materials. We demonstrate our approach for the AlN/GaN interface and analyse the GW corrections to the band offsets.

HL 52.6 Thu 11:30 H17

Theory of reduced built-in polarization in nitride-based [0001] **quantum dots** — •Stefan Schulz[1] and Eoin P. O'Reilly[1,2] — [1]Tyndall National Institute, Lee Maltings, Cork, Ireland — [2]University College Cork, Physics Department, Cork,Ireland

For energy-efficient solid state lighting, InGaN systems are promising candidates since the assistance of phosphor is not required for a white light source [1]. However, the emission efficiency of *c*-plane InGaN quantum wells (QWs) drops significantly when going to thicker QWs and/or higher indium content and therefore to longer wave length. This behavior is attributed to the strong electrostatic built-in field in nitride-based heterostructures grown along the *c*-direction.

Here, we use a surface integral method [2] to determine the polarization potential in QDs and QWs grown along the *c*-direction. We focus our attention in particular on InGaN nanostructures. Our analysis of the behavior of the electrostatic potential in these systems reveals that the field in QDs is strongly reduced compared to a QW of the same height. This reduction of the built-in field originates from two effects (i) a reduction of the [0001] surface area and (ii) strain redistributions in the QD system. The analysis is carried out for different QD geometries. Furthermore, because of the reduction of the built-in field in a QD compared to a QW of the same composition and height the indium content in the dot can be increased considerably for a fixed field value.

[1] C. J. Humphreys, MRS Bulletin **33**, 459 (2008)
[2] D. P. Williams *et al.*, Phys. Rev. B 72, 235318 (2005)

HL 52.7 Thu 11:45 H17

Characterization of catalytic nanoparticle-semiconductor heterostructures by XPS and cyclic voltammetry — •Susanne Schäfer[1], Sonja Wyrzgol[2], Ian Sharp[1], Mehdi Kashani[1], Johannes A. Lercher[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Catalysis Research Centre, Technische Universität München, Lichtenbergstr. 4, 85747 Garching, Germany

GaN is investigated as a promising material for the electronic control of catalytic reactions via platinum nanoparticles. For all experiments platinum nanoparticles were applied to MOCVD- or MBE-grown GaN substrates by spin coating or physical vapour deposition. Particle size and distribution were investigated with TEM and AFM. The interfacial properties of the catalyst-semiconductor heterostructures were characterized by XPS and cyclic voltammetry. The influence of substrate doping (n-GaN and p-GaN) and morphology (smooth layers and nanowires) were investigated. The detected shifts in Pt4f core levels were correlated to chemical shifts while the shifts in Ga3d, Ga2p and N1s were ascribed to surface band bending in the substrate. Cyclic voltagramms were recorded in darkness and under illumination, as well as with or without a redox couple in the electrolyte. Based on this, devices can be designed for optical as well as electrical excitation of the catalyst-semiconductor system.

HL 52.8 Thu 12:00 H17

Si and Be incorporation into GaAs nanowires — •Maria Hilse, Manfred Ramsteiner, Steffen Breuer, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Berlin

As catalyst seeds are suspected to introduce impurities into nanowires (NWs), a much higher purity is expected for NWs grown by mechanisms that do not require any foreign material. Therefore, it is particularly important to investigate the doping, which is a prerequisite for the fabrication of devices, of NWs prepared by such mechanisms. A further requirement for controlled doping is the incorporation of dopants on the particular lattice sites of the desired electrical activity. We studied the incorporation of Si and Be into GaAs NWs grown on Si(111) by molecular beam epitaxy. The formation of these NWs was induced by Ga droplets that developed under the appropriate growth conditions on the native silicon oxide. Concerning the NW morphology, no influence was observed for Si doping but high Be doping concentrations cause a kinking and tapering of the NWs. The incorporation of the dopant atoms on the different lattice sites of GaAs was investigated by resonant Raman scattering. As expected, Be was found to be incorporated dominantly as an acceptor on Ga-sites leading to p-type conductivity. For Si doping, however, both donors on Ga sites and acceptors on As sites have been observed with similar abundance, leading to strong self-compensation and a resulting p-type conductivity.

HL 52.9 Thu 12:15 H17

Impact of silicon doping on InAs nanowires grown by selective area MOVPE — •Kamil Sladek[1], Andreas Penz[1], Stephan Wirths[1], Karl Weis[1], Steffi Lenk[1], Martina Luysberg[2], Hilde Hardtdegen[1], Thomas Schäpers[1], and Detlev Grützmacher[1]

— [1]Institute of Bio- and Nanosystems (IBN-1), Jülich Aachen Research Alliance (JARA), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Institute of Solid State Research and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

InAs nanowires are an attractive candidate for the realization of high-speed and low-power electronic devices due to the material's very high room temperature mobility. However, as recently reported by Dayeh et al. their conductivity could be influenced negatively by often observed stacking faults. In this contribution, we have investigated the influence of Si-doping during growth with the aim to tune nanowire conductivity and crystalline structure.

The nanowires were deposited by selective area MOVPE on (111)B GaAs masked substrates. The samples were characterized structurally by transmission and scanning electron microscopy. We observed that above a certain partial pressure ratio, doping has an influence on morphology. The nanowires exhibit higher uniformity and specific conductance, but decreasing height vs. diameter aspect ratio as the partial pressure ratio increases. This leads to the question, whether the incorporation of doping atoms or a structural change has the main influence on conductivity.

HL 52.10 Thu 12:30 H17

Site-selective molecular beam epitaxial growth of InAs quantum dots on pre-patterned GaAs substrates — •Mathieu Helfrich[1,2], Dongzhi Hu[2], Joshua Hendrickson[3], Daniel Rülke[1,4], Pablo Asshoff[1,2,4], Heinz Kalt[1,2,4], Michael Hetterich[1,2,4], Galina Khitrova[3], Hyatt M. Gibbs[3], and Daniel M. Schaadt[2] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [3]College of Optical Sciences, The University of Arizona, Tucson, AZ 85721, USA — [4]KSOP - Karlsruhe School of Optics and Photonics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

Semiconductor quantum dots (QDs) are promising candidates for the realisation of a quantum computer. Integrating QDs into optical resonator structures may be one way to realise such a device. Therefore, it is necessary to fabricate QDs with controllable properties at predefined positions. It has been demonstrated that pre-patterning of the substrate offers a tool to achieve good control of QD nucleation sites. However, site-controlled QDs still lack in quality compared to randomly nucleated QDs. Post-growth treatment is believed to enhance the optical properties of site-controlled QDs and is investigated in this study. InAs QDs are grown on pre-patterned GaAs (100) substrates by molecular beam epitaxy and are analysed by atomic force microscopy, scanning electron microscopy and photoluminescence measurements.

HL 52.11 Thu 12:45 H17

Quantum Jitter of a single electron source — Adrien Mahé[1], François Parmentier[1], Erwann Bocquillon[1], Jean-Marc Berroir[1], Christian Glattli[1,2], Takis Kontos[1], •Bernard Placais[1], and Gwendal Fève[1] — [1]Laboratoire Pierre Aigrain, ENS, 24 rue Lhomond 75005 Paris, France — [2]Service de Physique de l'Etat Condense, CEA, 91192 Gif-sur-Yvette, France

This contribution is identical to HL 46.9 and has been withdrawn from this session.

HL 53: Invited Talk: H. Zandvliet

Time: Thursday 12:30–13:00 Location: H15

Invited Talk HL 53.1 Thu 12:30 H15

Self-lacing nanowires on semiconductor surfaces — •Harold Zandvliet — MESA+ instute for Nanotechnology and University of Twente, Enschede, The Netherlands

The deposition of Pt or Au on Ge(001) followed by annealing results into well-ordered nanowire arrays. The self-lacing Pt induced nanowires have a cross section of only one atom, are perfectly straight, thousands of atoms long and virtually defect free. The nanowires are composed of dimers that have their bond aligned in a direction parallel to the chain direction. At low temperatures the nanowires undergo a Peierls transition: the periodicity of the nanowires doubles from a 2x to 4x periodicity and an energy gap opens up. At low temperatures (T<80 K) novel quasi one-dimensional electronic states are found. These quasi one-dimensional electronic states originate from an electronic state of the underlying terrace that is confined between the nanowires. The Au induced nanowires are composed of dimers as well, however their dimer bond is aligned perpendicular to the chain direction. The electronic, structural as well some intriguing dynamic properties of the nanowires will be briefly reviewed.

HL 54: Photonic Crystals: Theory

Time: Thursday 14:00–15:45 Location: H13

HL 54.1 Thu 14:00 H13

Thermal emission from finite photonic crystals — •Kurt Busch[1], Christian Schuler[1], Christian Wolff[1], and Marian Florescu[2] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]Department of Physics, Princeton University, Princeton, NJ 08544, U.S.A.

We present a microscopic theory of thermal emission from truncated photonic crystals and show that the relevant physical parameters such as the directional spectral emissivity can be obtained from standard photonic bandstructure computations without any approximation. This allows us to identify the physical mechanisms how interfaces modify the potentially super-Planckian radiation flow inside infinite photonic crystals [1] such that thermal emission from truncated systems remains consistent with the fundamental limits set by Planck's law [2]. As an application, we further demonstrate how a judicious choice of a surface termination facilitates considerable control over both the spectral and angular thermal emission properties [2,3].

[1] M. Florescu et al., Phys. Rev. B **75**, 201101(R) (2007).
[2] C.J. Schuler et al., Appl. Phys. Lett., in press.
[3] C.J. Schuler et al., submitted.

HL 54.2 Thu 14:15 H13

Simulations of Liquid Crystal Infiltrated Photonic Crystal Fibers Using the Fourier Modal Method — •Thomas Zebrowski, Sabine Essig, and Kurt Busch — Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruher Institut für Technologie (KIT), 76128 Karlsruhe, Germany

Liquid crystal infiltrated photonic crystal fibers are challenging systems for an accurate simulation because of their characteristic tiny features in the transverse plane coupled with a huge aspect ratio in propagation direction. In this contribution we demonstrate that the Fourier Modal Method is applicable to treat such problems. First, we extend the method to handle anisotropic materials and fully exploit the system symmetries which leads to significantly reduced demand for computational resources. This allows to make maximum use of the method's advantages which come via a scattering matrix algorithm that handles the typically slow or periodic structural variations along the propagation direction.

HL 54.3 Thu 14:30 H13

Transport Theory of Diffusive Random Lasers — •Regine Frank[1,2], Andreas Lubatsch[1], and Johann Kroha[1] — [1]Physikalisches Institut, Universität Bonn, 53115 Bonn, Germany — [2]Present address: KIT Karlsruhe, Germany

Despite substantial investigations mostly for low dimensional systems,

the physics of homogeneously disordered random lasers bears intriguing, open problems. The conditions for transport and localization and, in particular, the origin of confined spacial regions from which laser radiation is emitted ("lasing spots") as well as the dependence of their size on the pump rate, have remained poorly understood. We present a semi-analytic transport theory for light propagating diffusively, in a random, lasing medium, including self-interference ("Cooperon") corrections [1]. The diffusion coefficient is strongly renormalized by the non-linear gain rate. The latter is obtained from the local laser rate equations which, in turn, are controlled by loss channels due to diffusion and surface losses. In the stationary lasing state, the volume gain is compensated by surface losses. We solve the resulting surface boundary condition problem to obtain an analytical equation for the average lasing spot size. The full spatial intensity profile of lasing spots is obtained numerically in dependence of the pump rate. We show that the lasing spot size is closely related to the requirement of causality within a coherent lasing mode. The results are in qualitative agreement with experimental findings.

[1] R. Frank. A. Lubatsch, J. Kroha, J. Optics A **11**, 114012 (2009).

HL 54.4 Thu 14:45 H13

Light Propagation in Anisotropic Disordered Media, Transverse Diffusion — •Andreas Lubatsch[1] and Regine Frank[2] — [1]Physikalisches Institut, Universitaet Bonn, 53115 Bonn, Germany — [2]Institut fuer Theoretische Festkoerperphysik, Universitaet Karlsruhe, 76128 Karlsruhe, Germnany

We present a semi-analytical theory for light propagation in three dimensional, strongly scattering, anisotropic , disordered dielectrics. The anisotropy of the system is incorporated by a tensor dielectric function. By starting at Maxwell's equations, we derive a general transport theory for ligh including transport quantities such as energy transport velocity, transport mean free path and diffusion coefficient. This approach is based on a fully vectorial treatment of the generalized kinetic equation and also incorporates a generalized Ward identity for these systems. Furthermore, self-interference contribution to the transport are included by means of a generalized localization theory based on a cooperon resummation first derived for electrons by Vollhardt and Wölfle. Numerical evaluations including transverse diffusion in presence of magnetic fields are discussed.

HL 54.5 Thu 15:00 H13

Diagrammatic Theory of Anderson Localization of Light in Random Photonic Crystals Including Polarization — Zhong Yuan Lai, •Andreas Lubatsch, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115, Bonn

Anderson localization of light (ALL) is of interest both for fundamental reasons, because it is not disturbed by interaction effects, and for applications, e.g. in random lasers. However, the realization of ALL has been hampered by weak scattering amplitudes as well as by the reduced interference due to the polarization degree of freedom.

We develop a realistic description of diffusion and localization of light in random photonic crystals, where ALL is expected to be enhanced near a photonic band gap. Starting from a Wannier representation, we develop a tight-binding model of the disordered photonic crystal. The transverse vector nature of light implies the existence of two modes per site in the relevant energy band. They are coupled due to the disorder. The resulting pseudospinor theory is analytically tractable with strongly reduced effort compared to a plane-wave expansion [1]. We generalize the existing, selfconsistent theory of Anderson localization of classical waves [2] to include polarization. The transport velocity and the diffusion coefficient are calculated including a selfconsistent resummation of backscattering ("Cooperon") diagrams.

We find important corrections to the scalar theory due to different disperions of the two polarization modes and due to absorption in the medium.

HL 54.6 Thu 15:15 H13

Simulation model of 2D metallic photonic quasicrystals — •Christina Bauer, Georg Kobiela, and Harald Giessen — 4th Physics Institute, University of Stuttgart, 70550 Stuttgart, Germany

We are going to present a step-by-step model to predict the optical properties of 2D metallic photonic quasicrystals. For this model a 2D Fourier transform of the spatial arrangement of the nanoparticles in combination with polarization properties and dispersion relations is used. In the final step the line shape of such structures is considered. We manufactured a number of these structures and verified our model which yields very good quantitative agreement. This model can also be extended for angle-dependent incidence of the light, which we confirmed experimentally as well. We verify our results also for 2D rectangular lattices. Our findings are important for plasmonics in quasicrystal arrangements in general, for example in nanohole arrays [1, 2, 3].

[1] T. Matsui et al., Nature 446, 517 (2007).
[2] C. Rockstuhl et al., Appl. Phys. Lett. 91, 151109 (2007).
[3] N. Papasimakis et al., Appl. Phys. Lett. 91, 081503 (2007).

HL 54.7 Thu 15:30 H13

Resonant mode approximation for deriving optical properties of nanostructured materials — •Thomas Weiss[1,2], Nikolay Gippius[2,3], Sergei Tikhodeev[3], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]LASMEA, University Blaise Pascal, France — [3]General Pyhsics Institute, Russian Academy of Science, Russia

A lot of attention has been paid in the last years to the optical properties of nanostructured materials such as photonic crystals, metamaterials, and nanoantennas. The numerical calculation of these properties is often very time-consuming and, hence, simple models are desired for a fast approximation of the spectral behavior. We are going to present the resonant mode approximation, where the spectra can be derived from the calculation of the resonant mode. As a starting point, we use the scattering matrix approach for stacked periodic structures to obtain the resonant field distribution as well as the resonance position in the complex frequency plane. Then, we can approximate the scattering matrix for frequencies close to the resonance without any fitting procedures for describing the response of the structure on plane wave incidence. Several examples will be shown to elucidate the versatility of the method.

HL 55: Quantum Dots and Wires, Optical Properties IV: Spin

Time: Thursday 14:00–15:45 Location: H14

HL 55.1 Thu 14:00 H14

Effect of spin relaxation on the exciton dynamics in a charged quantum dot — •Eleftheria Kavousanaki and Guido Burkard — Department of Physics, University of Konstanz, Germany

We theoretically model the exciton dynamics in a semiconductor quantum dot doped with a single electron when the two lowest quantum dot levels are photoexcited by two circularly polarized femtosecond optical pulses in a pump-probe configuration. We calculate the differential transmission spectrum as a function of the time delay between the two pulses by using a density matrix formalism and treating intraband relaxation with the Lindblad semigroup method. We take into account relaxation processes in which the electron relaxes into the lowest quantum dot level either with or without a spin flip and investigate the possibility for spin-dependent blocking of intra-band relaxation due to the presence of the ground state electron. We show that the differential transmission spectrum is initially dominated by the fast no-flip mechanism before the slower spin-flip processes start to contribute at longer time scales, which allows for the spin polarization of the ground state electron to affect the dynamics.

HL 55.2 Thu 14:15 H14

Ultrafast optical rotations of electron spins in an InGaAs/GaAs quantum dot ensemble — •Stefan Spatzek[1], Alex Greilich[1], Sophia E. Economou[2], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[4], Thomas L. Reinecke[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany — [2]Naval Research Laboratory, Washington, DC 20375, USA — [3]3A. F. Ioffe Physico-Technical Institute, RAS, 194021 St. Petersburg — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We report on fast optical rotation operations on electron spins in a

quantum dots ensemble [1]. The spins are initialized in the z direction (quantum dot growth and light propagation direction). The spin vector oscillates about a transversal magnetic field B till a ultrafast 2π-"control" laser pulse induces rotations of the spins about the z axis. The 2π-control pulse rotates the spin without generating a new spin polarization. The rotation angle is determined by the photon energy detuning of the control pulse from the optical resonance. For the first time for optically controlled spins, spin echoes and extension of the dephasing time were seen. By combining the rotation about the two axis a spin rotations about arbitrary axis has been realized. This robust optically controlled single spin rotation gate provides the basis for single-qubit logic operations.

[1] A. Greilich, S. E. Economou, S. Spatzek, D. R. Yakovlev, D. Reuter, A. D. Wieck, T. L. Reinecke and M. Bayer, Nature Physics 5, 262

HL 55.3 Thu 14:30 H14

Spin-ensembles in (In,Ga)As/GaAs quantum dots — •Alexander Schwan[1], Stefan Spatzek[1], Steffen Varwig[1], Sophia E. Economou[2], Alex Greilich[1], Dmitri R. Yakovlev[1], Dirk Reuter[3], Andreas D. Wieck[3], Thomas L. Reinecke[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Naval Research Laboratory, 20375 Washington DC, USA — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Optically controlled electron spins in ensembles of quantum dots (QDs) provide an attractive candidate to implement quantum information technologies in a solid-state environment. Electron spin coherence in an inhomogeneous ensemble of singly charged (In,Ga)As/GaAs QDs was studied by means of time-resolved techniques [1][2].

The inhomogeneity of the QDs allows us to address two different spin-ensembles, separated in energy. For the optical orientation of the spin-ensembles we use two synchronized pulsed Ti:Sapphire lasers, which have a well defined spectral detuning. The temporal evolution of the spin precession of the ensembles is measured by time-resolved Faraday-Rotation. Results are reported for a wide range of excitation parameters.

[1] A. Greilich, D. R. Yakovlev, A. Shabaev, Al. L. Efros, I. A. Yugova, R. Oulton, V. Stavarache, D. Reuter, A. Wieck, and M. Bayer, Science 313, 341 (2006)

[2] A. Greilich, A. Shabaev, D. R. Yakovlev, Al. L. Efros, I. A. Yugova, D. Reuter, A. D. Wieck and M. Bayer, Science 317, 1896 (2007)

HL 55.4 Thu 14:45 H14

Electrical spin injection and ultrafast charging of single InAs quantum dots — •Jörg Nannen[1], Tilmar Kümmell[1], Jan Wenisch[2], Karl Brunner[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik & CeNIDE, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg — [2]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg

Single quantum dots (SQD's) are highly interesting candidates for future spin-based devices, which utilize electron spins as information carriers. Due to spin relaxation times up to the ms regime, self-assembled InAs quantum dots are ideal model systems to establish concepts to inject, store and read-out the spin information of single electrons.

We use an all-electrical approach to charge single InAs quantum dots embedded in a p-i-n-diode structure with a single electron. Using micro-photoluminescence spectroscopy, an abrupt switching between the neutral exciton and the negatively charged exciton can be observed. In combination with a diluted magnetic semiconductor (ZnMnSe) as a spin-aligner it is possible to electrically inject spin-polarized electrons with polarization degrees of more than 40 % [1]. An all-optical read-out scheme is demonstrated, which is independent from the injection process and does not destroy the spin information of the injected electron. To use this approach for future spin-based devices, electrical control of the charge state of the SQD's must be accomplished in the GHz-range. By high-frequency adaptation of the sample setups we are able to demonstrate electrical charging of the SQD's in less than 2 ns.

[1] Ghali et al., Appl. Phys. Lett. 93, 073107 (2008)

HL 55.5 Thu 15:00 H14

Creation of mode-locked spins by up to 80 ps pulses — •Steffen Varwig[1], Stefan Spatzek[1], Alexander Schwan[1], Irina A. Yugova[2], Mikhail M. Glazov[3], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[4], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia — [4]Angewandte Festkörperphysik, Ruhr- Universität Bochum, D-44780 Bochum, Germany

Precessing electron spins in an ensemble of singly charged quantum dots are of high interest for quantum information processing. To overcome the problem of fast spin dephasing due to inhomogenities within a quantum dot ensemble, it was shown that it is possible to synchronize the precession modes of the electron spins to the repetition rate of the exciting laser [1].

In previous measurements mode-locking was studied by a pump-probe technique with a laser repetition rate of 13.2 ns and a pulse duration of 2 ps. The spectral pulse width was about 1.5 nm. With a smaller bandwidth less quantum dots are excited, thus presumably increasing the spin dephasing time. However, the excitation time has to be short in comparison to a precession period. Hence, we investigated the influence of pulses with durations up to 80 ps and corresponding bandwidths of 0.6 nm on the possibility of mode-locking in spin ensembles.

[1] A. Greilich et al., Science 313, 341 (2006).

HL 55.6 Thu 15:15 H14

Long excitonic spin relaxation in InAs/AlAs quantum dots — •Birgit Brinkmann[1], T. S. Shamirzaev[2], J. Debus[1], D. Dunker[1], D. R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, 44227 Dortmund, Germany — [2]Institute of Semiconductor Physics, pr. Lavrentieva, 13, Novosibirsk 630090, Russia

We investigated the excitonic spin relaxation in self-assembled InAs quantum dots, embedded in an AlAs matrix, by means of time-resolved, circularly polarized photoluminescence.

The atomic-like electronic structure of self-assembled quantum dots suppresses not only elastic but also inelastic processes of spin relaxation mechanisms, thus increasing the exciton spin relaxation time τ_s. The experimental determination of τ_s is typically inhibited by the short exciton lifetime of a few nanoseconds. However, the novel InAs/AlAs quantum dot system, characterized by the lowest electron state at the direct Γ or indirect X conduction band minima, exhibits exciton lifetimes of several milliseconds. At a temperature of 1.8 K the exciton spin relaxation time τ_s is in the range of 100 μs. It strongly depends on the optical excitation density, temperature and quantum dot size.

Differences between the direct and indirect bandgap transitions have been observed in the temporal evolution of the non-equilibrium exciton spin-orientation induced by an external magnetic field or excitation with circularly polarized light. Spectral and temperature dependencies of photoluminescence kinetics are explained in terms of an electron redistribution between long-lived indirect and short-lived direct states of the quantum dot conduction band.

HL 55.7 Thu 15:30 H14

Spin-flip Raman scattering in InGaAs/GaAs quantum dots — •Jörg Debus[1], V. F. Sapega[2], D. R. Yakovlev[1,2], and M. Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Strong spin-flip Raman scattering (SFRS) from self-assembled n-doped InGaAs/GaAs quantum dots as well as from an undoped sample has been observed in external magnetic fields up to 10 T. In both cases the SFRS exhibits a strong dependence on the geometry of the experiment. The predominant Raman signal is attributed to a spin-flip of a resident electron induced by a photocreated exciton.

The magnetic field dependencies of the electronic Raman shift, measured in Voigt- and tilted Faraday-geometry, demonstrate similar slopes ($|g|^e_{||} \approx 0.62$ and $|g|^e_{\perp} \approx 0.54$), but tend to different Raman shifts at zero magnetic field. In tilted Faraday-geometry the Raman shift tends to $\delta = 0.4\,\mathrm{cm}^{-1}$, it depends also on the optical excitation energy as well as on the annealing temperature of the samples. The offset at $B = 0$ T can be related to excitonic exchange interaction and to additional nuclear magnetic fields acting on the resident electrons. At $B = 10$ T the electronic spin-flip shift is larger in tilted Faraday- than in Voigt-geometry, which originates from an electron g factor anisotropy.

The electron g factor dispersion has been measured across the emission band of the inhomogeneously broadened quantum dot ensemble.

HL 56: Non- and Semi-polar Group-III-Nitrides

Time: Thursday 14:00–17:45 Location: H15

HL 56.1 Thu 14:00 H15

Optical anisotropy of *a*- and *m*-plane InN grown on free-standing GaN substrates — •Jochen Räthel[1], Pascal Schley[1], Egidius Sakalauskas[1], Gerhard Gobsch[1], René Müller[1], Thomas A. Klar[1], Jörg Pezoldt[1], Rüdiger Goldhahn[1], Gregor Koblmüller[2,3], James S. Speck[2], Matthias Wieneke[4], Jürgen Bläsing[4], and Alois Krost[4] — [1]Institut für Physik, Technische Universität Ilmenau — [2]Materials Department, University of California — [3]Walter Schottky Institut, Technische Universität München — [4]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

The optical response of wurtzite nitride semiconductors at the band gap and in the spectral region of high-energy critical points differs appreciably for light polarization perpendicular (ordinary configuration) and parallel (extraordinary) to the *c*-axis. In order to demonstrate this effect, films (or bulk crystals) are required for which the optical axis lies in the surface plane (*a*- or *m*-plane). For InN, the only studies reported so far employed an *a*-plane layer deposited on *r*-plane sapphire with an *a*-plane GaN buffer. Considerable improvement of the film quality was recently achieved by growing *a*- and *m*-plane InN directly on free-standing *a*- and *m*-plane GaN by PAMBE. In this contribution, we present a comprehensive characterization of these higher-quality non-polar InN materials by polarization-dependent Raman spectroscopy and ellipsometry. The influence of stress on the transition energies is discussed based on the lattice parameters obtained by high-resolution XRD.

HL 56.2 Thu 14:15 H15

Polarization-dependent photoluminescence studies of semipolar and nonpolar InGaN quantum wells — •Lukas Schade[1], Ulrich Schwarz[1], Tim Wernicke[2], Markus Weyers[2], and Michael Kneissl[2,3] — [1]IAF, Freiburg, Germany — [2]FBH Berlin, Germany — [3]Institute of Solid State Physics, TU Berlin, Germany

Light emitted from optical devices based on semi- and nonpolar GaN quantum well (QW) structures is partially or totally polarized, as a consequence of crystal symmetry and band structure. This can be an additional advantage over polar (0001) GaN in specific applications, e.g. in LED backlighting. Fundamentally, the polarized emission stems from breaking the isotropic symmetry of the hexagonal c-plane, resulting in two discrete semi- and nonpolar directions (parallel and normal to the projection of (0001)). We use the k.p method to simulate the crystal-direction dependent emission. The resulting transition matrix elements assign a specific (partial) polarization for each subband. The thermal occupation of the subbands results in a temperature dependent effective polarization of the light emission. We study MOVPE grown homoepitactical polar, semi- and nonpolar samples, measuring the polarization properties of the resonantly excited photoluminescence from the QW. With the complete polarization of the subbands for nonpolar devices it is possible to measure the energetic difference of the first two valence band levels. In contrast to our calculations we find a higher degree of polarization also in semipolar directions. A possible explanation could be a higher energetic subband difference than computed.

HL 56.3 Thu 14:30 H15

Heteroepitaxial growth of basal plane stacking fault free a-plane GaN — •Matthias Wieneke, Thomas Hempel, Martin Noltemeyer, Hartmut Witte, Armin Dadgar, Jürgen Bläsing, Jürgen Christen, and Alois Krost — Otto-von-Guericke Universitaet Magdeburg, FNW/IEP, Postfach 4120, 39016 Magdeburg

Growth of light emitting quantum-wells based on a-plane GaN is a possibility to reduce or even to avoid polarization correlated luminescence red shift and reduction of radiative recombination efficiency. But until now heteroepitaxially grown a-plane GaN films are characterized by a poor crystalline quality expressed by a high density of basal plane stacking faults (BSF) and partial dislocations. We will present Si doped a-plane GaN films grown on r-plane sapphire substrates by metal organic vapor phase epitaxy using high temperature AlGaN nucleation layers. FE-SEM images revealed three dimensionally grown GaN crystallites sized up to tenth micrometer in the basal plane and a few tenth micrometers along the c-axes. Though, the full width at half maxima of the X-ray diffraction ω-scans of the in-plane GaN(1-100) and GaN(0002) Bragg reflections exhibited a very high crystal quality. Furthermore, luminescence spectra were dominated by near band gap emission, while there was no separated peak of the basal plane stacking fault. In summary we will present heteroepitaxially grown a-plane GaN without an evidence of basal plane stacking faults in X-ray diffraction measurements and luminescence spectra.

HL 56.4 Thu 14:45 H15

Surface morphology of homoepitaxial GaN grown on non- and semipolar GaN substrates — •Tim Wernicke[1], Simon Ploch[2], Veit Hoffmann[1], Jens Rass[2], Carsten Netzel[1], Lukas Schade[3], Ulrich Schwarz[3], Arne Knauer[1], Markus Weyers[1], and Michael Kneissl[1,2] — [1]FBH Berlin, Germany — [2]Institute of Solid State Physics, TU Berlin, Germany — [3]IAF, Freiburg, Germany

Recently a number of groups have reported laser diodes in the green spectral range on semi- and nonpolar GaN. Nevertheless the growth process on semipolar surfaces is not well understood. In this study $3.5\,\mu m$ thick MOVPE grown GaN layers on bulk m-plane, $(11\bar{2}2)$, $(10\bar{1}2)$, and $(10\bar{1}1)$ GaN substrates were investigated. XRD rocking curves exhibit a FWHM of less than 150", indicating excellent crystalline quality. But the surface morphology exhibits hillocks with a height of $1\,\mu m$ and lateral extension of $150\,\mu m$ in many cases. Depending on the substrate orientation and the growth temperature different hillock shapes were observed. Morphology and luminescence data point to threading dislocations as formation sources. In QWs the hillock structure is reproduced in the emission intensity and wavelength distribution on $(10\bar{1}1)$ but not on the m-plane surfaces. The hillocks could be eliminated for the semipolar planes (not for the m-plane) by increasing the reactor pressure and lowering the growth temperature. Hillock free separate confinement laser structures emitting at $405\,nm$ feature a very homgeneous luminescence in micro-PL and show amplified spontaneous emission under high power stripe excitation. Furthermore the In incorporation was found to be highest in QWs on $(10\bar{1}1)$.

HL 56.5 Thu 15:00 H15

Influence of stacking faults on the optical properties of m-plane GaInN quantum wells — •Holger Jönen[1], Uwe Rossow[1], Heiko Bremers[1], Torsten Langer[1], Daniel Dräger[1], Lars Hoffmann[1], Sebastian Metzner[2], Frank Bertram[2], Jürgen Christen[2], Lukas Schade[3], Ulrich T. Schwarz[3], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig — [2]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [3]Institut für Angewandte und Experimentelle Physik, Universität Regensburg

In the past few years GaN-based light emitting devices grown on non-polar planes have continuously attracted increasing attention due to their promising optical properties. While conventional structures grown on the polar c-plane suffer from the quantum-confined Stark effect (QCSE) non-polar structures are free from polarization fields in growth direction and thus might be more efficient. However, without defect reduction techniques heteroepitaxy of non- or semi-polar layers commonly results in high densities of threading dislocations and stacking faults. In this contribution we report on the optical properties of m-plane GaInN quantum wells grown on m-plane SiC. A reduced bandgap energy and the presence of two emission lines, which we attribute to basal and prismatic stacking faults, respectively, indicate that the optical properties are dominated by regions where stacking faults intersect the quantum wells. Quantum-wire-like states formed at these intersections may provide an effective carrier confinement resulting in high internal quantum efficiencies up to 45%.

HL 56.6 Thu 15:15 H15

Growth of *M*- and *A*-plane GaN on $LiGaO_2$ by plasma-assisted MBE — •Ralf Schuber[1], Mitch M.C. Chou[2], and Daniel M. Schaadt[1] — [1]Institut für Angewandte Physik/DFG-Center for Functional Nanostructures (CFN), Karlsruher Institut für Technologie (KIT), 76131 Karlsruhe, Germany — [2]Department of Materials Science and Opto-electronic Engineering, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan, ROC

Non-polar GaN presents a way to circumvent unwanted effects which arise due to its intrinsically built-in electric fields. Since GaN sub-

strates are not readily available for homoepitaxy, various alternative substrates have been examined for growth of high quality *M*- or *A*-plane GaN crystals. $LiGaO_2$ (LGO) presents the closest lattice matched substrate that has been considered for GaN heteroepitaxy. However, so far only *C*-plane growth of GaN has been reported on (001)LGO.

Here we present the successful growth of *M*-plane GaN on (100)LGO and *A*-plane GaN on (010)LGO for the first time using plasma-assisted molecular beam epitaxy. Structural and morphological analysis was performed using x-ray and reflective high energy electron diffraction, scanning electron and atomic force microscopy. The phase purity of the grown films is shown to be very high. The surface morphology is in both cases flat and smooth.

HL 56.7 Thu 15:30 H15

Plasma supported cleaning of galliumnitride (11$\bar{2}$0) surfaces — •Hendrik Geffers, Christian Schulz, Jan Ingo Flege, Thomas Schmidt, and Jens Falta — Institute of Solid State Physics, University of Bremen, 28359 Bremen, Germany

In this work we investigated the cleaning of non-polar galliumnitride (11$\bar{2}$0) surfaces of metal organic chemical vapor phase epitaxy (*MOVPE*) grown samples by thermal annealing and sequential nitrogen plasma treatment. The chemical composition of the surface was analysed by x-ray photoelectron spectroscopy (*XPS*) before the treatment and after every cleaning step. The morphology and structure of the sample's surface was observed by scanning tunneling microscopy (*STM*) and low energy electron diffraction (*LEED*).

The XPS data of the untreated samples show large carbon and oxygen contaminations. The STM images exhibit a high roughness which is also reflected in the LEED patterns by a high background and diffuse diffraction spots. Most of the carbon contamination was found to be removed after the thermal annealing, while the amount of oxygen contamination could significantly be lowered with the plasma treatment. The STM images show a smoother surface after the cleaning process, this is also reflected in the LEED patterns by sharper diffraction spots and a lower background.

15 Min. Coffee Break

HL 56.8 Thu 16:00 H15

Atomic model of the Interface between m-plane sapphire and semi-polar GaN — •Martin Frentrup[1], Simon Ploch[1], Markus Pristovsek[1], and Michael Kneissl[1,2] — [1]TU Berlin, EW 6-1, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

InGaN based blue and green light emitting devices (LEDs) grown on c-plane GaN experience strong piezoelectric and spontaneous polarization fields. This results in a reduced radiative recombination efficiency due to the quantum confined Stark effect (QCSE). These effects are less pronounced for other surface orientation, like {11$\bar{2}$2} or {10$\bar{1}$3}. Thus we investigate the MOVPE growth of semi-polar GaN on {10$\bar{1}$0} (m-plane) sapphire substrates. Based on high resolution X-ray diffraction and AFM measurements, an atomic model of the interface and in-plane alignment between sapphire and GaN is proposed. The observed prefered {10$\bar{1}$3} and {11$\bar{2}$2} orientations show the best lattice match to m-plane sapphire of all regarded semipolar types. Furthermore our model gives an explanation for the often observed twinning effect of the {10$\bar{1}$3} orientation, which lead to a very defective surface morphology.

HL 56.9 Thu 16:15 H15

Charakterisierung von AlGaInN mittels Röntgenbeugung und -fluoreszenz — •Lars Groh, Christoph Hums, Matthias Wieneke, Phannee Saengkaew, Jürgen Bläsing und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Quantum Well Strukturen für Nitrid-basierte Leuchtdioden werden derzeit zumeist c-Achsen orientiert gewachsen, wobei der Quantum Confined Stark-Effekt den Überlapp zwischen Elektron- und Lochwellenfunktion und somit die Effizienz der Bauelemente reduziert. Ursache dafür ist die unterschiedliche Polarisation der verschiedenen zum Einsatz kommenden Nitride, im Well und der Barriere. Zum Angleich dieser beiden Polarisationen wurden mittels MOVPE quaternäre Schichten aus AlGaInN gewachsen, die - zusätzlich zum Freiheitsgrad der Bandlücke der ternären Verbindungen - eine Anpassung der Polarisation erlauben. Die strukturelle Charakterisierung derartiger Schichten (Dicke, Verspannung, Twist, Tilt, Relaxationsgrad) ist mittels Röntgenbeugung nur begrenzt möglich, da die quaternäre Zusammensetzung keine eindeutige Bestimmung der Schichtkomposition mehr zulässt. Daher wurden verschiedene Röntgenfluoreszenzversuche (XRF, TXRF, GIXRF, GEXRF) unternommen, um die fehlende Information zur Bestimmung der Schichtkomposition zu ergänzen.

HL 56.10 Thu 16:30 H15

Detailed investigation of the defect-related emissions around 3.3 eV in GaN ELOG structures — •Ingo Tischer[1], Hady Yacoub[1], Martin Schirra[1], Martin Feneberg[1], Thomas Wunderer[2], Ferdinand Scholz[2], Levin Dieterle[3], Erich Müller[3], Dagmar Gerthsen[3], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm — [3]Laboratorium für Elekronenmikroskopie, Universität Karlsruhe, 76128 Karlsruhe

We investigate the origin of defect-related emission lines in a sample with triangular shaped GaN stripes forming semipolar {1$\bar{1}$01} facets. The emission lines between 3.0 eV and 3.41 eV are characterized by high resolution transmission electron microscopy (HRTEM) and scanning electron microscope cathodolumence (SEM-CL). We are able to distinguish between different types of basal plane stacking faults which correspond to different emission energies. The assignment of the optical features to the different types of basal plane stacking faults and other defects are discussed using a one-to-one correlation between HRTEM and SEM-CL results.

HL 56.11 Thu 16:45 H15

Spectrally resolved cathodoluminescence microscopy of an InGaN SQW on hexagonally inverted GaN pyramids — •Christopher Karbaum[1], Frank Bertram[1], Sebastian Metzner[1], Juergen Christen[1], Thomas Wunderer[2], and Ferdinand Scholz[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Institute of Optoelectronics, University of Ulm, Germany

Three-dimensional self organized hexagonally shaped inverted GaN pyramids with semipolar {11$\bar{2}$2} facets were grown using MOVPE by applying selective area epitaxy on a two-dimensional pattern of hexagonally shaped SiO_2-masks on an optimized c-GaN buffer layer. Subsequently, an InGaN SQW suited for green emission was deposited on the semipolar facets to make use of the reduced QCSE. The spatially-integral spectrum exhibits the near band edge (D^0,X) emission of GaN at about 357 nm and an intense broad InGaN luminescence at about 500 nm having a FWHM = 320 meV. The evolution of the (D^0,X) luminescence of GaN will be discussed in detail. The InGaN luminescence at the top of the facets is centered at about 535 nm and shifts about 960 meV to shorter wavelengths indicating a strong gradient of the In-concentration. Finally, the InGaN luminescence reaches up to 378 nm close to the (D^0,X) luminescence of GaN. Simultaneously the InGaN emission band narrows from FWHM = 235 meV at the top to FWHM = 104 meV above the masks. Furthermore, the temperature-dependence of the InGaN emission energy and the influence of enduring excitation on the InGaN luminescence will be discussed.

HL 56.12 Thu 17:00 H15

Microscopic correlation of real structure and recombination kinetics in semipolar InGaN SQW using spatio-time-resolved cathodoluminescence — •Sebastian Metzner[1], Frank Bertram[1], Jürgen Christen[1], Thomas Wunderer[2], Frank Lipski[2], Stephan Schwaiger[2], and Ferdinand Scholz[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg — [2]Institute of Optoelectronics, University of Ulm

Highly spatially, spectrally and time-resolved cathodoluminescence microscopy of an InGaN SQW grown on semipolar facets of 3D inverse pyramids formed by MOVPE on hexagonally masked c-plane GaN is presented. The spectra mapping of the SQW exhibits an emission at $\lambda = 400$ nm at the center of the inverted pyramids and $\lambda = 530$ nm at the hexagonal ridge. For a correlation with the recombination kinetics the same sample area was investigated by time-resolved CL using an electrostatic beam-blanking that switches "on" the electron beam, keeps it "on" for a selected time and turns it "off" extremely fast allowing a transient mapping in single-photon-counting mode. This gives the opportunity to evaluate time-delayed intensity images in order to generate an initial lifetime map by a digital box-car method. So, the high energy emission at the center exhibits initial lifetimes of $\tau = 200$ ps whereas the low energy emission at the ridge developes

nearly two orders of magnitude more slowly in time ($\tau > 13$ ns). For different positions along a facet time-delayed spectra were recorded to study the spectral *and* temporal characteristics of the InGaN SQW observing the impact of localization and polarization fields.

HL 56.13 Thu 17:15 H15

Towards green electroluminescence of semipolar InGaN-MQWs on GaN pyramids — •Alexander Meyer, Clemens Wächter, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

InGaN-structures have attracted much interest due to their properties which allow the development of optoelectronic devices such as light emitting diodes (LEDs) and laser diodes. Recently, blue and green InGaN-LEDs are available, but the so-called quantum-confined Stark effect (QCSE) reduces the emission efficiency of these devices by bowing of the band structure.

To lower the QCSE, hexagonal Si-doped GaN-pyramids were deposited, providing semipolar sidewalls tilted 62° with respect to the GaN c-plane. These planes are used for the deposition of InGaN-multiple quantum wells (MQWs). The whole structure is fabricated by low-pressure metal-organic vapor-phase epitaxy (MOVPE). Next to the structural characterization of the samples by scanning electron microscopy, photoluminescence techniques are used to reveal the optical properties.

Besides these optical investigation of the Indium distribution on the pyramidal structures, p-i-n junctions are formed by placing a hole injection coating on top of the pyramids. Contact structures were developed to allow electrical injection and the examination of electroluminescence.

HL 56.14 Thu 17:30 H15

Growth of planar semipolar GaN via epitaxial lateral overgrowth on pre-patterned sapphire substrate — •Stephan Schwaiger, Ilona Argut, Thomas Wunderer, Frank Lipski, Rudolf Rösch, and Ferdinand Scholz — Institute of Optoelectronics, University of Ulm

We report on the growth of planar semipolar GaN on pre-patterned sapphire substrates via metalorganic vapor phase epitaxy. The sapphire templates were structured with grooves perpendicular to the c-direction of the crystal. Using appropriate growth parameters semipolar GaN can be grown from the c-plane like sidewall of the patterned sapphire, resulting in a flat and planar semipolar surface. Hence, this method allows the growth of semipolar GaN on large areas. Scanning electron, transmission electron and atomic force microscopy measurements show an atomically flat surface. Photoluminescence spectroscopy spectra show the high quality of the material since the spectra are dominated by the near band edge emission but still exhibit some defect related contributions. Furthermore high resolution x-ray diffraction rocking curve measurements result in small full widths at half maximum of less than 400arcsec for both, the symmetrical reflection and the asymmetrical (0002) reflection.

HL 57: Focussed Session: ZnO-based Semiconductors

Time: Thursday 14:00–18:00 Location: H17

Invited Talk HL 57.1 Thu 14:00 H17

Exploring Zinc Oxide: From band structure towards devices — •Bruno Meyer — 1. Physik. Institut, JLU Giessen, Giessen

One of the key issues in modern solid-state electronics is energy band engineering for design and fabrication of heterostructures and quantum wells. ZnO can be alloyed with MgO to form high quality single crystal MgxZn1-xO films with the Mg content up to 33 at %, while retaining the wurzite crystal structure. Alloying ZnO with MgO increases the direct bandgap of ZnO from 3.3 eV to about 4.0 eV (for 33% Mg incorporation). ZnO/ MgxZn1-xO forms type-I heterostructures, ideal for electrical and optical confinement. The small lattice mismatch and high bandgap ensure the effective use of MgxZn1-xO as a barrier layer for ZnO based heterostructures and quantum wells.

We report on the investigation of electronic and opto-electronic band structure effects of ZnO/MgZnO heterostructures grown on different polar and non-polar ZnO bulk substrates, and ZnO on GaN (AlGaN) templates where large conduction band offsets give rise to type II band alignment and band offsets can be tuned by the different heterovalent interfaces. From a substantially improved microscopic understanding of the electronic and opto-electronic properties of the ZnO-based quantum heterostructures one can expect to predict future device applications with complex designs such as field effect transistors and 2DEGs.

HL 57.2 Thu 14:30 H17

Magneto-optical properties of bound excitons in ZnO — •Benjamin Neuschl, Martin Feneberg, and Klaus Thonke — Institute of Quantum Matter, University of Ulm

High resolution, low temperature magneto-photoluminescence of ZnO single crystals is recorded in magnetic fields up to 28 Tesla. Full width at half maximum below 80 μeV for bound excitons and strong magnetic perturbation allow to observe rich splitting patterns of degenerate energy states and allow a unique insight into the magneto-optical properties of bound excitons. Interaction with excited rotor and valence band states of the hole involved are taken into account to obtain a perfect fit to the experimental data. By comparing the intensity dependence of the fine structure of single bound excitons at different temperatures and magnetic field orientations, we are able to clearly distinguish between donor and acceptor bound excitons, as well as between transitions assigned to ground or excited hole states.

HL 57.3 Thu 14:45 H17

Uniaxial stress dependent analysis of the optical and vibrational properties of high quality ZnO substrates — •Gordon Callsen[1], Markus R. Wagner[1], Ronny Kirste[1], Jan Schulze[1], Axel Hoffmann[1], Anna V. Rodina[2], and André Schleife[3] — [1]Technische Universität Berlin, Department of solid state physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]A. F. Ioffe Physico-Technical Institute, 194021 Sankt-Petersburg, Russia — [3]Friedrich-Schiller-Universität, Institut für Festkörpertheorie, Max-Wien-Platz 1, 07743 Jena, Germany

We analyze ZnO substrates from suppliers like Cermet, Crystek, Tokyo Denpa and UniWafer by PL and Raman measurements with strong focus on the observed uniaxial stress dependencies. Zero stress field PL measurements reveal varying energetic positions of the e.g. bound excitons and exciton-polaritons among the selection of ZnO substrates which indicates different built-in strain levels. Polarization dependent PL measurements under application of uniaxial stress yield different pressure coefficients for the full set of exciton-polaritons of all analyzed ZnO substrates. Therefore, different dependencies for the evolution of the A-C- and A-B-exciton-polariton-splitting under the influence of uniaxial stress are measured. First principal calculations which model the influence of uniaxial strain on the electronic band structure of ZnO allow detailed insight into the obtained PL results. Uniaxial stress dependent Raman measurements facilitate further comparison of the analyzed ZnO substrates based on their vibrational properties which are also directly influenced by the application of uniaxial stress.

HL 57.4 Thu 15:00 H17

Dielectric passivated ZnO-based Schottky diodes — •Stefan Müller, Holger von Wenckstern, Zhipeng Zhang, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik, Linnéstr. 5, 04103 Leipzig

Vacuum-activated surface conduction (VASC) is a well known phenomenon of ZnO. Concerning ZnO-based devices, it can significantly reduce the parallel resistance of, e.g., Schottky diodes. Therefore, its formation must be suppressed to realize high quality, long-time stable devices. We have recently shown for the case of Au/ZnO Schottky-diodes, that dielectric passivation suppresses a VASC completely[1]. Here, we report on electrical and optical properties of passivated PdO_y/ZnO- and PtO_y/ZnO-Schottky diodes. The diodes were realized by reactive dc-sputtering of Pd and Pt, respectively, on nominally undoped ZnO thin films grown on a-plane sapphire substrate by pulsed laser deposition (PLD). On those Schottky-diodes a dielectric passivation, e.g. Al_2O_3 or $CaHfO_3$, was deposited by PLD at room temperature. For optical characterisation, we used depth-resolved cathodo-

luminescence and light beam induced current measurement, allowing the investigation of the lateral homogenity of the barrier potential on the μm-scale. Current-voltage- and capacitance-voltage-spectroscopy was measured in a temperature range from 10 K up to the point of thermic degradation and revealed that VASC does not play a role.

[1] H. von Wenckstern et al., J. Electron. Mater., DOI: 10.1007/s11664-009-0974-1

HL 57.5 Thu 15:15 H17

Excitation dynamics in ZnO random lasers — •Janos Sartor, Felix Eilers, Jonas Conradt, Cornelius Thiele, Claus Klingshirn, and Heinz Kalt — Angewandte Physik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Random lasing is a phenomenon that appears in strongly scattering systems providing optical gain. In our work we investigate the spatial extent of laser modes in ZnO powders with grain sizes of the order of the emission wavelength. It has been shown that this material system is well suited for research on random lasing since the ZnO nanoparticles provide sufficient gain and scattering at the same time. Usually the emission of a random laser fluctuates too much to distinguish the vast amount of lasing modes. By reducing the volume of our random lasing medium to micro-sized structures we were able to reduce the number of modes as well, until only a few distinguishable modes remained. We observe the coexistence of strongly localized and extended modes and thus solve a longstanding discussion in current theoretical work. The mode extent is directly linked to the strength of the optical gain.

15 Min. Coffee Break

Invited Talk HL 57.6 Thu 15:45 H17

Interface Induced Gap States and ZnO Schottky Contacts — •Steven M. Durbin and Martin W. Allen — University of Canterbury, Christchurch, New Zealand

Practical aspects of fabricating Schottky contacts, such as lateral inhomogeneity, contaminants, and defects, can complicate the comparison of experimentally obtained barrier heights to theoretical predictions. The diode ideality factor η (which should approach unity for laterally homogeneous interfaces, after accounting for image force effects) is also strongly affected by the same issues, and correlations can be observed between barrier height and η when measuring large numbers of devices. ZnO could prove to be an interesting test case for evaluating various theoretical models, as it is significantly more ionic than most semiconductors, resulting in weaker Fermi pinning due to interface states. ZnO also does not require the removal of a native oxide layer for device processing, thereby avoiding often aggressive cleaning procedures. We have fabricated arrays of rectifying metal-ZnO contacts using bulk wafers and a wide variety of metals, using a technique which results in large barrier heights (typically > 0.8 eV) and low η (approaching the image force limit). Using the electrical characteristics of these diodes, we evaluate both Tung′s chemical bonding and Mönch′s metal induced gap states + electronegativity models, and discuss the limits of our current understanding of metal-ZnO interfaces.

HL 57.7 Thu 16:15 H17

Quantum confined Stark effect in ZnO/MgZnO quantum wells fabricated with different growth processes — •Marko Stölzel, Matthias Brandt, Alexander Müller, Michael Lorenz, Gabriele Benndorf, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

The properties of quantum wells (QWs) are very sensitive to the interface quality. Ideally, atomically flat interfaces are required to enclose a perfect square well. In the ZnO/MgZnO system the potential landscape changes into a triangular potential due to the electric polarization difference between both materials and the resulting electric field. The quantum confined stark effect (QCSE) is therefore expected to be observed in such heterostructures. Its presence and the related phenomena can be used as a criterion for the interface quality. In the present study QW-structures were grown by PLD directly on sapphire, on a ZnO buffer layer on sapphire and on O-polar ZnO single crystal substrates. The surface morphology was investigated by AFM. Structural quality was assessed by HR-XRD. All samples were grown pseudomorphically and in the step flow mode, excluding major influences from interface roughening.

The occurrence of the QCSE has been determined by intensity-dependent as well as time-resolved photoluminescence measurements. A redshift of the QW luminescence as well as an immense increase in the exciton lifetime is observed for high quality samples.

HL 57.8 Thu 16:30 H17

Einfluss der Exzitonen-Phononen-Wechselwirkung auf das Absorptionsverhalten von MgZnO — •Maciej Neumann[1], Gerhard Gobsch[1], Rüdiger Goldhahn[1], Thomas A. Wassner[2], Bernhard Laumer[2] und Martin Eickhoff[3] — [1]Technische Universität Ilmenau, Institut für Physik, PF 100565, Ilmenau 98684 — [2]Technische Universität München, Walter Schottky Institut, Garching D-85748 — [3]Justus-Liebig-Universität Giessen, I. Physikalisches Institut, Giessen

Die Verbindungshalbleiter ZnO und MgZnO sind bekannt für ihre hohen Exzitonenbindungsenergien sowie die starke Polarität der Bindung. Diese Eigenschaften spiegeln sich in den Absorptionsspekten wider und können nicht allein durch das von Elliott abgeleitete Modell wiedergegeben werden. Die vorliegende Studie untersucht den Einfluss der Exzitonen-Phononen-Kopplung auf die Absorptionseigenschaften auf Basis der Analyse der dielektrischen Funktion (DF). Dazu wurden hexagonale $Mg_xZn_{1-x}O$-Schichten mit Mg-Konzentrationen von $x = 0$ bis $x = 0.23$ mittels plasmaunterstützter Molekularstrahlepitaxie auf Saphir-Substraten gewachsen und durch spektroskopische Ellipsometrie sowie Photolumineszenzspektroskopie (PL) untersucht. Die Beiträge von Exzitonen, coulombverstärkten Interbandübergängen sowie Exzitonen-Phonen-Komplexen auf die DF wird analysiert. Dies liefert die Bandlücke bei Raumtemperatur und zeigt, dass der Beitrag durch die Exzitonen-Phononen-Wechselwirkung nicht vernachlässigt werden kann. Der Vergleich mit der PL weist eine schwache Stokes-Verschiebung durch Lokalisierung der Exzitonen auf.

HL 57.9 Thu 16:45 H17

Growth and Characterization of Hetero- and Homoepitaxial ZnO/ZnMgO Quantum Wells. — •Bernhard Laumer[1], Thomas A. Wassner[1], Fabian Schuster[1], Martin Stutzmann[1], and Martin Eickhoff[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Gießen

In this study, $ZnO/Zn_{1-x}Mg_xO$ single quantum wells (SQW) with different well widths have been grown by plasma-assisted molecular beam epitaxy on c-plane sapphire as well as on c-plane (O-face) bulk ZnO crystals. For heteroepitaxy on c-plane sapphire, a MgO/ZnO double buffer has been introduced to overcome the large lattice mismatch. Reflection high energy electron diffraction was used for in-situ growth monitoring and atomic force microscopy for ex-situ investigation of the sample morphology. The rms roughness of both hetero- and homoepitaxial SQW samples ranges from 0.2 to 0.4 nm, indicating the presence of well-defined and abrupt heterointerfaces. The optical properties of the quantum well structures were investigated by photoluminescence spectroscopy (PL). At 4.2 K, excitonic emission from the SQW is observed, that blue shifts for decreasing well width due to enhanced quantum confinement. As shown by temperature-dependent PL measurements, this emission line can be attributed to excitons localized at potential fluctuations of the SQW due to fluctuations of the barrier height or well width. At higher temperatures a second peak emerges that is attributed to free excitons.

HL 57.10 Thu 17:00 H17

Structural defect bound excitons in ZnO — •Markus R. Wagner[1], Gordon Callsen[1], Jan-Hindrik Schulze[1], Martin Kaiser[1], Ronny Kirste[1], Axel Hoffmann[1], Martin Noltemeyer[2], Anna V. Rodina[3], Stefan Lautenschläger[4], Sebastian Eisermann[4], and Bruno K. Meyer[4] — [1]TU Berlin, Inst. für Festkörperphysik, 10623 Berlin — [2]OvGU Magdeburg, Inst. für Exp. Physik, 36106 Magdeburg — [3]A.F. Ioffe Physico-Technical Inst., 194021 St.-Petersburg, Russia — [4]JLU Giessen, I. Physikalisches Inst., 35592 Giessen

Excitons bound to structural defects are a common feature of many semiconductor materials. In ZnO the narrow transition line in luminescence and absorption at 3.333eV is a typical example for this category of excitons. In this contribution we present a comprehensive study of defect bound excitons under the influence of external magnetic and stress fields. The defect centers are identified as neutral donor states with low activation energies despite of their much larger localization energies. Time resolved photoluminescence reveals a significant discrepancy compared to the Rashba-like behavior of the shallow bound excitons. This difference is further supported by the quantitative anal-

ysis of the pressure coefficients under the influence of uniaxial stress. The excitation channels of the defect bound excitons are compared with those of the I4 to I9 lines by PLE measurements. Monochromatic CL images provide insights into the microscopic nature of these transitions. Possible defect models for the deeply bound excitons will be discussed.

HL 57.11 Thu 17:15 H17

Charge states of a hydrogen defect (3326 cm^{-1} line) in ZnO — •Frank Herklotz, Eduard Lavrov, and Jörg Weber — Technische Universität Dresden, 01062 Dresden, Germany

Hydrogen in ZnO is a common impurity that strongly influences its electrical and optical properties, in particular, via formation of shallow donor states [1,2].
An IR absorption study of a H-related defect resulting in a local vibrational mode (LVM) at 3326 cm^{-1} [3] is presented. We observed that a sub band-gap illumination results in the appearance of an IR absorption line at 3358 cm^{-1} at the expense of the 3326 cm^{-1} signal. The results of isotope substitution experiments strongly reveal that the two signals are LVMs of the same defect in different charge states. From the energy of the sub band-gap light it is concluded that this defect has a deep level in the band-gap. Data on thermal stability as well as the transition between the different charge states at different temperatures are also presented. The microscopic nature of the defect will be discussed.

[1] C.G. Van de Walle, Phys. Rev. Lett. 85, 1012 (2000)
[2] E.V. Lavrov, F. Herklotz, C.G. Van de Walle, Phys. Rev. B 79, 165210 (2009).
[3] M.D. McCluskey, S.J. Jokela, K.K. Zhuravlev, P.J. Simpson, and K.G. Lynn, Appl. Phys. Lett. 81, 3807 (2002).

HL 57.12 Thu 17:30 H17

Spin Coherence in ZnO — •Christoph Schwark[1], Vera Klinke[1], Gernot Güntherodt[1], Matthias Althammer[2], Sebastian T.B. Goennenwein[2], Matthias Opel[2], Rudolf Gross[2], Thomas Wassner[3], Martin S. Brandt[3], and Bernd Beschoten[1] — [1]Physikalisches Institut IIA, RWTH Aachen University, Aachen, and JARA - Fundamentals of Future Information Technology, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [3]Walter Schottky Institut, Technische Universität München, Garching, Germany

ZnO is a promising candidate for future spintronic applications due to its wide bandgap and small spin-orbit coupling. Using time resolved Faraday rotation experiments, we have studied the spin dephasing time T_2^* as a function of temperature in epitaxial ZnO thin films. Two sets of samples were investigated: one set of ZnO films was deposited on sapphire substrates via pulsed laser deposition, the other was grown using plasma-assisted molecular beam epitaxy. At 10 K, we observe spin dephasing times in excess of 20 ns, surpassing all previously reported values in ZnO bulk single crystals and thin films [1]. We will discuss the correlation between the spin dephasing time observed experimentally and the crystalline quality, as well as the evolution of T_2^* with temperature.

Financial support by DFG through SPP 1285 and by HGF through VISel - Virtual Institute of Spin Electronics is gratefully acknowledged.

[1] Gosh *et al.*, Appl. Phys. Lett **86**, 232507 (2005).

HL 57.13 Thu 17:45 H17

Majority and minority carrier traps in a n - type ZnO thin film — •Matthias Schmidt, Martin Ellguth, Holger v. Wenckstern, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany

The majority of the published deep level transient spectroscopy (DLTS) data on defects in ZnO stems from energy levels in the upper third of the ZnO band gap. This is due to the p doping difficulty and the wide band gap. Only few reports on DLTS studies using pn junctions for the investigation of hole traps in the vicinity of the valence band exist.

In this work we investigated defects present in a ZnO thin film grown by pulsed laser deposition on a two side polished a-plane sapphire substrate. Space charge regions (SCR) were provided by Pd Schottky contacts. We employed standard DLTS for the detection of majority carrier traps, e.g. E3. Using the double DLTS technique, we observed the Poole Frenkel effect for the E3 deep level. Hole traps were studied by minority carrier spectroscopy, a DLTS technique, where instead of the voltage pulse a UV LED pulse illuminates the sample from the back such that electron hole pairs are created. Due to the electric field at the Schottky barrier, the electrons drift towards the bulk and the holes into the SCR. In doing so, hole traps are filled during the pulse and hole emission is observed by DLTS. These experiments revealed the existence of a deep level approx. 430 meV above the valence band.

HL 58: Photonic Crystals: Experiment

Time: Thursday 16:00–17:45 Location: H13

HL 58.1 Thu 16:00 H13

Liquid crystal infiltrated photonic crystal fibers — •Alexander Lorenz, Heinz Kitzerow, and Rolf Schuhmann — University of Paderborn, Warburger Str. 100, 33098 Paderborn

Experimental results obtained by means of a cut back technique indicate low attenuations ($<$ 1 dB/cm) for a solid core photonic crystal fiber filled with the nematic liquid crystal E7. These results observed in the visible wavelength range are compared with electromagnetic field simulations. The latter are carried out with a full vectorial finite element algorithm. Based on the modal properties under the condition of perpendicular anchoring of the liquid crystal molecules, the wavelength dependent attenuation is estimated using a power loss model considering the turbidity of the nematic liquid crystal. The results indicate that the scattering properties of this type of materials make them extremely interesting for fiber optical filters in the visible wavelength range and that filling materials with a relatively high turbidity are in general potentially useful as filling materials for solid core photonic crystal fibers.

HL 58.2 Thu 16:15 H13

Photonic crystal resonators with electrical contacts — •Martin Kamp, Benedikt Friess, Thomas Schlereth, Sven Höfling, and Lukas Worschech — Technische Physik, Am Hubland, 97074 Würzburg

Photonic crystal (PhC) resonators with embedded quantum dots have become an intensively studied solid state system for experiments on cavity quantum electrodynamics. Contacts that allow carrier injection/extraction or the possibility to apply an electric field to the quantum dots provide an additional degree of control over these structures.

We have investigated PhC resonators fabricated in GaAs membranes with embedded InGaAs quantum dots. The upper and lower half of the GaAs membrane were doped, thus forming a pn junction. After definition of the contact metallization to the front and back side of the sample, photonic cystal resonators based on three missing holes in a PhC lattice were fabricated. The structures were measured by low temperature photo- and electroluminescence. The latter was observed when operating the structures in forward bias. A reverse bias allowed to tune the emission wavelength of quantum dots in the cavity by the quantum confined Stark effect. In addition, photocurrent spectroscopy was performed by scanning a tunable laser over the resonance of the cavity and detecting the photocurrent. The resonance of the PhC cavity is clearly observed, with a quality factor comparable to that observed in the photoluminescence.

HL 58.3 Thu 16:30 H13

Angle-resolved fluorescence detection by defocused wide-field imaging — •Rebecca Wagner, Georg Kropat, and Frank Cichos — Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

Photonic Crystals (PCs) are materials where the dielectric constant varies periodically. Multiple scattering of light on this spatially modulated refractive index leads to the formation of a photonic band structure including photonic band gaps where light can not propagate through the material. This band structure can for example be probed by angle resolved reflection spectroscopy. However, for every

angle of incidence the detection angle has to be varied since reflections can occur on different lattice plane families, which makes this method very time consuming. A faster method is angle resolved fluorescence spectroscopy of internal emitters where only the angle of detection has to be varied. Still the problem remains to make sure that one measures always at the same position, otherwise one averages over different crystal domains and defects. We are developing a way to collect light emitted in all directions in one measurement, based on defocused imaging of single emitters in 3D PCs. Since these images result from the diffraction of electromagnetic waves from the aperture of the microscope objective, the diffraction patterns change when light emission in certain directions is inhibited by the PC. We observe this modification for example in a threefold symmetry of the image, which we attribute to reflections on different lattice plane families of the PC.

HL 58.4 Thu 16:45 H13

Optical Microresonators Fabricated by Epitaxial DBR Overgrowth of Pyramidal GaAs Cavities — •Daniel Rülke, Matthias Karl, Dongzhi Hu, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Karlsruher Institut für Technologie (KIT), 76131 Karlsruhe, Germany

Based on the fabrication technique of recently investigated pyramidal GaAs microresonators, we have developed a method to create microcavities with the shape of truncated pyramids sandwiched between two distributed Bragg reflectors (DBRs). To this end, an AlAs sacrificial layer is utilized for facet formation in a wet-chemical etching process. The sacrificial layer is then removed in a selective etching step and, after a further selective etching step, truncated pyramids with a DBR underneath are obtained. Overgrown with a second DBR on top, these cavities serve as high-quality (Q) resonators with observed Q-factors of optical modes up to 8000. Compared to conventional cylindric pillar-resonators their smooth facet angle of about 20° promises reduced scattering losses at the edges of the cavity and a reduced density of leaky modes.

HL 58.5 Thu 17:00 H13

Optical properties of waveguide circuits in GaAs-based photonic crystals — •Rebecca Saive, Norman Hauke, Alexander W. Holleitner, and Jonathan J. Finley — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany

We present micro-photoluminescence measurements on GaAs photonic crystal waveguides, designed with transmission bands between 875 nm and 950 nm. The photonic waveguide properties were simulated using RSOFTs CAD, FullWave and BandSolve modules which operate with finite-difference time-domain and planewave expansion methods, respectively. The structures were defined by electron-beam lithography and then, transferred to the GaAs matrix with reactive ion etching. In a final step, we underetched the waveguide structures with hydrofluoric acid to obtain a freestanding membrane. Light was coupled into the waveguide via a tapered optical fiber, while the transmitted, out-of-plane scattered light, at the end of the waveguide was collected with a microscope objective and detected with a Si-photodiode. The transmission bands in simulation and experiment are in good agreement.

HL 58.6 Thu 17:15 H13

Long living surface acoustiv wafes in a phononic-photonic crystal — Alexey S. Salasyuk[1], Alexey V. Scherbakov[1], Dmitriy R. Yakovlev[1,3], Andrey V. Akimov[1,3], Alexander A. Kaplyanskii[1], Saveliy F. Kaplan[1], Sergey A. Grudinkin[1], Alexey V. Nashekin[1], Alexander B. Pevtsov[1], Valeriy G. Golubev[1], Thorsten Berstermann[2], Christian Brüggemann[2], •Michael Bombeck[2], and Manfred Bayer[2] — [1]Ioffe Physical-Technical Institute of the Russian Academy of Sciences, 194021 St.Petersburg, Russia — [2]Experimentelle Physik 2, Technische Universität Dortmund, D-44227 Dortmund, Germany — [3]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, UK

The time evolution of bulk and surface acoustic wafes in synthetic opals with different sintering is detected by the changes of reflectivity. The opal system is a three dimensional array of close packed silica spheres with approximately 350nm diameter. It is known to provide a photonic stopband in the near infra red and also posses a full three dimensional phononic band gap in the GHz range. An acoustic puls is injected into the opal by a thermo-elastic transducer from a 800nm 150fs Ti:Sa laser puls. The changes of the reflectivity due to acoustic excitation of the opal are sampled by a probe pulse from the same laser. The main result of our measurments is the observation of a long-living acoustic mode corresponding to the first band gap of the phononic crystal with weak sintering. There is no observation of a long living mode in an opal with stronger sintering according to theory predictions.

HL 58.7 Thu 17:30 H13

Strain dependence of second harmonic generation in silicon — •Clemens Schriever[1], Christian Bohley[1], Jörg Schilling[1], and Ralf Wehrspohn[2] — [1]ZIK "Sili-nano", Martin-Luther-University Halle — [2]Martin-Luther-University Halle Wittenberg

In recent years, silicon has become a favored material in photonics, mainly due to its highly optimized CMOS processing technology and its suitable optical properties at telecommunication wavelengths. Here it has proven itself as passive optical component. The difficulty of integrating silicon into active optoelectronics, where electrical and optical functionalities are combined in a monolithic device is due to its limited active optical properties. Generally, second order nonlinear optical effects like second harmonic generation are forbidden in silicon because of its inversion symmetry. However, an induced inhomogeneous strain can reduce the symmetry of the crystal and therefore give rise to a second order nonlinear susceptibility. This opens the possibility to create silicon based active optical devices, e.g. electro-optical modulators and switches. Here we determine experimentally the strain dependence of the second order nonlinear susceptibility on the applied strain by means of second harmonic generation in a reflecting geometry. The components of the second order nonlinear susceptibility are determined and compared to the unstrained case. The results agree well with theoretical predictions that take into account the applied strain. There, an analytical dependence of the second order nonlinear susceptibility on the strain is derived from an sp^3-orbital concept.

HL 59: Quantum Dots and Wires, Optical Properties V

Time: Thursday 16:00–17:45 Location: H14

HL 59.1 Thu 16:00 H14

How to watch a pulse become coherent — •Marc Assmann[1], Franziska Veit[1], Manfred Bayer[1], Christopher Gies[2], Frank Jahnke[2], Stephan Reitzenstein[3], Sven Höfling[3], Lukas Worschech[3], and Alfred Forchel[3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute for Theoretical Physics, University of Bremen, 28334 Bremen, Germany — [3]Technische Physik, Physikalisches Institut, Universität Würzburg, 97074 Würzburg, Germany

Ultrafast changes of the statistical properties of light emission are studied for quantum-dot micropillar lasers. Using pulsed excitation with varying power we follow the time-evolution of the output intensity as well as the second-order correlation function $g^{(2)}(t,\tau=0)$ reflecting two-photon coincidences. Due to the previously impossible time resolution of 2 picoseconds we can study the dynamical transition between thermal and coherent light emission. The build-up and breakdown of coherence during a pulsed emission occurs with the same time dependence as the variation of the output intensity in the emission pulse and broadens with increasing excitation. This shows that the same physical mechanisms, the interplay of stimulated emission and cavity losses, determines both, the mean photon number and two-photon coincidences. Results of a microscopic theory confirm the experimental findings.

HL 59.2 Thu 16:15 H14

Quantum Kinetics of Multiple Exciton Generation in Quantum Dots — •Franz Schulze, Carsten Weber, and Andreas Knorr — Institut für Theoretische Physik, Technische Universität Berlin, Germany

The simultaneous generation of multiple excitons in quantum dots by a single photon, called multiple exciton generation (MEG), is of spe-

cial interest for increasing the photovoltaic conversion efficiency [1,2]. We investigate the quantum kinetics of the creation of multiple excitons in multilevel quantum dots within a density matrix approach and present corresponding numerical results. We focus on the Auger-type Coulomb processes of impact ionization and Auger recombination to derive the equations of motion for exciton densities, electron densities and coherences.

[1] R. J. Ellingson *et al.*, Nano Lett. **5**, 865 (2005)
[2] P. Kowalski, P. Machnikowski, Acta Phys. Pol. A **114**, 1187 (2008)

HL 59.3 Thu 16:30 H14

Theory of phonon assisted relaxation in quantum dot systems — •Matthias-René Dachner, Janik Wolters, Felix Schlosser, Marten Richter, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

We investigate microscopically the phonon assisted relaxation channels in an electrically pumped quantum dot (QD) system consisting of 0D QD states, 2D wetting layer (WL) states and 3D bulk states. For the WL–QD scattering multiphonon processes are included by a higher order Markovian approach based on a projection operator theory. Subsequently applying an effective second quantization treatment many body effects like Pauli blocking are included in the calculated scattering rates.

Furthermore, we investigate the population dynamics in the WL and observe carrier heating of the pumped system, where the temperature and current dependence is discussed [1].

[1] J. Wolters et al., Phys. Rev. B (accepted).

HL 59.4 Thu 16:45 H14

Coherent spectroscopy of single GaAs/AlGaAs quantum dots — •Christian Wolpert[1,2], Lijuan Wang[3], Paola Atkinson[3], Armando Rastelli[3], Oliver G. Schmidt[3], and Markus Lippitz[1,2] — [1]Max-Planck Institut für Festkörperforschung, Stuttgart, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Germany — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Germany

Semiconductor quantum dots (QDs) are a promising candidate for the realization of qbits for quantum computation. With coherence times of below 1 ns, writing, manipulation and read-out of a qbit requires ultrafast laser pulses interacting coherently with the system. A key experiment in this context is the observation of Rabi oscillations, where the population of a two-level system can be driven coherently back and forth between the ground state and the excited state. An almost shot-noise limited reflection pump-probe technique was employed by which we accomplished to measure Rabi oscillations in one of the fine structure split ground state excitonic states of our QDs, monitoring its population by the bleaching it imposes on the second ground state exciton transition. The first period of these population oscillations yields a dipole moment of about 10 Dy for the s-shell exciton. A second period is still visible, but stretched and shifted to higher pulse areas, which could be due to screening processes caused by carriers that are optically excited in the GaAs substrate.

HL 59.5 Thu 17:00 H14

Polarization and coherence properties of semiconductor micropillar lasers — •Jean-Sebastian Tempel[1], Ilya Akimov[1], Christian Schneider[2], Sven Höfling[2], Alfred Forchel[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, D-44221 Dortmund — [2]Technische Physik, Universität Würzburg, D-97074 Würzburg

We present systematic, polarization selective investigations on the coherence properties of AlGaInAs quantum-dot micropillar lasers. The study of the first-order field-correlation function $g^{(1)}(\tau)$ reveals a polarization splitting of the fundamental mode of nominally circular pillars. It can be shown that the two orthogonally polarized components of the fundamental mode differ in both strength and coherence time. At excitation powers well above the lasing threshold, one mode is dominating the emission with an extinction ratio of more than 99 %. The stronger mode reveals an increase of the coherence time up to a record value of about 20 ns.

HL 59.6 Thu 17:15 H14

Coherent manipulation of the exciton phase via the AC-Stark effect — •Simon Gordon[1], Steffen Michaelis de Vasconcellos[1], Max Bichler[2], Torsten Meier[1], and Artur Zrenner[1] — [1]CeOPP, Universität Paderborn, Paderborn, Germany — [2]WSI, TU München, Garching, Germany

Excitons in InGaAs/GaAs quantum dots are an interesting implementation of qubits, especially concerning the interaction with photons. To achieve universal coherent control over a single qubit, a quantum phase gate is fundamental requirement. In our current contribution, we show that a quantum phase for an exciton qubit can be manipulated coherently by a non-resonant light field via the AC-Stark effect.

The effect of this non-resonant light field is investigated experimentally as well as theoretically by calculations based on the optical Bloch equations. In the experimental realization we used a Ramsey-like setup [1] to detect the phase shift and possible effects on the population of the qubit. Thereby, a first resonant laser pulse creates an coherent superposition of the exciton state and a second laser pulse after a fixed time delay probes the phase and population of the exciton qubit. During the delay time, the quantum phase is manipulated with either a non-resonant cw laser or a non-resonant ps laser pulse. We could demonstrate, that under selected conditions only the phase of the exciton qubit and not its population is influenced. The phase shift is thereby a function of the amplitude and the detuning of the non-resonant light field.

[1] Stufler et al. Phys. Rev. Lett. **96**, 037402 (2006)

HL 59.7 Thu 17:30 H14

Coherent Coupling of Two Different Semiconductor Quantum Dots via an Optical Cavity Mode — •Arne Laucht, José M. Villas-Bôas, Norman Hauke, Felix Hofbauer, Gerhard Böhm, Michael Kaniber, and Jonathan J. Finley — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany

We present a combined experimental and theoretical study of a strongly coupled system consisting of two spatially separated self-assembled InGaAs quantum dots and a single optical nanocavity mode. Due to their different size and strain profile, the two dots exhibit markedly different electric field dependences due to the quantum confined Stark effect. This allows us to tune them into resonance simply by changing the applied bias voltage and to independently tune them into the photonic crystal nanocavity mode. Photoluminescence measurements show a characteristic triple peak during the double anticrossing, which is a clear signature of a coherently coupled system of three quantum states. We fit the emission spectra of the coupled system to theory and are able to investigate the coupling between the two quantum dots directly via the cavity mode. Furthermore, we investigate the coupling between the two quantum dots when they are detuned from the cavity mode in a V-system where dephasing due to incoherent losses from the cavity mode can be reduced.

HL 60: Poster II: Optical Properties, incl. Photonic Crystals and Ultrafast Phenomena

Time: Thursday 18:00–20:00 Location: Poster D1

HL 60.1 Thu 18:00 Poster D1

A numerical adaptive wavelet approach to excitonic absorption spectra of disordered semiconductor nanostructures — •Christian Mollet[1], Torsten Meier[2], and Angela Kunoth[1] — [1]Institut für Mathematik, University Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Department of Physics and CeOPP, University Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Semiconductor nanostructures always contain a certain degree of disorder due to interface roughness and/or alloy disorder. The disorder has significant in uence on the optical properties, e.g., excitonic absorption spectra [1]. An adaptive wavelet approach [2,3] for the solution of the excitonic Schrödinger equation, i.e., the semiconductor Bloch equation for the interband coherence linear in the external field, has been developed and applied to compute absorption spectra and/or wave functions. Results obtained for a thin GaAs semiconductor quantum wire considering a number of different model disorder potentials are

presented and discussed.

[1] T. Meier, P. Thomas, and S. W. Koch, Coherent Semiconductor Optics: From Basic Principles to Nanostructure Applications, Springer, Berlin, 2007.

[2] W. Dahmen, T. Rohwedder, R. Schneider, and A. Zeiser, Numer. Math. 110, 277-312 (2008).

[3] C. Burstedde and A. Kunoth, Numer. Algor. 48, 161-188 (2008).

HL 60.2 Thu 18:00 Poster D1

Influence of Coulomb correlations on the quantum well intersubband absorption — •Thi Uyen-Khanh Dang, Andreas Knorr, Carsten Weber, and Marten Richter — Institut für Theoretische Physik, Technische Universität Berlin, Germany

We present a non-Markovian theory for the description of quantum well intersubband dynamics, focusing on the influence of the electron-electron interaction on the absorption properties at low temperatures. The many-body problem is treated within a density-matrix approach using the correlation expansion to obtain equations of motion for the electron density and the intersubband coherence [1]. The inclusion of the electron-electron interaction leads to a correlated electronic ground state and a self-consistently determined broadening of the intersubband absorption spectrum. The resulting influence on the absorption line shape is investigated and discussed for different quantum well widths and doping densities.

[1] I. Waldmüller et al., Phys. Rev. B 69, 20530766 (2004).

HL 60.3 Thu 18:00 Poster D1

Degree of ionization and excitonic BEC window in Cu_2O and ZnSe — •Felix Richter, Dirk Semkat, Günter Manzke, Dietrich Kremp, and Klaus Henneberger — Institut für Physik, Universität Rostock, 18051 Rostock

We evaluate the ionization equilibrium in the high-density electron–hole plasma of Cu_2O and ZnSe. The influence of many-particle effects on the chemical potentials of carriers, the exitonic binding energy, and the Mott transition (density ionization) is investigated over a wide range of temperatures and carrier densities. In contrast to simplifying approximations used in the literature we consider full dynamical screening between carriers and find the Mott transition to occur at densities more than one order of magnitude higher than estimated before.

The results are given as a phase diagram of the ionization. Special attention is directed to the determination of the region where an excitonic fraction can reach the critical density and, therefore, Bose–Einstein condensation can occur.

[1] D. Semkat, F. Richter, D. Kremp, G. Manzke, W.-D. Kraeft, and K. Henneberger, *Phys. Rev. B* **80**, 155201 (2009) [2] F. Richter, D. Semkat, D. Kremp, and K. Henneberger, *Phys. Status Solidi C* **6**, 532 (2009) [3] G. Manzke, D. Semkat, F. Richter, D. Kremp, and K. Henneberger, submitted for publication (2009)

HL 60.4 Thu 18:00 Poster D1

Quantum-optical radiation laws for confined semiconductor systems — •Felix Richter and Klaus Henneberger — Institut für Physik, Universität Rostock, 18051 Rostock

We present a quantum-kinetically exact theoretical framework for the propagation, emission and scattering of light in bounded media in the context of semiconductor optics. The theory is based on the nonequilibrium photon Green's functions. Its advantage is that the spatial inhomogeneity inherent to bounded media and, hence, to many semiconductor optics problems, is fully and exactly considered. The electromagnetic properties of media are treated microscopically rather than in an effective approximation, and media may be arbitrarily dispersive and absorptive.

Relations for the propagation of quantized (squeezed) light are given. In this respect, our approach may serve as a replacement for the input-output formalism in quantum optics, which implies some severe approximations as a concession to its simplicity.

The theory yields a generalized Kirchhoff–Planck radiation law which provides insight into the interplay of emission and absorption in nonequilibrium steady-state systems.

[1] F. Richter, M. Florian, and K. Henneberger, *Phys. Rev. B* **78**, 205114 (2008) [2] K. Henneberger and F. Richter, *Phys. Rev. A* **80**, 013807 (2009)

HL 60.5 Thu 18:00 Poster D1

Coupling plasmons and excitons — •Markus Pfeiffer[1,2], Klas Lindfors[1,2], Markus Lippitz[1,2], Harald Giessen[2], Paola Atkinson[3], Armando Rastelli[3], and Oliver G. Schmidt[3] — [1]Max Planck Institut für Festkörperforschung, Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart — [3]IFW Dresden

The spontaneous emission of a single quantum system may be significantly modified by changing the local density of states at the position of the emitter. This allows controlling the light emission properties, e.g., emission rate and direction, using a suitable nanostructure. Plasmon resonant metal structures are a particularly interesting choice since the electromagnetic field is significantly enhanced at the plasmon resonance wavelength. This offers exciting possibilities in both fundamental light-matter studies as well as in applications.

We experimentally investigate the influence of plasmon resonant gold nanostructures on the photoluminescence properties of individual semiconductor quantum dots (QDs). The quantum dots are epitaxially grown AlGaAs/GaAs QDs which are buried a few nanometers beneath the semiconductor surface and photoluminesce at approximately 760 nm wavelength. The advantage of this system is that the optical properties of the QDs are very stable and the transition dipole moments have a fixed orientation. The thin barrier layer allows efficient coupling between the exciton in the quantum dot and a plasmon resonant gold nanostructure on the semiconductor surface. We observe modifications in both the photon emission rate and excited state lifetime when the quantum dot is close to a gold nanostructure.

HL 60.6 Thu 18:00 Poster D1

Simulation of Photonic Crystal Microcavities in Silicon-on-Insulator Waveguides — •Lin Zschiedrich[1], Jan Pomplun[2], Frank Schmidt[1,2], and Sven Burger[1,2] — [1]JCMwave GmbH, Berlin — [2]Zuse Institute Berlin (ZIB)

Photonic crystal microcavities can strongly confine light within a small volume. High Q factors of such structures have been reported [1,2].

We have developed finite-element method (FEM) based solvers for the Maxwell eigenvalue and for the Maxwell scattering problems. The method is based on higher order vectorial elements, adaptive unstructured grids, and on a rigorous treatment of transparent boundaries.

We have simulated experimental setups reported in the literature [1,2]. We present a convergence analysis of the numerical results, and we present very good agreement with experimental results. We further investigate the influence of structural parameters, such as placement and tilt of photonic crystal air holes, on the microcavity Q factor.

[1] P. Velha et al., New J. Phys. 8, 1 (2006).

[2] A. R. M. Zain et al., Opt. Expr. 16, 12084 (2008).

HL 60.7 Thu 18:00 Poster D1

Gain photonic crystal resonators for THz quantum-cascade lasers — •Alexander Benz[1], Christoph Deutsch[1], Gernot Fasching[1], Karl Unterrainer[1], Aaron M. Andrews[2], Pavel Klang[2], Werner Schrenk[2], and Gottfried Strasser[2] — [1]Photonics Institute and Center for Micro- and Nanostructures, Vienna University of Technology, Gusshausstrasse 29/387, A-1040 Vienna, Austria — [2]Institute of Solid-State Electronics and Center for Micro- and Nanostructures, Vienna University of Technology, Floragasse 7/362, A-1040 Vienna, Austria

The terahertz (THz) spectral region is very attractive for applications such as real-time imaging, heterodyne detection or spectroscopy. The preferred, monolithic sources are quantum-cascade lasers (QCLs). Due to inhomogeneous gain broadening a multi-mode emission is typically observed. Photonic crystals (PhCs) are excellent systems for laser resonators, as the full dispersion relation can be designed.

Here, we present the design are realization of microcavity lasers based on active PhCs. The PhC consists of an array of isolated, subwavelength pillars and is fabricated directly from the active region of the THz-QCLs [1, 2]. Thereby, we are able to realize a spatially distributed gain, a central gain region is not required. This resonator concept offers a stable single-mode emission, independently of the driving conditions, and a lithographic tuning range of 15 % of the center lasing frequency.

[1] H. Zhang et al., Opt. Express 15, 16818 (2007)

[2] A. Benz et al., Opt. Express 17, 941 (2009)

HL 60.8 Thu 18:00 Poster D1

Optical properties of high-Q conical polymeric microcavities — •Simone Schleede[1], Mario Hauser[1], Tobias Grossmann[1,2], Julian Fischer[1], Torsten Beck[1], Christoph Vannahme[2], Timo Mappes[2], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institut für Mikrostrukturtechnik, Karlsruhe Institute of Technology

(KIT), Karlsruhe, Germany

We report on the fabrication of novel high-Q microresonators made of low loss, thermoplastic polymer poly(methyl methacrylate) (PMMA), which are directly processed on a silicon substrate. Using this polymer-on-silicon material in combination with a thermal reflow step enables cavities of conical shape and ultra smooth surface, dramatically reducing the optical losses caused by surface scatting of the whispering-gallery-modes (WGMs). The cavity Q factor is above two million in the 1300 nm wavelength region and can theoretically reach values greater than ten million in the visible spectral range. Finite element simulations show the existence of a variety of higher order radial and axial WGMs explaining the complexity of the transmission spectra measured using a tunable diode laser coupled to a tapered optical fiber waveguide.

Furthermore, integration of dyes as gain media to the polymer cavities, offers a new possibility for realization of optically pumped, low-threshold, organic microlasers.

HL 60.9 Thu 18:00 Poster D1

Mode Behavior of Coupled Photonic Cavities — •Dennis Ehmer, Matthias Reichelt, and Torsten Meier — Department Physik, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

The mode behavior of several coupled photonic cavities embedded in a dielectric Bragg structure is investigated numerically using the finite-difference time-domain algorithm [1]. It is shown that for the case of three cavities the well-known symmetry of the eigenmodes leads to a zero field in one of the cavities which has also been recently measured for three coupled microdisk resonators [2]. Furthermore, the coupling strength between two cavities depending on geometrical parameters is determined. [3] It is planned to additionally introduce semiconductor quantum dots into the cavities.

[1] A. Taflove, *Advances in Computational Electrodynamics*, Artech House, (1998).

[2] C. Schmidt *et al.*, Phys. Rev. A **80**, 043841 (2009).

[3] D. Ehmer, *Modellrechnungen zu eindimensionalen gekoppelten photonischen Resonatoren und Zweiniveausystemen* , Bachelor Thesis, University of Paderborn, to be published.

HL 60.10 Thu 18:00 Poster D1

Fiber Coupled Waveguided Metallic Photonic Crystals — •Shengfei Feng[1,2], Peter J. Klar[2], Achim Kronenberger[2], Torsten Henning[2], and Xinping Zhang[1] — [1]College of Applied Sciences, Beijing University of Technology, Beijing 100124, P. R. China — [2]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Germany

Fabrication and characterization of waveguided metallic photonic crystals on the facets of multimode fibers are demonstrated. A layer of zinc oxide (ZnO) is used as the waveguide in the device. The ZnO layer is deposited on the facet of the fiber by radio-frequency magnetron sputtering. The one-dimensional gold-grating on top of the ZnO layer is fabricated using electron beam lithography and a lift-off process. This device combines the unique property of waveguide metallic photonic crystal structure with the transmission property of a fiber. When a beam of broadband white light is coupled into the fiber from the non-structured end, a strong and narrow band signal can be obtained in the reflected light, which is transmitted back through the fiber. The wavelength of the reflection peak of the narrow-band reflection is sensitive to the refractive index of the environment. Therefore, this device may be used to detect the refractive index changes of the opaque liquids.

HL 60.11 Thu 18:00 Poster D1

2D photonic crystals for manipulation of emission of the InGaAs/GaAs — •Sabrina Darmawi[1], Torsten Henning[1], Peter J. Klar[1], Wolfgang Stolz[2], Kerstin Volz[2], and Sangam Chatterjee[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Gießen — [2]FB Physik, Philipps-Universität, Renthof 5, 35032 Marburg

We aim at suppressing local losses in III-V based vertical emitters by using two-dimensional photonic crystals. As a proof of principle we fabricated a hexagonal 2D photonic crystal in GaAs layers and a single InGaAs/GaAs quantum well structure. Electron beam lithography was used to define the pattern. The pattern was transferred into the specimens by wet-chemical etching. The structures obtained were characterized by atomic force microscopy and scanning electron microscopy. The luminescence of the structures with and without 2D photonic crystals will be compared.

HL 60.12 Thu 18:00 Poster D1

Multiple Bragg diffraction in photonic crystals — •Georg Kropat, Rebecca Wagner, and Frank Cichos — Molecular Nanophotonics Group, University Leipzig, Linnéstr. 5, 04103 Leipzig

We investigated colloidal fcc crystals made of polystyrene spheres in air by angle resolved reflectivity measurements. Bragg reflections occur due to constructive interference of the light which is diffracted by the crystalline structure of the photonic crystal. For angles of incidence of around 35°, multiple reflection peaks are observed at points of intersecting planes. The dependence of this multiple reflection on the turning angle around the surface normal of the incident plane was checked. Simulated photonic band structures reveal that the multiple peaks are caused by simultaneous Bragg diffraction at (111) and (200) planes. We demonstrate that this leads to significant deviations from simple Bragg diffraction. As the emission of dye molecules inside the photonic crystal is also influenced by Bragg reflections, we expect this band repulsion also to be of importance for the modification of the angular emission of dye doped beads in photonic crystals.

HL 60.13 Thu 18:00 Poster D1

Macroscopically Homogeneous Inverse Opal Films — •Parvin Sharifi Rajabi and Frank Marlow — Max-Planck-Institut für Kohlenforschung, Mülheim (Ruhr), Germany

Slow photons are states with low group velocity in the photonic crystals. They exist at energies just above and below the photonic stop bands. These states can be used for enhancing chemical reactions of photocatalysts in photonic crystal shape. Then the material structure on the sub-micrometer scale manipulates the light propagation and influences the photochemical reaction rate. For fabricating the microstructured photocatalyst, polystyrene opal films [1] were used as templates for titania inverse opals. The capillary deposition method (CDM) was used for the opal film preparation [2] and the titania was synthesized in a sol-gel process also inside thin capillary cells. Macroscopically homogeneous titania inverse opal films with visible opalescence were successfully prepared. The influence of inverse opal structure on the optical properties and photochemical activity of these films is investigated.

[1] F. Marlow, Muldarisnur, P. Sharifi, R. Brinkmann, C. Mendive, Angew. Chem. Int. Ed. 2009, 48, 6212.

[2] H. L. Li, W. Dong, H. J. Bongard, F. Marlow, J. Phys. Chem. B 2005, 109, 9939.

HL 60.14 Thu 18:00 Poster D1

Local Infiltration of Individual Pores with multiple Dyes in Macroporous Silicon Photonic Crystals — •Peter W. Nolte[1], Daniel Pergande[1], Roland Salzer[3], Brian T. Makowski[2], Stefan L. Schweizer[1], Markus Geuss[2], Martin Steinhart[4], Christoph Weder[2] und Ralf B. Wehrspohn[1,3] — [1]Martin-Luther-University Halle-Wittenberg — [2]University of Fribourg — [3]Fraunhofer Institute for Mechanics of Materials — [4]University of Osnabrück

Photonic crystals (PhC) are promising candidates for novel optical components. Passive devices realized with PhC, e.g. complex waveguides, are widely known. However, for many applications active devices are required. One possible way to realize such devices is the functionalization of 2D PhC. This can be done by combining 2D PhC with polymers, liquid crystals or dyes. Especially the functionalization of individual pores is of great interest. We present a method that allows the infiltration of individual pores of 2D silicon PhC with various materials in one sample. For the infiltration of individual pores we use 2D PhC templates made of macroporous silicon, electron beam physical vapor deposition, focused ion beam technique, electrochemical deposition and the wetting assisted templating (WASTE)-process.

HL 60.15 Thu 18:00 Poster D1

Nonlinear Optical Spectroscopy of Metamaterials — •Mathieu Gentile[1], Richard Taubert[2], Mario Hentschel[2], Harald Giessen[2], and Manfred Fiebig[1] — [1]Helmholtz-Institut für Strahlen- und Kern- physik, Universität Bonn, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Germany

Optical metamaterials are the gateway to fundamentally new optical properties: they allow materials with negative values for the effective electric permittivity, ε, and magnetic permeability, μ.

We present a set of second harmonic generation (SHG) spectra of

gold structure arrays on a glass substrate with various geometries. With amplified 130 fs laser pulses, the spectral response was measured in the range from 1.55 eV to 3.00 eV.

Measurements are in perfect agreement with the SHG tensor components allowed by the sample symmetry. The linear reflection spectrum of these structures displays a resonance for photon energies around 0.82 eV. In contrast, SHG spectra reveal resonances at different photon energies that are determined by the geometry of the metamaterial "atoms" while the linear optical properties of the metamaterial and the spectral characteristics of the gold appear to be of minor significance.

HL 60.16 Thu 18:00 Poster D1

Optical Conductivity of Graphene in the THz Range — •Alexander Urich, Juraj Darmo, Daniel Dietze, Michael Martl, and Karl Unterrainer — Vienna University of Technology, Photonics Institute, 1040 Vienna, Austria

A striking feature of single layer graphene is the linearity of its band structure around the points K and K' in k-space. This fact is theoretically expected to result in strong interaction of graphene with terahertz (THz) radiation under certain conditions and thus makes this material very interesting for the THz spectral range.

Absorption in single layer graphene is dominated by interband processes for high frequencies leading to a universal behavior of the optical conductivity measured in the visible spectrum, whereas intraband processes play the dominant role for low frequencies. Depending on temperature and Fermi energy a transition from a frequency regime with dominant interband contribution to a regime with dominant intraband contribution is predicted to occur in the THz spectral range resulting in a strong frequency dependence of the optical conductivity.

In this contribution we present optical conductivity measurements of an isolated graphene monolayer by means of THz time domain spectroscopy. Due to the poor availability of high quality large scale graphene samples we chose an on-chip approach involving a coplanar waveguide structure for THz generation and detection.

HL 60.17 Thu 18:00 Poster D1

Temperature dependence of the optical energy gap in the absorption edge of the ZrS_xSe_{2-x} layered semiconductor — •Mohamed Moustafa, Anke Wasnick, Christoph Janowitz, and Recardo Manzke — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, D-12489 Berlin, Germany

The energy band gap values Eg of single crystals of layered transition metal dichalcogenide semiconductors of ZrS_xSe_{2-x} (where $0 \leqslant x \leqslant 2$) have been determined from the optical absorption measurements at different temperatures. The samples were prepared by the chemical vapour transport technique and characterized with help of different methods such as LEED and EDX. The band gap values showed an approximate linear dependence with the composition parameter x. The temperature dependence of Eg is presented and compared to the semi-empirical model proposed by Mannogian and Woolley [1]. Additionally, the observed exponential behaviour of the absorption coefficient tail near the fundamental edge is analysed and interpreted based on the Urbach rule [2].

[1] A. Mannogian and J. C. Woolley, Can. J. Phys. 62, 285 (1984)
[2] F. Urbach, Phys. Rev. 92, 1324 (1953)

HL 60.18 Thu 18:00 Poster D1

Low-temperature dielectric function of *a*-plane $Mg_xZn_{1-x}O$ — •David Schumacher, Rüdiger Schmidt-Grund, Philipp Kühne, Helena Hilmer, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

The object of our investigation is the temperature dependent dielectric function of $Mg_xZn_{1-x}O$ ($x < 0.1$) thin films. It has been obtained by means of spectroscopic ellipsometry in the energy range of 1 - 4.5 eV and at temperatures between 10 K and 470 K. The *a*-oriented $Mg_xZn_{1-x}O$ thin films were deposited by pulsed laser deposition (PLD) on *r*-oriented sapphire (Al_2O_3) substrate. All measurements were performed under UHV conditions ($p < 10^{-9}$ mbar) in order to prevent an accumulation of ice and residual gases on the sample surface. Since previous experiments had shown a degradation of the surface quality due to the high-temperature measurements under UHV conditions, all samples were passivated by an amorphous 60 nm thick YSZ (Yttria-stabilized zirconia) layer.

The independent components of the dielectric tensor parallel $\varepsilon_\parallel$ and perpendicular $\varepsilon_\perp$ to the crystal axis were found by layer stack model analysis using parameterized model dielectric functions. We derived the temperature and alloy dependence of the near band gap band-to-band transition energies, exciton binding energies and broadening parameters.

HL 60.19 Thu 18:00 Poster D1

Four-Wave Mixing in Gallium Selenide (GaSe) with a cw HeNe Laser — •Martin Baaske[1], Lothar Kador[1], Kerim R. Allakhverdiev[2,3], Tarik Baykara[2], and Eldar Yu. Salaev[3] — [1]University of Bayreuth, Institute of Physics and Bayreuther Institut für Makromolekülforschung (BIMF), 95440 Bayreuth, Germany — [2]Marmara Research Centre of TÜBITAK, Materials Institute, P. K. 21, 41470 Gebze/Koçaeli, Turkey — [3]Azerbaijan National Academy of Sciences, Institute of Physics, 370073 Baku, Azerbaijan

Quasi-degenerate four-wave mixing (FWM) experiments have been performed on the layered chalcogenide semiconductor gallium selenide (GaSe) with a 15 mW cw HeNe laser. Since the band gap of this material is close to the photon energy of the laser, its third-order susceptibility $\chi^{(3)}$ experiences very strong resonance enhancement, so FWM signals can be readily detected with a setup adapted from [1]. The laser radiation is split into three parts, two of which are frequency-shifted with acousto-optic modulators (AOMs) by $\nu_1 = 70$ MHz and $\nu_2 = 110$ MHz, respectively, and focused into a thin GaSe crystal. The generated FWM signal is superimposed with the unshifted laser beam on a fast photodiode, generating a beat note at $2\nu_1 - \nu_2 = 30$ MHz, which is phase-sensitively demodulated using standard radio-frequency electronics. The FWM signal of GaSe is analyzed as a function of temperature.

[1] A. Sherman et al., Opt. Lett. **34**, 49 (2009).

HL 60.20 Thu 18:00 Poster D1

Optical spectroscopy on rolled-up metal semiconductor microtubes in the visible and infrared regime — •Jochen Kerbst, Stephan Schwaiger, Markus Broell, Ricardo Costa, Jens Ehlermann, Andrea Stemmann, Yuliya Stark, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Strained planar metal and semiconductor films are rolled up with multiple rotations to create three-dimensional metamaterials which show the extraordinary optical behavior of a hyperlens [1]. In order to investigate the optical properties of the microtube walls we perform reflection and transmission measurements, respectively, at or through the walls of the microtube. The transmission measurements are realized by manipulating a tapered optical single mode fiber into the tube. At the untapered end the fiber is connected to a supercontinuum white light source with broadband output from 500nm to 2400nm. Holes prepared in the metallized fiber tip emit light which transmits through the walls of the microtube and is collected with a 50x near-infrared-corrected microscope objective and detected with an InGaAs photodiode. By comparing the experimental results with calculations using the transfer matrix method we obtain the effective permittivity of the microtube walls. We find that their plasma frequency is in the visible regime. We gratefully acknowledge support by the SFB 508 and the DFG through GrK 1286.

[1] S. Schwaiger et al., Physical Review Letters 102, 163903 (2009)

HL 60.21 Thu 18:00 Poster D1

An x-ray waveguide fabrication scheme using e-beam lithography, reactive ion etching and wafer bonding — •Henrike Neubauer[1], Mike Kanbach[1], Klaus Giewekemeyer[1], Sebastian Kalbfleisch[1], Sven Philip Krüger[1], Till-Hartmut Metzger-Kleinberg[2], and Tim Salditt[1] — [1]Institut für Röntgenphysik, Universität Göttingen, D-37077 Göttingen, Germany — [2]European Synchrotron Radiation Facility (ESRF), 38043 Grenoble, France

Two-dimensional x-ray waveguide channels can be used as versatile optical components suitable for various applications as high resolution x-ray spectroscopy, diffraction, microscopy and holography[1,2]. We report on a second generation x-ray waveguide fabrication scheme based on e-beam lithography, reactive ion etching and Silicon wafer bonding[3], yielding waveguide channels in the relevant sub-100 nm regime. A successful holographic imaging of a suitable test pattern using hard x-ray radiation is demonstrated[4].

[1] F. Pfeiffer *et al.*, Science 297 (2002) 230.
[2] A. Jarre *et al.*, Phys. Rev. Lett. 94 (2005) 074801.
[3] A. Kohlstedt *et al.*, Appl. Phys. A 91 (2008) 7-12.
[4] H. Neubauer *et al.*, in preparation.

HL 60.22 Thu 18:00 Poster D1

Observation of Landau Levels in the Photoluminescence-Spectra of Direct and Indirect Magnetoexcitons — •Xaver Vögele[1], Katarzyna Kowalik[1], Florian Seilmeier[1], Dieter Schuh[2], Jörg Kotthaus[1], and Alexander Holleitner[3] — [1]Center for NanoScience, Ludwig-Maximilians-Universität, D-80539 München — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg — [3]Technische Universität München, Walter Schottky Institut, D-85748 Garching

By means of photoluminescence (PL) spectra we have investigate the Landau level structure of direct and indirect excitons in AlGaAs/GaAs coupled-quantum-wells (CQW). The electric and magnetic fields were applied perpendicular to the CQW. For magnetic fields B > 2T higher Landau levels (LL) can be observed. The non-equilibrium carrier density was estimated from the intensity evolution of the different LLs for the indirect excitons: i) the second LL disappears for the fields corresponding to filling factor $\nu < 2$ and ii) the intensity of the first LL decreases at $\nu = 1$. We have noted that the effective density increases with increasing electric field. The observed phenomena will be discussed. We acknowledge financial support by the Center for NanoScience (CeNS), the Nanosystems Initiative Munich (NIM), the DFG Project KO 416/17 and A. v. Humboldt Stiftung.

HL 60.23 Thu 18:00 Poster D1

Electrostatic Traps for Indirect Excitons in Coupled Quantum Wells — •Georg Schinner[1], Enrico Schubert[1], Markus Stallhofer[1], Dieter Schuh[2], Andreas Wieck[3], and Jörg Kotthaus[1] — [1]Fakultät für Physik and CeNS, Ludwig-Maximilians-Universität München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, Germany — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

In coupled double quantum wells (DQW) photo-generated and spatially indirect excitons can be widely manipulated via an externally applied voltage. Photoluminescence (PL) experiments employing gated devices reveal a strong quantum confined Stark effect (QCSE) with varying gate voltage and resulting in both a larger red shift of excitonic energy and a lifetime prolonged up to microseconds.

Here we report on PL experiments on indirect excitons in an InGaAs DQW device in which semitransparent gates are employed to tune the in-plane potential landscape. Using a confocal microscope at liquid Helium temperatures we map the in-plane excitons distribution.

Thus in transmission we are able to quantify the potential landscape for indirect excitons with high spatial and spectral resolution. We create via the QCSE efficient trapping potentials with electric fields and demonstrate control of the in-plane dynamics of an excitonic ensemble.

HL 60.24 Thu 18:00 Poster D1

Spatially resolved spectroscopy of dense excitons in potential traps — •Rico Schwartz[1], Nobuko Naka[2], Dietmar Fröhlich[3], Jan Brandt[3], Christian Sandfort[3], and Heinrich Stolz[1] — [1]Institut für Physik, Universität Rostock, D-18051 Rostock, Germany — [2]Division of Physics and Astronomy, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan — [3]Institut für Physik, Universität Dortmund, D-44221 Dortmund, Germany

We report experiments on excitons in Cu_2O confined in a stress-induced trap [1, 2]. The paraexcitons were created by resonant excitation of orthoexcitons followed by ortho-para conversion [3]. The pulsed excitation laser has a linewidth of 1 GHz, a repetition rate of 1 kHz and a pulse length of about 150 ns. In the spatially resolved luminescence spectra we observe a dramatic change from a high temperature shape, where the exciton density follows the potential energy surfaces of the trap, to a low temperature shape with a sharp flank at a z-independent energy. Concomitant, the power dependence of the intensity changes from the usual square root behaviour to a linear law [1]. We discuss whether these observations point towards a condensation of excitons.

[1] D. P. Trauernicht, J. P. Wolfe, and A. Mysyrowicz, Phys. Rev. B 34, 2561 (1986)

[2] N. Naka and N. Nagasawa, Phys. Rev. B 65, 075209 (2002)

[3] J. I. Jang, K. E. O'Hara, and J. P. Wolfe, Phys. Rev. B 70, 195205 (2004)

HL 60.25 Thu 18:00 Poster D1

Distribution of resonance fluorescence from excitons in quantum wells at different temperatures — •Gerolf K. G. Burau, Günter Manzke, Frank Kieseling, and Heinrich Stolz — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18055 Rostock

Resonance fluorescence has been established as a valuable tool for the detection of excitons in quantum wells (QW) [1,2]. We have developed a setup using high numerical aperture objectives giving a spatial resolution of 650 nm at a wavelength of 812 nm of the exciting laser. This enables (i) the spectroscopy of single localized excitons, and (ii) an increase of the intensity of the laser spot by a factor of 50. The sample consists of a series of single QWs with varying well width. Even in highest quality QWs with large well width, the image of the excitation spot under resonant conditions shows a granular structure indicating the localisation of the exciton states.

Exciting any of these states resonantly with a 1 MHz line width single mode cw laser. The resultant resonant Rayleigh scattering could be observed with high spectral and spatial resolution. The spectra show a strong dependent excitation power and temperature. The origins these effects are discussed.

[1] Ch. Nacke et al., Eur. Phys. J. B 30, 303-312 (2002)

[2] D. Schwedt et al., physica status solidi (c) 3, 2477 (2006)

HL 60.26 Thu 18:00 Poster D1

Optical signatures of a Bose-Einstein condensate of excitons in a potential trap — •Siegfried Sobkowiak[1], Dirk Semkat[1,2], Heinrich Stolz[1], Thomas Koch[2], and Holger Fehske[2] — [1]Institut für Physik, Universität Rostock, 18051 Rostock — [2]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald

The theoretical description of excitons in traps has been carried out so far mostly in the frame of a model of ideal bosons. In contrast, concepts for the inclusion of the interaction are well known from the theory of atomic condensates [1], first applications to excitons exist, too [2]. Our first investigations in the framework of a mean-field formalism in local density approximation show distinct signatures of a condensate in the decay luminescence spectrum of the non-condensed excitons [3]. Beyond that, we present here a generalization of the theory to a multi-component gas of interacting para- and orthoexcitons [4], where the consequences of the interaction on the condensation process are of particular interest. We show results for the densities of the individual components and their spatially resolved luminescence spectra and compare with experimental data.

[1] N. P. Proukakis and B. Jackson, J. Phys. B 41, 203002 (2008).

[2] L. A. Banyai et al., Phys. Rev. B 70, 045201 (2004).

[3] H. Stolz and D. Semkat, submitted to Phys. Rev. B (2009).

[4] S. Sobkowiak, D. Semkat, H. Stolz, Th. Koch, and H. Fehske, in preparation.

HL 60.27 Thu 18:00 Poster D1

Polarization sensitive cross-sectional microphotoluminescence of disorder in AlGaAs/GaAs quantum wells

— •Lars Liebermeister and Rainer G. Ulbrich —
IV. Physikalisches Institut, Georg-August Univ. Göttingen, Germany

Polarization sensitive microphotolumniescence measurement is used to create a map of local width and orientation of a quantum well. Atomic disorder causes variation in thickness and local orientation of the quantum well. The emission of exciton states - confined in the quantum well potential - is polarized depending on the orientation of the confinement. This in-plane polarization has been measured with cross-sectional mircophotolumniescence, which gives information about width and orientation of the local quantum well.

HL 60.28 Thu 18:00 Poster D1

Disorder effects in Ga(AsBi) — •Sebastian Imhof[1], Alexej Chernikov[2], Sangam Chatterjee[2], Xianfeng Lu[3], Shane Johnson[3], Dan Beaton[4], Thomas Tiedje[5], Oleg Rubel[6], Angela Thränhardt[1], and Stephan W. Koch[2] — [1]Technische Universität Chemnitz, Deutschland — [2]Philipps-Universität Marburg, Deutschland — [3]Arizona State University, USA — [4]University of British Columbia, Kanada — [5]University of Victoria, Kanada — [6]Lakehead University and Thunder-Bay Regional Research Institute, Kanada

The incorporation of Bi into GaAs reduces the band gap by as much as 60–80 meV per percent Bi. Thus a wide wavelength range in the near and middle infrared region can be reached and Ga(AsBi) is a serious candidate for many applications e.g. diode lasers.

The photoluminesence of the present Ga(AsBi) samples show an

S-shape and the PL linewidth has a maximum at intermediate temperatures. These are typical indications of disorder effects on a very large energy scale. We describe the disorder effects using a kinetic Monte-Carlo simulation. In order to characterize the disorder effects we use experimental time-integrated and time-resolved data and compare these to our theoretical results.

HL 60.29 Thu 18:00 Poster D1

Photoluminescence of extremely dilute semiconductor nanoparticle films — •Matthias Offer[1], Martin Geller[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics and CeNIDE, University Duisburg-Essen — [2]IVG and CeNIDE, University Duisburg-Essen

Light-emitting silicon nanoparticles are attractive candidates for future optoelectronic applications due to ther visible photoluminescence with an efficiency, that is several orders of magnitude higher than for bulk Si. To realize of such devices, a detailed knowledge of the recombination dynamics is an important prerequisite. The photoluminescence (PL) of silicon nanoparticles exhibits an interesting exitonic fine structure with a bright and a dark state, which, surprisingly, have very similar radiative recombination lifetimes [1]. To elucidate the intriguing excitonic properties of Si nanoparticles, it is highly desirable to investigate single particles or few-particle ensembles to answer questions regarding homogeneous line broadening and Zeeman shift. We have dispersed Si nanoparticles in toluene with 1% PMMA, which makes it possible to deposit extremely dilute films of Si particles on arbitrary surfaces. As a reference system, we prepared a similar dispersion with CdSe nanoparticles. Furthermore, a scanning micro-PL setup was designed and realized to map out the local optical properties of nanoscopic semiconductor structures. First results of spatially resolved PL on nanoparticles will be presented and compared to spectra of large-scale ensembles.

[1] S. Luettjohann et al., Europhys. Lett. **79**, 37002 (2007)

HL 60.30 Thu 18:00 Poster D1

Investigations of crystal defects at low temperatures by cathodoluminescence measurements — •Stefan Saager, Matthias Allardt, Ellen Hieckmann, and Jörg Weber — Professur für Halbleiterphysik, Institut für Angewandte Physik, TU Dresden, D-01062 Dresden

Cathodoluminescence (CL) investigations in a scanning electron microscope with a field emission gun offer the possibility to analyse the structure of semiconductor materials and, to localize the origin of luminescence simultaneously.

We studied plastically deformed n-type silicon single crystals with dislocation slip lines on the sample surface. Several emission bands in the IR-range, the so called D-lines, could be observed by CL measurements at low temperatures. These bands can be correlated with certain crystal defects within the dislocations. Attempts will be described to improve the intensity of the D-lines.

HL 60.31 Thu 18:00 Poster D1

Optical Properties of Silver Nanoparticles in Glass — •Christian Matyssek[2,3], Andrei Stalmashonak[1], Oleksiy Kiriyenko[2], Wolfram Hergert[2], and Gerhard Seifert[1] — [1]MLU Halle, Optics Group, von-Danckelmann-Platz 3, 06120 Halle — [2]MLU Halle, Theoretical Physics Group, von-Seckendorff-Platz 1, 06120 Halle — [3]Max-Planck-Institute for Microstructure Physics, Weinberg 2, 06120 Halle

The optical properties of silver nanoparticles (SNPs) in glass are studied. It is possible to transform initially spherical particles with the help of laser pulses with linear polarisation resulting in a prolate spheroidal shape[1]. The transformation process stops for wavelengths shorter than the plasmon resonance of the SNPs. A model for the explanation of the SNP shape modification based on the electric field enhancement at the particle-glass-interface was developed[2]. In order to confirm this model, the extinction efficiency and the electric field enhancement around the particles are calculated. Though for spherical particles Mie theory can be applied, and in principle it could be extended to spheroidal particles, no implementation of this method exists yet. Therefore the calculations for the spheroidal particles are done using the Finite-Element-Method (FEM). The results are in good agreement with experimental findings. While the calculations were done assuming the bulk permittivity for silver, the application of a non-local permittivity for small particles is discussed.

[1] A. Stalmashonak et. al., Opt. Lett. 32, 3215 (2007)
[2] A. Stalmashonak et. al., App. Phys. B. 94, 459 (2009)

HL 60.32 Thu 18:00 Poster D1

Optical Near-Field Measurements on Arrays of Nanoscaled Holes in Gold Films — •Jens Ehlermann, Stephan Schwaiger, Markus Broell, Daniel Stickler, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Scanning near field optical microscopy (SNOM) is a method to examine the distribution of the electromagnetic near field on a samples' surface [1,2]. Using our SNOM we are able to either excite or detect the electromagnetic field with a resolution of about 200 nm using a metallized tapered single mode fiber with a 200 nm aperture. This fiber is mounted on a xyz piezo stage and scans the sample to achieve a two-dimensional image of the topography and the field distribution. We present first near field images of an array of 180 nm holes with 500 nm periodicity in a 50 nm thick gold film. Such structures reveal an enhanced transmission [3] which is attributed to the excitation of surface plasmons [4]. We discuss the detection of these surface plasmons in our structures. We gratefully acknowledge support by the DFG through GrK 1286, SFB 508 and the LEXI Cluster 'Nano Spintronics'.

[1] A. Lewis et al., Ultramicroscopy 13, 227 (1984)
[2] D. W. Pohl et al., Applied Physics Letters 44, 651 (1984)
[3] Ebbesen et al. Nature 391, 667 (1998)
[4] U. Schröter and D. Heitmann, Phyical Review B 60, 4992 (1999)

HL 60.33 Thu 18:00 Poster D1

Self focusing of electromagnetic beam in nonlinear medium. — •Anita Thakur[1,2] and Jamal Berakdar[2] — [1]Max Planck Institute of Microstructure Physics Weinberg 2, D-06120 Halle, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Heinrich-Damerow-Str.4, D-06120 Halle (Saale), Germany

Recent years have witnessed a rapid progress in the controlled optical pulse generation, shaping and propagation in various media. Here we theoretically investigate the self focusing of a laser beam in a parabolic medium by using Wentzel-Kramers-Brillouin (WKB) method within the paraxial ray approximation. We demonstrate numerically the effect of the beam intensity on the focusing /defocusing of the beam. Furthermore, we conducted calculations for inhomogeneous light fields that carry an orbital angular momentum and contrast the results to conventional Gaussian beams.

HL 60.34 Thu 18:00 Poster D1

Ultrafast relaxation dynamics of coherent optical phonons in α-quartz — •Konrad von Volkmann[1], Tobias Kampfrath[2], Marcel Krenz[1], Alexander Grujic[3], Christian Frischkorn[1], and Martin Wolf[1,4] — [1]Freie Universität Berlin, FB Physik, Arnimallee 14, 13353 Berlin, Germany — [2]FOM Institute AMOLF, Science Park 113, 1098 XG Amsterdam, The Netherlands — [3]Femtolasers GmbH, Fernkorngasse 10, 1100 Vienna, Austria — [4]Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin, Germany

Femtosecond laser excitation of α-quartz causes oscillation of the transmitted intensity and polarization of probe light. This is due to coherent phonons modulating the real and imaginary part of the refractive index α-quartz $\tilde{n}_{\mathrm{quartz}} = n + i\,k$. Optical phonon modes are found at 3.9, 6.3, 10.5, 12.2, and 13.9 THz. The observed amplitudes significantly depend on the probe method, either transient transmission or ellipsometry. In the case of transient transmission the signal is due to a transient lens. This effect will be discussed together with thickness and fluence dependent measurements.

We present fluence and temperature dependent data for both probe methods. These measurements show a pump-fluence *in*dependent lifetime indicating that the decay mechanism of the lattice vibrations is phonon-phonon scattering. The temperature dependence of the phonons confirms this finding and enables a detailed discussion of the relaxation mechanism of the involved coherent phonons, the anharmonic three-phonon-decay.

HL 60.35 Thu 18:00 Poster D1

Resonant generation of coherent LO phonons in optically excited biased quantum wells — •Thomas Papenkort[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany

We study the generation of coherent and incoherent phonons in a quantum well. When two exciton lines are simultaneously excited with a short laser pulse, a quantum beat with a frequency determined by the

splitting of the two lines is created. If spatial symmetry is broken by an external electric field, this leads to an oscillating polarization along the growth direction which in turn drives LO phonons. At the same time the electric field can be used to tune the splitting energy due to the quantum confined Stark effect. Experiments by Kojima et al. (Phys. Rev. B **70**, 233306 (2004)) have shown that the generation of coherent phonons is resonantly enhanced when the splitting is tuned to the LO phonon energy. We have performed numerical simulations in the density matrix formalism which reproduce the resonant enhancement. As the splitting energy approaches the LO phonon energy, relaxation by emission of incoherent phonons becomes important. Our model includes this process on a quantum kinetic level, i.e. without using the Markov approximation. We find that although incoherent phonons are dominant in terms of the energy transferred to the lattice, this does not hinder the resonant generation of coherent phonons.

HL 60.36 Thu 18:00 Poster D1

Non-classical phonon states in bulk and quantum dot structures — •Jonas Daniels[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

Non-classical phonon states are of fundamental interest in the field of solid state physics. When optical phonons are generated, they may decay into a pair of acoustic phonons. This so-called Klemens decay channel is similar to the well known photon parametric down-conversion. For photons this leads to the creation of squeezed photon states. Analogously also in the present case squeezed acoustic phonon states emerge, i.e., the fluctuations of the acoustic phonons are smaller than the vacuum fluctuation. We study the spatio-temporal dynamics of the acoustic phonon distributions including the fluctuation and coherence properties in both GaAs bulk and quantum dot systems. In bulk systems the acoustic phonons stem only from the q=0 optical phonon mode and are spatially homogeneous. In contrast, in quantum dot systems also optical modes with nonvanishing q occur, corresponding to spatially inhomogeneous displacement fields. We find that while part of the generated acoustic phonon population leaves the dot, the squeezing mainly remains inside the dot region.

HL 60.37 Thu 18:00 Poster D1

Ultrakurzzeitanalyse von der Ladungsträgerthermalisierung in (GaIn)As und Ge Quantenfilmen — •Kolja Kolata[1], Christoph Lange[1], Niko Köster[1], Sangam Chatterjee[1], Hans Sigg[2], Daniel Chrastina[3], Giovanni Isella[3] und Hans von Känel[3] — [1]Fachbereich Physik, Philipps-Universität Marburg — [2]Labor für Micro- und Nanotechnologie, Paul Scherrer Institut, Schweiz — [3]CNISM und L-NESS, Dipartimento di Fisica del Politecnico di Milano, Polo Regionale di Como

Die transiente Anrege-Abfrage-Spektroskopie ermöglicht es die Ladungsträgerdynamik in Halbleiternanostrukturen, spektral aufgelöst zu untersuchen. Hierdurch gelang es die Zeitregimes der Thermalisierung von optisch injizierten Ladungsträgern in (GaIn)As und Ge Quantenfilmen zu bestimmen. In beiden Materialien wurde eine nicht thermische Verteilung der Ladungsträger beobachtet. Die Relaxation der Ladungsträgerverteilung vom Injektionspunkt an, hin bis zum Grundzustand, wurde auf einer Zeitskala von 500 fs bei Raumtemperatur gemessen. In (GaIn)As thermalisieren die angeregten Ladungsträger (250 meV oberhalb der Bandkante) innerhalb von 300 fs. Durch spinverbotene Übergänge im Leichtlochsystem und der daraus folgenden verlangsamten Relaxation, sind unterschiedliche Ladungsträgerverteilungen im Schwer- und Leichtlochsystem zu beobachten. Im Vergleich zu (GaIn)As erfolgt die Thermalisierung in Ge etwas langsamer, auf Grund der fehlenden Fröhlichwechselwirkung.

HL 60.38 Thu 18:00 Poster D1

Experiments on the spin dephasing anisotropy in asymmetrically Si-delta-doped (001)-grown $Al_{0.3}Ga_{0.7}As$/GaAs quantum wells — •Dominik Waller[1], Michael Griesbeck[1], Vera Lechner[1], Sergey Ganichev[1], Tobias Korn[1], Dieter Schuh[2], Werner Wegscheider[1], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland

It was theoretically predicted [1] and demonstrated experimentally [2] that in zinc blende semiconductors the inplane spin dephasing time of asymmetric, (001)-grown quantum wells depend on the crystal orientation due to the different symmetries of the Rashba and Dresselhaus effective spin-orbit fields. In a series of asymmetrically Si-delta-doped, (001)-grown $Al_{0.3}Ga_{0.7}As$/GaAs multiple quantum wells, where the Si-delta-doping layer position is varied on both sides of the quantum well, the spin relaxation anisotropy was detected at room temperature by using the magnetogyrotropic photogalvanic effect [3].
In our experiments we investigate the spin dephasing anisotropy of this sample series at low temperatures. By using ultrafast time-resolved Kerr rotation technique we were able to detect dependencies of the spin dephasing anisotropy on the sample temperature and the asymmetry of the doping, which controls the strength of the Rashba term.
[1] N. S. Averkiev and L. E. Golub, Phys. Rev. B **60**, 15582 (1999)
[2] N. S. Averkiev et al., Phys. Rev. B **74**, 033305 (2006)
[3] V. Lechner et al., Appl. Phys. Lett. **94**, 242109 (2009)

HL 60.39 Thu 18:00 Poster D1

Cyclotron effect on coherent spin precession of two-dimensional electrons — •Michael Griesbeck[1], Mikhail Glazov[2], Tobias Korn[1], Dominik Waller[1], Dieter Schuh[1], Werner Wegscheider[1], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Peterburg, Russia

We report on time-resolved studies of a two-dimensional electron system (2DES) with a very high mobility of about 15 million cm^2/Vs at sub-Kelvin temperatures. Using the all-optical time-resolved Faraday rotation technique, we could observe coherent oscillations of the optically excited electron spin ensemble about the intrinsic spin-orbit field. By applying classical magnetic fields normal to the sample plane, we were able to detect at sub-Kelvin temperatures the predicted fast oscillations of the spin ensemble about a non-zero value and a strong increase of the spin dephasing time. The fast oscillations rise due to an interplay of the ballistic cyclotron motion of the electrons and the precession of the electrons spins about the intrinsic spin-orbit field. The cyclotron motion rotates the k-dependent spin-orbit fields in the sample plane, this leads to the fast oscillations with a frequency determined by the geometric sum of the cyclotron frequency and the spin-orbit field. The determined values for the oscillation frequency, the oscillation amplitude and the spin dephasing times of the long living tail are in good agreement with a theory based on a kinetic equation approach.

HL 61: Poster II: Materials, Interfaces and Heterostructures

Time: Thursday 18:00–20:00 Location: Poster D1

HL 61.1 Thu 18:00 Poster D1

Phase Change RAM: Non-volatile switching at DRAM speeds — •Philipp Merkelbach[1], Gunanr Bruns[1], Carl Schlockermann[1], Martin Salinga[1], Matthias Wuttig[1], Thomas Happ[2], Jan Boris Philipp[3], and Michael Kund[3] — [1]I. Physikalisches Institut (IA), RWTH Aachen University, 52056 Aachen, Germany — [2]Qimonda Dresden GmbH & Co. OHG, Königsbrücker Strasse 180, 01099 Dresden, Germany — [3]Qimonda AG, Bibergerstr. 93, 82008 Unterhaching, Germany

Phase Change Materials are promising candidates for novel data storage. Known from rewritable optical media like CD-RW and DVD-RW they possess a unique combination of properties: the ability to be switched within nanoseconds between the amorphous and the crystalline phase and a large optical and electrical contrast between both phases. Yet the physical driving mechanism of this transition is not fully understood.

Regarding their crystallization behavior phase change materials can be divided into two different classes, i.e. growth and nucleation dominated. Previously this classification has been established by laser induced crystallization, where the smallest diameter was approximately 1 μm. Now experiments are presented where the bit size is as small as 60

nm. A clear trend of higher switching speeds with smaller amorphous region was observed. This finding is attributed to the increasing impact of crystal growth upon decreasing switchable volume. Using GeTe or materials with similar crystal growth velocities, hence promises nonvolatile phase change memories with DRAM like switching speeds.

HL 61.2 Thu 18:00 Poster D1

Ultrafast phase change RAM cell characterization — •Carl Schlockermann, Gunnar Bruns, Philipp Merkelbach, Hanno Volker, Martin Salinga, and Matthias Wuttig — 1. Physikalisches Institut (1A)

Phase Change materials possess unique material properties which already allow nonvolatile rewritable data storage in optical media (e.g. DVD-RW). The information is stored by the distinct difference of optical properties between the amorphous and crystalline structure. A sufficient data rate can be achieved by the ultrafast crystallization at elevated temperatures. A distinct difference in electrical properties between the phases together with the phenomenon of threshold switching, a sudden drop in resistivity at high electric fields, allows the use of such materials as a purely electronic storage called phase change RAM. Although such memory devices are close to the market with comparable properties as NOR FLASH memories, the afore mentioned phenomenon of threshold switching and the limits of crystallization speed are not yet identified. One reason are limits in the measurement techniques used so far which restrict the measurement speed of such electronic memory cells. In addition they did not allow the measurement of the cell current during the application of voltage pulses with high bandwidth. In this work we present a new measurement setup which overcomes these limits. Our results show that crystallization is possible at extremely high speed in these materials[1]. This may offer the possibility for such memories to compete with DRAM in the future. [1] Bruns G. et. al., App. Phys. Lett. 95, 043108 (2009)

HL 61.3 Thu 18:00 Poster D1

Neutron Scattering and ab initio Studies of $CuCrS_2$ — •Karin Schmalzl[1], Julia Rasch[2,3], Martin Boehm[2], Hannu Mutka[2], Juerg Schefer[3], G. M. Abramova[4], and Joerg F. Loeffler[5] — [1]IFF, Forschungszentrum Juelich, JCNS at ILL, 38042 Grenoble, France — [2]Institut Laue-Langevin, BP 156, 38042 Grenoble, France — [3]LNS, ETH Zuerich and PSI, 5232 Villigen PSI, Switzerland — [4]L. V. Kirensky Institute of Physics, SB RAS, Krasnoyarsk, 660036, Russia — [5]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zuerich, 8093 Zuerich, Switzerland

Transition metal dichalcogenides show a quasi-two dimensional layered structure leading to interesting electronic properties like charge density wave or superconductivity. Due to the triangular lattice of the Cr^{3+} ions $CuCrS_2$ is prone to geometrical frustration. Below T_N=37 K a complex magnetic structure with an incommensurable magnetic propagation vector is present. The magnetic order is coupled to a structural transition. At higher temperatures ionic conductivity of the weakly bound Cu ions emerges.

Inelastic neutron scattering experiments below T_N show a strong non-dispersive, localised mode in Q at about 12 meV. Additionally an enhanced intensity has been observed at crossings of phonon and magnon modes at about 8 meV. Temperature dependent measurements of the phonon density of states show a change of low lying phonon branches, where the strongest change appears at about 150 K at an energy of about 8 meV. Ab initio calculations assign this energy to in plane motions of the Cu atoms.

HL 61.4 Thu 18:00 Poster D1

$Ba_{0.7}Sr_{0.3}O$ thin films on n-Si as high-k material: correlation between structural and electrical properties — •Lisa Kühnemund[1], Dirk Müller-Sajak[1], Alexandr Cosceev[2], Herbert Pfnür[1], and Karl R. Hofmann[2] — [1]Leibniz-Universität Hannover, Inst. f. Festkörperphysik — [2]Leibniz-Universität Hannover, Bauelemente der Mikro- und Nanoelektronik

Crystalline and perfectly lattice matched $Ba_{0.7}Sr_{0.3}O$ films were grown on Si(001), which have a dielectric constant of $\epsilon_r \approx 28$. The thin films have a perfect atomically sharp interface, as found by XPS. They were grown in a UHV chamber by MBE in oxygen ambient conditions and capped with 100nm Au for ex-situ electrical measurements. A 0.5-2ML thick Al intermediate layer improves the adhesion between the Au and the oxide, which have an influence on the electrical properties depending on the thickness of the Al layer.

This material has attractive electrical properties: XPS measurements at the interface show no evidence for SiO_2 formation. Furthermore the density of states at the interface (determined by the Terman method) is very low ($6.3 \cdot 10^{10} eV^{-1}cm^{-2}$) and a factor 10-100 lower than for amorphous BaO, SrO and $Ba_{0.7}Sr_{0.3}O$. This is caused by the good structural properties of the crystalline oxide. Low leakage current densities ($<10^{-6}A/cm^2$) have been found by current-voltage (IV) measurements, supported by sufficient valence and conduction band offsets >1eV at the semiconductor/insulator interface, as measured with XPS and EELS. These band offsets can be tuned by varying the conditions during growth of the interface.

HL 61.5 Thu 18:00 Poster D1

Lanthanide oxides thin films for graphene-based devices — •Ihor Petrov[1], Teodor Toader[1], Claudia Bock[1], Ulrich Kunze[1], Andrian Milanov[2], Anjana Devi[2], and Roland A. Fischer[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Anorganische Chemie II, Ruhr-Universität Bochum

We study the application potential of gadolinium and dysprosium oxide for graphene-based devices. Lanthanide oxide thin films of defined thickness are deposited in the presence of oxygen as well as nitrogen at 400 °C by thermal CVD on an n^+-Si(100) substrate [1]. The roughness of the films is determined by atomic force micrographs and the thickness by cross-section scanning electron microscopy. A breakdown field in the range of 0.3 Vnm^{-1} is determined by I-V measurements for both rare earth oxides. From C-V measurements at 1 MHz the dielectric constant of Gd_2O_3 ($\epsilon_r = 9$) and Dy_2O_3 ($\epsilon_r = 8$) are extracted. Since the dielectric constant of the rare earth oxides are higher compared to SiO_2 we expect an improved screening of charged impurities [2] and therefore an improved performance for graphene-based devices due to the oxides. By using a Fresnel-law based model [3] the contrast of graphene is calculated as a function of wavelength for different oxide thicknesses and compared to optical and atomic force micrographs of exfoliated graphene on Gd_2O_3 and Dy_2O_3.

[1] A.P. Milanov, *et al.*, Chemistry of Materials **21**, 5443 (2009).
[2] S.V. Morozov, *et al.*, Phys. Rev. Lett. **100**, 016602 (2008).
[3] P. Blake, *et al.*, Appl. Phys. Lett. **91**, 063124 (2007).

HL 61.6 Thu 18:00 Poster D1

First observation of the strong nonlinear optical response of graphene measured by four-wave mixing — Euan Hendry[1], Peter Hale[1], Julian Moger[1], Alexander Savchenko[1], and •Sergey Mikhailov[2] — [1]School of Physics, University of Exeter, UK — [2]Institute of Physics, University of Augsburg, Germany

We present the first experimental investigation of nonlinear optical properties of graphene at visible and near infrared frequencies measured by four-wave mixing technique. It is shown that graphene produces strong third-order nonlinear optical response, described by nonlinear susceptibility comparable to that of other strongly nonlinear materials, such as carbon nanotubes. In contrast to carbon nanotubes, however, this nonlinear response is essentially dispersionless over the wavelength range in our experiments (emission with wavelength of 760 - 840 nm). We show that the nonlinear response of graphene can be exploited for high-contrast optical imaging of flakes: the image contrasts for monolayer flakes on a dielectric substrate are several orders of magnitude higher than those in reflection microscopy.

This work was funded by the RCUK, EPSRC and Deutsche Forschungsgemeinschaft.

HL 61.7 Thu 18:00 Poster D1

Raman analysis of manipulated graphene — •Stefanie Heydrich, Michael Hirmer, Jonathan Eroms, Dieter Weiss, Tobias Korn, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We present recent results of Raman spectroscopy on unstructured graphene, gated graphene and graphene etched with anti-dot lattices.

We utilize fast, high-resolution scans to map graphene flakes on Si/SiO_2-substrates. The Raman spectrum, acquired by a Triple Raman System, optimized for maximum stray light suppression, is evaluated and height, position and FWHM of the characteristic G (1580 cm^{-1}), D (1350 cm^{-1}) and 2D (2700 cm^{-1}) peaks are plotted for each point. Thus, a Raman image of both the flake and its structured areas is created and the chirality of a flake's edges can be extracted.

In unstructured flakes, the D peak is observed only at the edges, while the G peak is present everywhere on the graphene sheet.

In flakes patterned with anti-dot lattices, both D and G peak are observed everywhere on the flake. We find a stiffening of the G-peak on the structured areas compared to unstructured parts. This could be due to the strain effect. The shift is dependent on diameter and

distance of the anti-dot holes.

Additionally, we study the G peak in a gated graphene flake. The gate voltage influences the charge-carrier density in the material and thus the LO-Phonon in graphene, which is coupled to this density. Therefore, by varying gate voltage, one can manipulate the G-peak position.

HL 61.8 Thu 18:00 Poster D1

Spin Transport and Spin Precession in Bilayer Graphene with Transparent Ferromagnetic Contacts — •Bastian Birkner, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We achieved electrical spin injection with a DC current from a ferromagnetic material (Co) into bilayer graphene without using any tunnel barrier. This results in a contact resistance of about 450 Ohm which indicates that the junctions between the Co and graphene are transparent. The graphene flakes were mechanically exfoliated from natural graphite by using adhesive tape. The induced spin accumulation diffuses away from the injection point and is probed in a non-local four terminal scheme where charge and spin current are completely separated from each other. We obtain a clear spin signal R_{nl}=U_{nl}/I whose sign depends on the magnetization orientation (parallel/antiparallel) of the ferromagnetic electrodes. By applying a perpendicular magnetic field we also detected spin precession (Hanle effect) that confirms that the non-local signal originates from spin injection and spin transport. Fitting of Hanle curves yields a spin relaxation time in the range of 60-130 ps and a spin diffusion length of below one micrometer. The polarization was estimated to be less than 5 percent.

HL 61.9 Thu 18:00 Poster D1

Investigation of top gates with ALD deposited dielectric on graphene structures — •Franz-Xaver Schrettenbrunner, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universtität Regensburg, 93040 Regensburg

We report the fabrication and transport measurements of top gated mono- and bilayer graphene devices. The insulating Al_2O_3 top gate was realized using atomic layer deposition (ALD). With a TMA/water process at 100 °C we could achieve complete coverage of the graphene flakes and produce stable gates with a thickness down to 30nm. In particular, using both the aluminum oxide top gate and the 300nm SiO_2 backgate on our Si-chip, we were able to create a gate-induced insulating state in bilayer graphene. Using a model which regards the two layers as electrically decoupled, we could determine the density of background impurities and on which of the two layers they were preferentially located.

HL 61.10 Thu 18:00 Poster D1

Fabrication of suspended graphene sheets — Benjamin Söll, Dieter Weiss, and •Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We report the fabrication of single layer graphene devices suspended 150 nm above a Si/SiO_2 substrate. Suspension of the graphene flake was achieved by dipping entire conventional devices with gold contacts into buffered oxide etch. Thereby we removed 150 nm of SiO_2, including the area underneath the flake, while SiO_2 masked by the gold electrodes remained unetched. To dry the samples we used a critical point dryer to avoid the surface-tension-induced collapse of the suspended sheet. After suspending, the devices were baked in forming gas at 200 °C for 10 minutes to remove residues left from sample fabrication. Further cleaning was carried out by current induced cleaning in the cryostat, with a typical current of 1mA per μm of sample width. First measurements show an improvement of sample properties after current induced cleaning.

HL 61.11 Thu 18:00 Poster D1

Electric properties of multiwall carbon nanotubes with defects — •Andreas Stetter, Johann Vancea, and Christian H. Back — Universität Regensburg

Carbon nanotubes are of high interest for future electronics. However, the performance of an electronic device generally depends on the quality of the material. Therefore, it is fundamental to study the properties of non ideal tubes.

We investigated the electric response on several defects in current conducting multiwall carbon nanotubes using scanning tunnelling potentiometry. This technique yields a potential profile along the tube while a current is flowing through it. We observed a voltage drop at the end of an incomplete outermost shell. We used this potential profile to separate the intrashell resistance and the intershell conductance. Furthermore, we studied a stretched carbon nanotube with a kink, where a strong increase in the resistance was observed.

HL 61.12 Thu 18:00 Poster D1

Temperature dependent combination modes in the intermediate frequency region of single walled carbon nanotubes — •Felix Fromm, Daniel Niesner, Jonas Röhrl, Ralf Graupner, and Martin Hundhausen — Universität Erlangen-Nürnberg, Lehrstuhl für Technische Physik, 91058 Erlangen, Germany

Single walled carbon nanotube (SWCNT) samples have different diameter distributions, depending on the production method. Resonant Raman scattering can be employed for their characterisation since it is sensitive to the diameters of the SWCNTs. We measured Raman spectra with different laser excitation energies in the temperature range between 10 K to 700 K in order to study SWCNTs produced by the laser ablation (LA) process and the high-pressure catalytic decomposition of carbon monoxide (HiPco). We focus here on the so called intermediate frequency modes (IFMs) which lie in between the well known radial breathing modes (RBMs) and the defect induced D-band. The Stokes Raman spectra of the IFMs contain both one-phonon and two-phonon modes. The two-phonon modes either correspond to the excitation of two phonons or to the excitation of one phonon of higher energy combined with the annihilation of one lower-energy phonon. Since the annihilation is strongly temperature dependent, it is possible to distinguish between these two alternatives. We also estimate the energy of the annihilated phonon from the temperature dependence.

HL 61.13 Thu 18:00 Poster D1

Effect of swift heavy ion irradiation on diamond — •Anne-Katrin Nix[1], Ulrich Vetter[1], Daniel Severin[2], Christina Trautmann[2], and Hans Hofsäss[1] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

Diamond is a wide band-gap semiconductor with many applications. Some of these applications require doping of diamond, which can be achieved by ion implantation. The process has the detrimental effect to produce many lattice defects, which in principal can be removed by thermal annealing. In the case of diamond, the treatment requires high temperatures which may result in surface graphitization before electronic or optical activation of the dopants becomes successful. In this work, we tested swift heavy ion beams as possible alternative method for annealing of doped diamonds as analyzed in [1]. Type Ia brownish diamonds were implanted with 100 keV Argon of fluences between $3 \cdot 10^{13}$ and 10^{14} ions/cm^2. Subsequently, the samples were irradiated at 500 °C using 1.4 GeV Xenon of fluence $2.8 \cdot 10^{12}$ ions/cm^2. Before and after implantation and irradiation, the cathodoluminescence of the samples was examined. We found that tempering alone at 500 °C for 1.5 h improves the luminescence and reduces the implantation damage. Swift heavy ion irradiation however did not lead to defect annealing and in non-implanted diamonds, the ion exposure leads to the formation of H3 centers.

[1] J. Nakata, Phys. Rev. B, 60 (1999) 2747

HL 61.14 Thu 18:00 Poster D1

Excited States of the Negatively Charged Nitrogen-Vacancy Color Center in Diamond — •Yuchen Ma[1], Michael Rohlfing[1], and Adam Gali[2] — [1]Fachbereich Physik, Universität Osnabrück, Germany — [2]Department of Atomic Physics, Budapest University of Technology and Economics, Hungary

Optical excitation in the negatively charged nitrogen-vacancy (NV) color center in diamond induces a strong spin polarization in the ground-state, which makes the NV center a competitive candidate for solid state quantum information processing and nanoscale magnetic imaging. However, the excited-state structure and the spin-polarization process of the NV center are not yet fully understood. Here we investigate details of the excitations within ab initio many-body perturbation theory (MBPT). We find that three singlets, one of which exhibiting an intersystem crossing with the excited triplet, may be relevant for the fluorescence process in a way which has never been considered before. The calculated zero-phonon line (ZPL) for the visible excitation and that for the transition among the singlets are in good agreement with the experiments. Our results provide new insight into the optical process in the NV center relevant for its future application.

HL 61.15 Thu 18:00 Poster D1

Relationship between structural properties and electrochemical characteristics of electrochemical double-layer electrodes in aqueous and organic electrolyte — •Volker Lorrmann[1], Mario Zeller[1], Gudrun Reichenauer[1], Jens Pflaum[1,2], and Vladimir Dyakonov[1,2] — [1]Bavarian Center of Applied Energy Research e.V. (ZAE Bayern), 97074 Würzburg — [2]Experimental Physics VI, Julius-Maximillians-University of Würzburg, 97074 Würzburg

Electrochemical double-layer capacitors (EDLC) are energy storage devices with rather low energy density, but high power density. The charges are stored at the interface between the electrode and the electrolyte. The capacitance and the transport kinetics to the interfacial surface area strongly depend on the porous nanostructure of the electrodes. Carbon aerogels, based on sol-gel derived organic precursors, are promising candidates for EDLC electrodes because their nanostructure (e.g. pore- and particlesize) is tuneable over a wide range. For the same reason these materials also represent excellent model systems for the investigation of correlations between structural properties and electrochemical characteristics. We prepared carbon aerogel EDLC electrodes with a different nanostructures by varying the catalyst and reactant concentration in the starting solution. The structure of the carbon was characterised by nitrogen sorption and scanning electron microscopy. Electrochemical investigation was performed by cyclic voltammetry and impedance spectroscopy in aqueous and organic electrolytes. The relationship between the nanostructure and the electrochemical performance of the EDLC electrodes is discussed.

HL 61.16 Thu 18:00 Poster D1

Hybrid electrode for electrochemical capacitors consisting of a MnO_2 infiltrated carbon aerogel — •Christian Weber[1], Volker Lorrmann[1], Jens Pflaum[1,2], Gudrun Reichenauer[1], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg — [2]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg

Electrochemical capacitors (EC) bridge the gap between conventional capacitors with high power but low energy density and batteries with high specific energy density but rather low power density. There are two types of EC: Double-layer supercapacitors, that store charges electrostatically in the Helmholtz-layer between the electrolyte and the electrode of large surface area, the latter typically consisting of activated carbon. In pseudocapacitance supercapacitors charging is of faradaic nature, e.g. by redox processes in MnO_2. We have prepared EC hybrid electrodes by infiltrating a carbon aerogel with MnO_2. Structural analysis of these electrodes shows a decrease of surface area with increasing MnO_2-loading. Cyclic voltammetry measurements reveal an increase of the total capacitance of the electrode with MnO_2 concentration. However, the increase in capacitance arises at the cost of the cycling behaviour: low conductivity of MnO_2 and narrowed electrolyte pathways resulting from dispersed MnO_2 lead to an increase in the total resistance of the electrode. Correlations between compostition, structural characteristics and electrochemical properties are discussed in detail.

HL 61.17 Thu 18:00 Poster D1

Ni(Al)-SiC-Interfaces studied by Transmission Electron Microscopy — •Alexander Alexewicz[1], Hartmut Bracht[1], Kathrin Rüschenschmidt[2], and Roland Rupp[2] — [1]Institut für Materialphysik, WWU Münster — [2]Infineon Technologies AG Villach

The development of a reliable, low-ohmic contact between a metallic conductor and a p-doped SiC-semiconductor is not yet controllable. An empirical approach is the use of nickel as metal-contact. SiC-Wafers with NiAl-layers of two different thicknesses (40 and 150 nm) on top were annealed at 980°C. For understanding the behaviour of the involved elements, analyses of the microstructure in the contact area have been performed. High Resolution Transmission Electron Microscopy (HRTEM) gives a representation of the atomic structure on a nanometer scale. In order to identify the silicide, which is formed in the layer, and to detect the aluminium distribution, Energy Dispersive X-Ray Spectroscopy (EDX) is used. The released carbon as well as the content of oxygen is localized by Electron Energy Loss Spectroscopy (EELS).

HL 61.18 Thu 18:00 Poster D1

Iron-related Defect Centers in 4H-SiC Detected by Deep Level Transient Spectroscopy — •Lia Trapaidze, Michael Krieger, and Gerhard Pensl — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7 / Bau A3, 91058 Erlangen, Germany

Iron (Fe) is a impurity, which is frequently introduced during the processing of semiconductors. It is known from silicon that Fe forms electrically active defect centers. However, for the wide-bandgap semiconductor silicon carbide (SiC) nothing has been reported in the literature so far.

In order to identify and investigate Fe-related defect centers in 4H-SiC, Fe ions have intentionally been introduced into n-type and p-type 4H-SiC epitaxial layers by means of ion implantation. A Fe box profile with a depth of 1.7 μm and a mean concentration of [Fe] = 1×10^{15} cm^{-3} was formed by multiple implantations of Fe^+ ions with different energies at T_impl = 300°C. Subsequently, the samples were annealed at various temperatures ranging from room temperature up to 1700°C. Schottky contacts were evaporated using Pd or Ti/Al for n-type or p-type layers, respectively. The samples have been analyzed by means of deep level transient spectroscopy (DLTS).

Compared to the DLTS spectra of not-implanted reference samples, a new defect center at E_C-E_T = 1080 meV is observed in the DLTS spectra taken on Fe-implanted samples. The dependence of the DLTS spectra on the annealing temperature and on the implanted Fe concentration is discussed.

HL 61.19 Thu 18:00 Poster D1

***Ab initio* study of strain effects on the quasiparticle bands and effective masses in silicon** — •Mohammed Bouhassoune and Arno Schindlmayr — Department Physik, Universität Paderborn, 33095 Paderborn, Germany

Strain engineering has emerged as a promising technology to improve the performance of silicon-based MOSFETs. In general, strain influences the carrier mobility and hence the switching times by two mechanisms: a partial lifting of band-edge degeneracies, which reduces the scattering rate, and modified effective masses due to band warping. For monoclinic deformations along the [110] direction, which have attracted particular interest, experimental evidence suggests that both factors contribute to the observed high electron mobility in n-doped samples. In order to assess their relative importance, we study the electronic properties of silicon under uniaxial and biaxial [110] strain quantitatively with *ab initio* computational methods. For this purpose we combine density-functional theory in the local-density approximation with the GW approximation for the electronic self-energy, which gives a highly accurate description of the quasiparticle band structure. The elastic constants, Poisson ratios and related structural parameters are determined with full volume and internal relaxation from the variation of the total energy. Then we calculate the energy splitting of the six originally degenerate conduction-band minima and the electron effective masses as a function of the applied strain. The results confirm a significant reduction of the effective mass associated with the lowest, twofold degenerate subband for tensile uniaxial strain.

HL 61.20 Thu 18:00 Poster D1

Effect of codoping donor atoms in germanium — •Hartmut Bracht[1], Alexander Chroneos[2], and Robin W. Grimes[2] — [1]Institut für Materialphysik, WWU, Münster, Germany — [2]Department of Materials, Imperial College, London, UK

It has been established that donor atoms migrate predominantly via their interaction with lattice vacancies in germanium. Under high doping conditions donor atoms can form large immobile clusters that contain vacancies. The control of the concentration of free vacancies is essential to control the diffusion of the donor atoms and the formation of larger clusters, which lead to the deactivation of a significant proportion of the donor atoms. In the present study electronic structure calculations in conjunction with mass action analysis are used to predict the concentrations of free vacancies and deactivated donor atoms in germanium codoped with different proportions of carbon, or fluorine, or another donor species. The effect of the different codoping species and the relative concentrations of these on the donor diffusion and deactivation is discussed over a wide temperature range.

HL 61.21 Thu 18:00 Poster D1

Structure and defect processes in $Si_{1-x-y}Ge_xSn_y$ random alloys — •U. Schwingenschlögl[1], A. Chroneos[2], C. Jiang[3], R.W. Grimes[2], and H. Bracht[4] — [1]PSE Division, KAUST, Thuwal 23955-6900, Saudi Arabia — [2]Department of Materials, Imperial College London, London SW7 2BP, United Kingdom — [3]Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [4]Institute of Material Physics, University of Mün-

ster, Wilhelm-Klemm-Straße 10, D-48149 Münster, Germany

Binary and ternary $Si_{1-x-y}Ge_xSn_y$ random alloys are being considered as candidate materials to lattice match III-V or II-VI compounds with Si or Ge in optoelectronic or microelectronic devices. The simulation of the defect interactions of these alloys is hindered by their random nature. Here we use the special quasirandom approach (SQS) in conjunction with density functional theory calculations to study the structure and the defect processes. For the binary alloy Ge_xSn_{1-x} the SQS method correctly describes the deviation of the lattice parameters from Vegard's Law. For the ternary alloy $Si_{0.375}Ge_{0.5}Sn_{0.125}$ we find an association of As atoms to lattice vacancies and the formation of As-vacancy pairs. It is predicted that the nearest-neighbour environment exerts a strong influence on the stability of these pairs.

HL 61.22 Thu 18:00 Poster D1

Definierte Variation der Nanostruktur in Ge-Schichten mittels Glanzwinkelabscheidung — •Michael Weise[1], Chinmay Khare[1], Bodo Fuhrmann[2], Jens Bauer[1] und Bernd Rauschenbach[1] — [1]Leibniz-Institut für Oberflächenmodifizierung, Permoserstraße 15, D-04318 Leipzig — [2]Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4, D-06120 Halle

Die Glanzwinkelabscheidung (GLAD) erlaubt eine einfache Herstellung von selbstorganisierten porösen Nanostrukturen auf dem Prinzip der gegenseitigen atomaren Abschattung. Über die Wahl der Abscheideparameter Einfallwinkel und Substratrotationsgeschwindigkeit (konstant oder mit definierter zyklischer Änderung) sowie unter Verwendung vorstrukturierter Oberflächen lassen sich variable Morphologien und geometrische Anordnungen erzeugen. Es wurde das Wachstum von Silizium und Germanium auf unbehandelten und vorstrukturierten Substraten untersucht. Die Variation des Einfallswinkels erlaubt eine Veränderung der Dichte der deponierten Schicht. In Abhängigkeit von der Rotationsgeschwindigkeit können säulen-, schrauben- oder spiralartige Morphologien erzeugt werden. Eine zyklische Änderung der Winkelgeschwindigkeit ermöglicht einen weiteren Einfluss auf die Formgebung der Strukturen, wie z.B. das Wachstum von Strukturen mit rechteckiger Grundfläche. Durch Substratvorstrukturierung, z.B. mittels Nanokugellithographie, Elektronenstrahllithographie oder unter Verwendung fokussierter Ionenstrahlen, lassen sich Wachstumsplätze vorgeben. Die dadurch festgelegte Abschattung hat Einfluss auf die Morphologie, z.B. dreieckige Säulen bei wabenartiger Anordnung.

HL 61.23 Thu 18:00 Poster D1

Epitaxial growth of ZnS thin films on GaP and GaAs — •Udo Römer, Stefan Lautenschläger, Sebastian Eisermann, Oliver Graw, Melanie Pinnisch, Sven Ole Steinmüller, Jürgen Janek, and Bruno K. Meyer — I. Physikalisches Institut und Institut für Physikalische Chemie Justus-Liebig-Universität Giessen

Due to its large band gap of 3.6 eV ZnS is a promising semiconductor for optoelectronic applications. Epitaxial ZnS films can be grown in zincblende structure using substrates like GaP or GaAs. For many applications, for example the construction of quantum well structures, this is an advantage compared to other wide band gap semiconductors like ZnO or GaN which crystallizes in the wurtzite structure only. To study the effects of the different substrates and the growth parameters on the quality of the ZnS films, we have investigated the films using X-ray diffraction (XRD), low temperature photoluminescence (PL), atomic force microscopy (AFM) and time of flight secondary ion mass spectroscopy (TOF-SIMS). The undoped films are electrically insulating, first experiments to dope the films n-type were undertaken.

HL 61.24 Thu 18:00 Poster D1

Quantitative Untersuchung von ZnTe-basierten optoelektronischen Heterostrukturen mittels Transmissionselektronenmikroskopie — •Kristian Frank[1], Marco Schowalter[1], Andreas Rosenauer[1], Wojciech Pacuski[1,2], Carsten Kruse[1] und Detlef Hommel[1] — [1]Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Deutschland — [2]Institute of Experimental Physics, University of Warsaw, *Hoża* 69, PL-00-681 Warszawa, Poland

Es wurde eine mittels MEE(migration enhanced epitaxy) gewachsene CdZnTe/ZnTe Quantenpunktschicht untersucht. Um die für die Untersuchung benötigten 10-20 nm dünnen Proben mit reiner Oberfläche zu erhalten wurden FIB(focused ion beam)-Lamellen präpariert, welche anschließend mit niederenergetischer Ionenätzung bei einer Ar^+-Ionenenergie von 400V behandelt wurden. Diese Proben wurden dann mit dem Transmissionselektronenmikroskop untersucht. Durch Abbildung mit dem verzerrungssensitiven 004-Reflex konnten Verzerrungsfelder sichtbar gemacht werden, welche auf das Vorhandensein von Quantenpunkten hindeuten. Sowohl Untersuchungen mittels der CELFA(composition evaluation by lattice fringe analysis)-Methode, als auch Analysen der Gitterverzerrung mit DALI(digital analysis of lattice fringe images) weisen auf signifikante Fluktuationen der Cadmium-Konzentration innerhalb der Quantenschicht hin. Für beide Methoden wurden hochaufgelöste Gitterebenenabbildungen aufgenommen und der Kontrast der Gitternetzebenen bei CELFA bzw. der Gitternetzebenenabstand bei der Verzerrungsanalyse ausgewertet.

HL 61.25 Thu 18:00 Poster D1

Systematic Study of the Influence of Photo-Generated Carriers on the Mn-Spins in CdMnTe Quantum Wells — •Sina Zapf[1], Christian Kehl[1], Hedwig Mueller[1], Georgy Astakhov[1], Jean Geurts[1], Wolfgang Ossau[1], Yuri Kusrayev[2], Kyrill Kavokin[2], Tomek Wojtowicz[3] und Greg Karczewski[3] — [1]Universitaet Wuerzburg, Phys. Inst., EP3, 97074 Wuerzburg, Germany — [2]Ioffe Institute, RAS, 194021 St. Petersburg, Russia — [3]Institute of Physics, PAN, 02668 Warsaw, Poland

In II-VI diluted magnetic semiconductor quantum wells the strong exchange interaction between the magnetic ions and a two-dimensional gas of heavy holes (2DHG) is predicted to reduce the Zeeman splitting of localized ion spins in an in-plane magnetic field [1]. This can be demonstrated by Spin-Flip-Raman Spectroscopy in a modulation doped CdMnTe/CdMgTe quantum well influencing the 2DHG concentration by photo-generated carriers from above barrier with the modulation doping caused by a thin capping layer of the quantum well.

Now a clear decrease of the Zeeman splitting quantified by the g-factor of the Mn-ions with increasing net charge carrier has been observed systematically by varying the cap layer thickness and the Mn-content, respectively. This influences specifically the carrier dynamics and thus the g-factor.

[1] K.V. Kavokin, Phys. Rev. B 59, 9822 (1999)

HL 61.26 Thu 18:00 Poster D1

Optical investigations of excitons in collodial semiconductor nanocrystals — •Sergey Skripets[1], Martin Pohl[1], Martin Kneip[1], Dmitrii Yakovlev[1], Manfred Bayer[1], Celso Mello-Donega[2], Dominika Grodzinska[2], and Daniel Vanmaekelbergh[2] — [1]Experimentelle Physik E2, TU Dortmund, Deutschland — [2]Debye Institut, Universität Utrecht, Niederlande

The optical properties of collodial semiconductor quantum dots with varying concentration were studied by means of optical methods. In these systems, electrons, holes and excitons are strongly confined in the nanocrystal host, resulting in discrete energy levels for these nanocrystals. Investigations were performed in resonant and nonresonant excitation regime over a wide temperature range from 2 up to 300 K with magnetic fields between 0 and 10 T. Furthermore the relaxation time of the photoluminescence was studied in picosecond range by means of streak camera and nanosecond range by means of gated ccd. Results will be shown for PbSe,CdSe core-shell and CdSe/Cd(S,Se)/ZnS core-shell-shell structures.

The workings were done in the framework of the Herodot-program "heterogeneous quantum rod and quantum dot nanomaterials" at the physics department of the TU Dortmund with samples grown at the University of Utrecht.

HL 61.27 Thu 18:00 Poster D1

Defect induced changes on the dynamics of the Mn $3d^5$ luminescence in ZnS:Mn nanowires — •Uwe Kaiser[1], Limei Chen[1], Wolfram Heimbrodt[1], Sebastian Geburt[2], and Carsten Ronning[2] — [1]Dept. Physics, Philipps University Marburg, Germany — [2]Inst. for Solid State Physics, Friedrich-Schiller-University Jena, Germany

ZnS nanowires with diameters between 100-300 nm and lengths of several micrometer have been ion-implanted with Mn yielding a concentration of $9,91 \cdot 10^{17}\, cm^{-3}$. The concentration of defects were varried by different annealing and Mn-implantation temperatures. The samples were afterwards irradiated with different fluence of Neon in order to create controlled numbers of defects.

The nanowires were studied by photoluminescence spectroscopy at 10 K. The temporal behavior of the internal $Mn^{2+}(3d^5)$ luminescence was measured in dependence of the defect concentration. The migration of Mn excitation is based on the dipol-dipol interaction inside the Mn subsystem. The decay is determined by dipol-dipol transfer from Mn to killer centres leading to a non-radiative annihilation. To inter-

pret the data a modified Förster model based on dipol-dipol interaction was applied [1]. The aim of this work was to reveal a relation between the concentration of defects and the behaviour of the transients of the Mn photoluminescence.
[1] L.Chen et al., Phys Rev B 76, 115325 (2007)

HL 61.28 Thu 18:00 Poster D1

THz photoresponse of devices with quantum wells of narrow-gap semiconductors. — •Fathi Gouider[1], Yuri.B. Vasilyev[2], Christoph Brüne[3], Hartmut Buhmann[3], Jens Könemann[4], Phil.D. Buckle[5], and Georg Nachtwei[1] — [1]Institut für Angewandte Physik, Technische Universität Braunschweig, Germany — [2]A. F. Ioffe Physical Technical Institute,St. Petersburg, Russia — [3]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg,Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [5]QinetiQ Ltd, Malvern WR14 3PS, United Kingdom

The THz spectral range is very intersting both from the aspect of fundamental physics as for technical applications.The THz waves we generate by a p-Ge laser system ($120\mu m < \lambda < 180\mu m$). We present observations of the photoresponse (PR) obtained at samples made from wafers with a narrow gap as HgTe quantum wells embedded in barriers of HgCdTe as well as InSb quantum wells embedded in barriers of AlInSb. We observed the cyclotron resonance by the measurement of the transmission as a function of the magnetic field B. Further, we measured the photoconductivity in Corbino-shaped devices made from the HgCdTe/HgTe/HgCdTe and AlInSb/InSb/AlInSb wafers.

HL 61.29 Thu 18:00 Poster D1

Fabrication of ZnO cavities for planar microresonators — •Helena Hilmer[1], Chris Sturm[1], Rüdiger Schmidt-Grund[1], Jesús Zúñiga-Pérez[2], Holger Hochmuth[1], Marina Cornejo[3], Frank Frost[3], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany — [2]CRHEA, Rue Bernard Grégory, 06560 Valbonne, France — [3]IOM e.V., Permoserstr. 15, 04318 Leipzig, Germany

We report on the growth of planar microresonators by pulsed laser deposition (PLD), which consist of two all-oxide Bragg reflectors (BR), made of yttria stabilized zirconia and alumina, surrounding a ZnO cavity as active medium. Detailed photoluminescence (PL) and reflectivity analyses have shown, that the resonators are in the strong coupling regime up to 410 K [1], but Bose-Einstein-Condensation is still a challenge. As the BR materials do not grow epitaxially on the substrates, the main task lies in the optimisation of the ZnO cavity layer, i.e low surface roughness and intensive, narrow luminescence.

Therefore suitable PLD growth conditions were combined with an annealing step as well as two additional strategies: First, conventional ZnO half-resonators, i.e. the lower BR with the ZnO cavity, have been ion beam polished to smooth the rough ZnO layer. Second, the cavity was grown by molecular beam epitaxy (MBE) on top of PLD-grown BR. Compared to PLD samples, PL measurements do not indicate any degradation due to ion beam smoothing of the PLD samples and show narrower ZnO luminescence for the (rougher) MBE samples.
[1] C. Sturm *et al.*, NJP **11**, 073044 (2009).

HL 61.30 Thu 18:00 Poster D1

Thermoelectric measurements on artificially structured ZnO/ZnS multilayers — •Steve Petznick, Achim Kronenberger, Gert Homm, Thorsten Henning, Peter J. Klar, and Bruno K. Meyer — 1. Physikalisches Institut, Gießen, Deutschland

A multilayer-system of alternating ZnO and ZnS layers of about 1 μm thickness in total is deposited by RF magnetron sputtering on different substrates. A pattern of square-holes in the μm range is transferred into this multilayer system by photolithography followed by ion beam or wet-chemical etching. In a second sputter step another multilayer-system of the same two materials is sputtered on the sample with the identical number of layers but with the reversed layer sequence. In the cross section of the sample one obtains a pattern of the alternating materials. The ZnO layers are n-type with different electron concentrations while the ZnS layers are almost insulating. The Seebeck coefficient of this system is measured in the temperature range of 50 to 300 K. The influence of the high number of interfaces on the transport behaviour and on the Seebeck coefficient is investigated.

HL 61.31 Thu 18:00 Poster D1

Fabrication and characterization of heterostructure LEDs based on the material system MgZnO/AlGaN — •Julian Benz[1], Sebastian Eisermann[1], Torsten Henning[1], Peter J. Klar[1], Bruno K. Meyer[1], Theeradetch Detchprohm[2], and Christian M. Wetzel[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY 12180-3590, U.S.A.

The wide band gap semiconductors ZnO and GaN and their related alloys are interesting materials for the production of blue and ultraviolet optoelectronic devices, such as light emitting diodes (LEDs), laser diodes and photo diodes. Active regions based on ZnO may further improve the efficiency of current short wavelength devices based on GaN and InGaN due to the higher exciton binding energy in ZnO. We report on the growth, fabrication, optical and electrical characterization of heterostructures based on the MgZnO/AlGaN material system, which can be seen as a first step towards more sophisticated devices including MgZnO/ZnO quantum wells in the active region.

HL 61.32 Thu 18:00 Poster D1

Photoluminescence studies of top-down $Zn_{1-x}Mg_xO$/ZnO quantum disk samples with different dimensions — •Martin Fischer[1], Markus Piechotka[1], Torsten Henning[1], Bernhard Laumer[2], Peter Klar[1], Martin Eickhoff[1], and Bruno Meyer[1] — [1]I. Physikalisches Institut, Justus Liebig Universität Giessen, Heinrich Buff Ring 16, 35392 Gießen — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Quantum disc structures with diameters of 100 and 200 nm were prepared from PAMBE-grown $Zn_{1-x}Mg_xO$/ZnO single quantum well structures of different well widths by using electron beam lithography followed by a combination of wet chemical and ion-beam etching. The samples were studied by photoluminescence spectroscopy. We investigated the influence of strain relaxation in quantum disks of different diameter on the excitonic transitions. We also study the impact of the quantum disc size on the linewidths of the excitonic energies as well as on the emission intensities in the PL spectra. The lateral dimension of the quantum discs allows one to exclude additional lateral quantum confinement effects in the samples.

HL 61.33 Thu 18:00 Poster D1

Polarization behaviour of the exciton-polariton emission — •Chris Sturm, Helena Hilmer, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

The formation and properties of exciton-polaritons in microresonators have been intensively investigated in the last years, since they can undergo a Bose-Einstein condensation (BEC). In this work we present the polarization behaviour of the exciton-polariton emission of a ZnO based resonator and deduce information on the relaxation into the ground state, such as the scattering rates. The resonator was grown by pulsed laser deposition consisting of a wedge shape cavity in order to investigate the exciton-polariton properties at different detunings. The photoluminescence (PL) spectra show a strong polarization dependence of the emission of the lower polariton branch (LPB). A maximum energy splitting of about 5 meV between s- and p-polarized light is obtained for an emission angle of about 34 °, caused by the uncoupled cavity-photon mode. The occupation (connected with PL-intensity) of the LPB for the two different polarizations was analyzed and we found a larger bottleneck effect for the p- than for the s-polarized light. With increasing detuning the magnitude of the bottleneck effect decreases and also the splitting between the two polarizations, i.e. the relaxation into the ground state is enhanced. Therefore large positive detunings are preferred for ZnO based resonators in order to reach a BEC, which is in agreement with theory [1].
1. R. Johne *et al.*, Appl. Phys. Lett. **93**, 249902 (2008).

HL 61.34 Thu 18:00 Poster D1

Electroluminescence of doped and undoped AlN/SiC-heterojunctions — •Christoph Brüsewitz, Ulrich Vetter, and Hans Hofsäss — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

AlN with its large and direct bandgap is a useful host for optoelectronic applications. Grown on 6H-SiC, a heterojunction is created, forming a diode. The light emitted by n-doped 6H-SiC via electroluminescence forms a broad band with a maximum at a wavelength of 475 nm. With the AlN layer on the surface, nitrogen atoms can diffuse into the 6H-SiC, creating new energy levels. Depending on the

direction of the current and additonal dopants in the AlN layer, the carrier concentration changes and new levels are available, resulting in different colours. It is shown that in this heterojunction blue, red and white colours are feasible.

HL 61.35 Thu 18:00 Poster D1

Pump Dynamics of Nuclear Spins in GaAs Nanostructures — •Wieland Worthoff and Dieter Suter — Experimentelle Physik III, TU Dortmund

Photons carry angular momentum, which must be transferred to the material when they are absorbed. This conservation law can be used to polarize the spins of charge carriers in semiconductors by irradiating the material with circularly polarized light. Part of the electrons' spin polarization is transferred via Fermi contact hyperfine interaction to the nuclear spins of the material. This can be used to increase the sensitivity of nuclear magnetic resonance by many orders of magnitude or to reduce decoherence in spin-based quantum computers working on the basis of semiconductor nanostructures. We explore the dynamics of the optical pumping process when a cw laser beam is applied to a GaAs/AlGaAs heterostructure in the presence of a magnetic field. We resonantly create electron-hole pairs in single quantum wells and measure the build-up of the nuclear spin polarization as a function of time through the effect of the average hyperfine interaction on the electron spins (the 'nuclear field'). This feedback of the nuclear spin polarization on the electron spins results in a nonlinear dynamics of the coupled electron-nuclear spin system. We model these dynamics and compare the result with experimental data.

HL 61.36 Thu 18:00 Poster D1

The influence of self-assembled quantum dots on the electrical properties of an inverted 2DEG — •Dominik Scholz[1], Antonio Badolato[2], Dieter Schuh[1], Imke Gronwald[1], Christian Reichl[1], Werner Wehscheider[3], and Elisabeth Reiger[1] — [1]Institute for Applied and Experimental Physics, University of Regensburg, Germany — [2]Department of Physics and Astronomy, University of Rochester, US — [3]Laboratory for Solid State Physics, ETH Zurich, Switzerland

The combination of two-dimensional electron gases (2DEGs) with self-assembled quantum dots (sa-QDs) in the vicinity of the 2DEG would enable the realization of a quantum optical interface. In such a quantum interface a single electron spin located in a gate-defined QD in the 2DEG could be converted into a polarized photon via tunneling into the optically active sa-QD [1]. Studies on the influence of sa-QDs on a 2DEG have already been performed on conventional 2DEG systems [2], however, for the proposed quantum optical interface a structure based on inverted 2DEGs is more favorable.

We fabricated various samples consisting of an inverted 2DEG with sa-QDs grown close to the 2DEG, varying the (tunneling) distance between the sa-QDs and the 2DEG as well as the QD density. We determined the electron mobility as well as the carrier density by Hall-bar and van-der-Pauw measurements and correlated the results to the QD density and the tunneling distance. By this an optimized sample design for the quantum optical interface can be developed.

HL 61.37 Thu 18:00 Poster D1

Thermoelectric measurements on suspended 2DES — •Matthias Schmidt, Andrea Stemmann, and Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, Germany

Low-temperature magnetothermoelectric properties of free-standing two-dimensional electron systems are studied. A suspended lamella containing a 2DES is prepared from GaAs/AlGaAs heterostructures grown by molecular beam epitaxy. Electron-beam lithography is used to structure a micro Hall bar, evaporated AuGe contact leads, micro-scaled thermometers and a Joule heater on top of the thin, free-standing lamella. The lamella is attached to cold reservoirs. A thermal gradient along the lamella is generated by a heating current in the central region. We present first measurements on the heat conductivity, the thermal gradient and the magnetothermopower along the free-standing lamella.

HL 61.38 Thu 18:00 Poster D1

Cross-Section Scanning Tunneling Spectroscopy on a resonant-tunneling diode structure — Karen Teichmann[1], Martin Wenderoth[1], •Sergej Burbach[1], Rainer G. Ulbrich[1], Klaus Pierz[2], and Hans W. Schumacher[2] — [1]IV. Physikalisches Institut, Georg-August Universität Göttingen — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We investigated a resonant-tunneling diode structure by Cross-Sectional Scanning Tunneling Microscopy (STM) and Spectroscopy. The diode structure was grown by molecular-beam epitaxy on a n^+-doped GaAs (100) substrate and consists of self-assembled InAs quantum dots embedded in AlAs barriers (both 4 nm) each followed by undoped GaAs prelayers (15 nm) [1]. We use a low temperature STM working under UHV conditions at 5 K. The samples are cleaved in UHV to obtain a clean and atomically flat surface perpendicular to the diode-structure. Atomically resolved constant current topography images taken simultaneously at different bias voltages, (both positive and negative voltage) show the high quality of the heterostructure. Local *I(V)*-spectroscopy resolves the band edge alignment across the heterostructure. On negative bias voltage several peaks in the differential conductivity are observed. The voltage position of these peaks varies with distance from the interface. We attribute the origin of the enhanced differential conductivity peak to an interaction between the potential induced by the tip and the quantum dot layer. We acknowledge financial support by the DFG SPP 1285.

[1] I. Hapke-Wurst, *et al.*, App. Phys. Lett. **82**, 1209 (2003)

HL 61.39 Thu 18:00 Poster D1

Suppression of interfacial intermixing of MBE grown Heusler Alloy Ni_2MnIn on (001)InAs — •Sascha Bohse[1], Andriy Zolotaryov[1], Stefan Singer[1], Andreas Volland[1], Dieter Lott[2], Andrea Stemmann[1], Christian Heyn[1], and Wolfgang Hansen[1] — [1]Universität Hamburg, Institut für Angewandte Physik, Germany — [2]GKSS Forschungszentrum, Germany

We study MBE grown Heusler Alloy Ni_2MnIn films on (001)InAs in order to inject spin polarized currents into semiconductor heterostructures. Our previous investigations revealed an optimal growth temperature for deposition of Heusler films on (001)InAs in the favored $L2_1$ phase at 300°C[1]. However, at this temperature a strong interfacial intermixing is found that reduces the quality of the interface. We pursue two promising methods to overcome the intermixing and present first results. Firstly, the application of a thin MgO layer as a diffusion barrier embedded between the substrate and the Heusler film is investigated. The second method is to use at the interface a growth temperature of 80 °C, at which intermixing is negligible, and ramp up the temperature to 300 °C during Heusler film growth. The structural properties of films with thicknesses of 20, 60 and 100 nm are studied with atomic force microscopy (AFM) and X-ray reflectivity measurements (XRR). The composition is analyzed with energy dispersive X-ray spectroscopy (EDX). For magnetization measurements SQUID magnetometry has been used.

[1] A. Zolotaryov et al. , Journal of Crystal Growth 311 (2009) 2397-2404

HL 61.40 Thu 18:00 Poster D1

Energy Level Alignment at Si interfaces with photovoltaic oxides by ab-initio quasiparticle calculations — •Benjamin Höffling, André Schleife, Frank Fuchs, Claudia Rödl, and Friedhelm Bechstedt — European Theoretical Spectroscopy Facility and Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Germany

Transparent conducting oxides (TCOs) are widely used as transparent electrodes in solar cells and other optoelectric and photovoltaic devices. Consequently, their interfaces with silicon are of great interest for a wide range of technical applications. The electronic band structures at the Si-oxide interfaces are controversially discussed in literature. We employ modern quasiparticle theory based on hybrid functionals and the GW approximation to obtain electronic band structures including gaps with a high accuracy for silicon and the TCOs In2O3, ZnO and SnO2. The resulting quasiparticle electronic structures are used to derive band discontinuities by two different methods, a modified Tersoff method employing the branch-point energy as charge neutrality level and the Shockley-Anderson model via the electron affinity rule employing the vacuum level as reference energy for band alignment. For the resulting Si-oxide interfaces we observe a tendency for staggered or even misaligned type-II heterostructures.

HL 61.41 Thu 18:00 Poster D1

Nanomechanical Resonators — •Tommy Schönherr[1], Jochen Grebing[1], Takashi Sasaki[2], Matthias Wieser[1], and Artur Erbe[1] — [1]Division of Nanofunctional Films, Forschungszentrum Dresden-Rossendorf, Germany — [2]Division of Nanosystem Engineering, Tohoku University, Japan

Nanomechanical resonators offer multiple possibilities for the use as

sensors and actors. The main challenges in this field of research are the understanding of the damping on the nanometer scale as well as reaching the quantum limit.

In order to measure the current transport in nanomechanical pendulums and vibrating nanowires reproducibly, arrays of nanometer sized structures have to be connected to micron sized contact pads in a reliable way. The pendulums should be designed in such a manner that they transport only single or few electrons during each oscillation. The fabrication of these devices made of silicon by using the techniques of electron-beam lithography, metal evaporation, lift-off and reactive ion etching is presented.

The temperature and magnetic field dependence of the damping of freely suspended silicon nanowires with eigenfrequencies in the order of several 100 MHz as well as measurement data on vertical nanomechanical pendulums between two electrodes are shown.

HL 61.42 Thu 18:00 Poster D1

Gas-assisted focused electron beam etching for direct nanopatterning of GaAs — •Arkadius Ganczarczyk, Martin Geller, and Axel Lorke — Experimental Physics and CeNIDE, Universität Duisburg-Essen

Sputtering and gas assisted etching of semiconductors with a focused ion beam (FIB) is a very useful tool in the semiconductor preparation on the nanoscale, as it allows direct fabrication without the intermediary of resist [1]. However etching/sputtering of materials with the ion beam has it drawbacks, especially because Ga-ions cause defects in the surrounding material. Therefore, gas assisted etching with a focused electron beam is a powerful and less destructive tool as demonstrated e.g. for Si substrates [1]. We demonstrate here the possibility of gas assisted focused electron beam etching of GaAs. We use a scanning electron microscope (SEM) in a dual beam FIB together with an iodine precursor gas that can be injected by a needle directly onto the sample surface. We demonstrate that the etching rate strongly depends on beam current and acceleration voltage as well as step size and dwell time. Furthermore, we consider the detrimental effects of the surface oxide and discuss possible strategies for oxide removal and surface passivation before the etching step.

[1] I. Utke et al., J. Vac. Sci. Technol. B 26, 4, (2008)

HL 61.43 Thu 18:00 Poster D1

Quantification of Impurities in Cu2O — •Andreas Laufer[1], Swen Graubner[1], Hauke Metelmann[1], Bruno Karl Meyer[1], Sebastian Geburt[2], and Carsten Ronning[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Cuprous oxide (Cu_2O) is considered to be a promising material for thin film solar cell applications. P-type Cu_2O, for example, could be obtained by N-doping. The identification of impurities that could act as compensating donors is very important. Among the methods for impurity analysis, secondary ion mass spectrometry (SIMS) is very attractive due to the fact that the chemical identity of the elements can be determined directly, independent of factors such as the ionisation state or binding type. In addition, the sensitivities are very high enabling one to detect some elements in concentrations of as little as a few ppm. The quantification of SIMS data is possible using the method of relative sensitivity factors (RSF). Unfortunately, these factors vary for each host crystal and while there are RSF tables for Si and for compound semiconductors such as GaAs, InP or GaN, such a reference did not yet exist for Cu_2O. In the presented work, the RSF for a number of important elements have been determined using ion implanted standards, thus allowing one to quantify the impurity concentrations found. These factors have then been applied to sputtered Cu_2O thin films.

HL 61.44 Thu 18:00 Poster D1

An all-digital time differential γ-γ angular correlation spectrometer for the study of defects in semiconductors — •Matthias Nagl, Ulrich Vetter, Michael Uhrmacher, and Hans Hofsäss — Georg-August-Universität Göttingen, II. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

The time differential perturbed angular correlation (PAC) technique permits the analysis of electric field gradients and magnetic fields at sites of radioactive probe atoms inserted into samples by means of implantation or diffusion. In this work a new all-digital PAC spectrometer is presented which overcomes some ot the limitations of earlier digital and analog setups and features improved time and energy resolutions. The application of the new spectrometer for the characterization of defects in semiconductors using isotopes that could not be efficiently used as probes before is discussed. Other possible applications of the methods developed for the spectrometer include positron annihilation, PET and time of flight studies as well as Lidar and Radar.

HL 61.45 Thu 18:00 Poster D1

Recoil Effect in Light Element Materials: a Hard X-Ray High Kinetic Energy Photoelectron Spectroscopy Study — •Mihaela Gorgoi and Franz Schäfers — BESSY II, Helmholtz Zentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin

Recoil effects originate from a well defined transfer of momentum from the photoemitted electron to the atom, they cause energy shifts and broadening of the photoemission lines and they were first observed in gas phase photoemission [3]. In soft x-ray photoemission performed on solids this effect was negligible due to the small momentum of the photoelectron. However, in hard x-ray high kinetic energy photoelectron spectroscopy (HX-HIKE or HAXPES) the recoil effects can not be neglected any further since the photoemitted electron has a considerable and well defined amount of momentum [1,2]. In this work recent HX-HIKE investigations of highly oriented pyrolitic graphite (HOPG) and SiC are presented. Evidence of core level shifts as a function of excitation energy has been found in both cases. The energy shifts are assigned to the recoil effect. Nevertheless surprisingly the recoil energies recorded for both SiC and HOPG show a non linear behavior as a function of energy regardless of the orbital from where the photoelectron originates. The found trends will be discussed in the light of a theoretical approach. [1] Y. Takata et al., Phys. Rev. B 75 (2007) 233404. [2] M. Vos et al., Phys. Rev. B 78 (2008) 024301. [3] E. Kukk et al., Phys. Rev. Lett. 95 (2005) 133001.

HL 62: Poster II: Photovoltaics and Organic Semiconductors

Time: Thursday 18:00–20:00 Location: Poster D2

HL 62.1 Thu 18:00 Poster D2

Charge transport in organic semiconductors — •Vera Stehr[1], Carsten Deibel[1], Vladimir Dyakonov[1], Johannes Pfister[2], and Reinhold Fink[2] — [1]Experimentalphysik 6, Institut für Physik und Astronomie, Universität Würzburg — [2]theoretische organische Chemie, Institut für organische Chemie, Universität Würzburg

We have analysed the mobility and the diffusion of charge carriers in organic semiconductors by means of a Monte Carlo simulation and the master equation approach. In disordered amorphous materials, deviations from the Einstein relation, which states that the ratio of the diffusion constant to the mobility equals the thermal voltage, are found. The impact of our findings on experimental charge transport measurements will be discussed. We furthermore determined the anisotropy of the mobility in organic crystals by means of quantum chemical calculations and the Marcus theory for charge carrier hopping.

HL 62.2 Thu 18:00 Poster D2

Inverse and direct photoemission spectroscopy measurements of inorganic-organic interfaces. — •Daniil D. Karnaushenko, Daniel Lehmann, Axel Fechner, and Dietrich R.T. Zahn — Chemnitz University of Technology, Semiconductor Physics, 09107 Chemnitz, Germany

The combination of inverse (IPES) and direct (PES) photoemission spectroscopy is a powerful approach for studying the electronic structure of surfaces and interfaces. Applied to organic materials information on the position of lowest unoccupied (LUMO) and highest occupied molecular orbital (HOMO) as well as on energy level alignment on interfacial states and dipoles can be obtained. More over the two techniques are sensitive to chemical interaction between surfaces and molecules. Here, IPES and PES measurements of several interfaces between inorganic substrate and molecules of the phthalocyanine fam-

ily are presented. The dependence of the interfaces electronic and chemical structure on deposition conditions is obtained.

HL 62.3 Thu 18:00 Poster D2

Electronic and Transport Properties of Quasi-1D Wires of Biological Molecules — •Björn Oetzel[1,2], Lars Matthes[1,2], Falk Tandetzky[1,2], Frank Ortmann[1,2], Friedhelm Bechstedt[1,2], and Karsten Hannewald[1,2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena — [2]European Theoretical Spectroscopy Facility, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

In the search for organic materials with good charge-transport properties, artificial stacks of biological molecules are considered attractive candidates [1,2]. In this spirit, we present ab-initio DFT calculations of the structural, electronic, and quantum-transport properties of quasi-1D wires based on guanine and eumelanin molecules [3]. Hereby, a special focus is put on the results for the electronic bandwidths and the consequences for potential applications.

[1] R. di Felice et al., Phys. Rev. B 65, 045104 (2001)
[2] P. Meredith et al., Pigment Cell Res. 19, 572 (2006)
[3] B. Oetzel et al. (unpublished)

HL 62.4 Thu 18:00 Poster D2

Electrons, Holes, and Polarons in Durene-Based Materials — •Martin Krause, Frank Ortmann, Friedhelm Bechstedt, and Karsten Hannewald — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena

Durene crystals are interesting candidates for high-mobility organic semiconductors [1,2,3]. Here, we present ab-initio studies of the structural and electronic properties of various durene-based molecules and crystals. Special attention is paid to the inclusion and calculation of polaronic effects (e.g., reorganization energies) due to intramolecular electron-phonon and hole-phonon coupling in durene molecules [4].

[1] Z. Burshtein et al., Phys. Rev. B **15**, 5769 (1977)
[2] C. Arndt, F. Ortmann, K. Hannewald, F. Bechstedt, and J. Pflaum, Poster DPG Spring Meeting 2008
[3] F. Ortmann, K. Hannewald, and F. Bechstedt, Appl. Phys. Lett. **93**, 222105 (2008)
[4] M. Krause, F. Ortmann, F. Bechstedt, and K. Hannewald (unpublished)

HL 62.5 Thu 18:00 Poster D2

Degradation of solution-processed pentacene field-effect transistors — •Teodor Toader, Claudia Bock, and Ulrich Kunze — Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum

In this work 13,6-N-Sulfinylacetamidopentacene (NSFAAP) [1] is used to study degradation of solution-processed bottom-contact pentacene transistors. We use conventional UV lithography and lift-off technique to structure Ti/Pd (1 nm/25 nm) electrodes on n-type oxidised silicon wafer. The pentacene thin films are deposited by spin-coating NSFAAP from a $CHCl_3$ solution (1 wt%) and thermally converting the precursor to pentacene in a nitrogen environment. After processing the samples are stored in a glovebox under nitrogen atmosphere and for comparison in ambient dark atmosphere at $T = 21$ °C and 50 % humidity. From two-terminal current-voltage (I–V) measurements characteristic transistor parameters like the effective and field-effect mobility, the On/Off ratio and the threshold voltage are extracted with respect to the time after processing. Additionally the degradation of samples stored under envorinmental conditions and protected with PMMA is studied. The I–V measurements are correlated with scanning electron micrographs.

[1] Ali Afzali, *et al.*, J. Am. Chem. Soc. **124** (30), 8812 -8813, (2002).

HL 62.6 Thu 18:00 Poster D2

Transport and recombination in the low band gap polymer APFO-Green 9 — •David Vocke[1], Jens Lorrmann[1], Alexander Foertig[1], Carsten Deibel[1], L. Matthias Andersson[2], Olle Inganäs[2], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Biomolecular and Organic Electronics, IFM, Linköping University, S-5813 Linköping, Sweden — [3]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg

Increasing the short-circuit current is one way of improving power conversion efficiencies (PCE) of organic solar cells. This could be achieved by using a polymer with a low band gap like the novel copolymer APFO-Green 9. Organic solar cells based on APFO-Green 9 and [6,6]-phenyl-C71-butyric acid methyl ester ($PCBM_{70}$) show a high photo current of 6.5 mA/cm^2 and a PCE of 2.3%. We investigated how charge carrier transport and recombination contribute to the performance. Photo-CELIV (charge extraction by linearly increasing voltage), transient photo voltage- and transient photo current-methods are used to measure pure APFO-Green 9 and solar cells blended with $PCBM_{70}$ in different stoichiometries at various temperatures. Fitting the recombination dynamics with a continuity equation shows a strong charge carrier density dependent Langevin prefactor. Furthermore, we do not observe a relaxation-time dependent mobility, which is sometimes observed in poly(3-hexyl thiophene):[6,6]-phenyl-C_{61} butyric acid methyl ester.

HL 62.7 Thu 18:00 Poster D2

Dissociation of singlet excitons in PPV derivatives with varying dielectric constant — •Julia Kern[1], Michael Binder[1], Markus Mingebach[1], Andreas Baumann[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Center for Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg

In bulk heterojunction solar cells, the low relative permittivity of conjugated polymers such as poly (p-phenylene vinylene) (PPV) is considered to be a limiting factor of the charge separation process. The lower the dielectric constant, the stronger the bond of the primary photoexcitations, i.e., singlet excitons. Here, we investigate the influence of the relative permittivity on the exciton binding energy. For this purpose, three PPV derivatives exhibiting similar charge carrier mobilities but different relative permittivities of 3.0, 4.0 and 5.5, respectively, are characterized by means of external quantum efficiency and field dependent photoluminescence measurements. We discuss our experimental results in terms of the two-step dissociation process from exciton via polaron pair to polarons as well as the impact on solar cell performance.

HL 62.8 Thu 18:00 Poster D2

Influence And Optimization Of The Exciton Blocking Layer In Diindenoperylene Based Photovoltaic Cells — •E. Runze[1], A.K. Topczak[1], M. Meseth[1], T. Roller[2], and J. Pflaum[1,3] — [1]Inst. Exp. Phys. VI, Julius-Maximilians-University, 97074 Würzburg — [2]3rd Phys. Inst., Stuttgart University, 70550 Stuttgart — [3]ZAE Bayern, 97074 Würzburg

The power conversion efficiency of small molecule Organic Photovoltaic Cells (OPVCs) strongly depends on the exciton diffusion length as well as on the respective energy level positions at the donor acceptor and the metal-organic interface. We discuss two major aspects determining the OPVC performance: the exciton blocking and the exciton diffusion. As bilayer systems, OPVCs based on Diindenoperylen (DIP) as donor and C_{60} as acceptor material were employed. We analyse the influence of various exciton blocking layers (EBL) like Batho-Phenanthrolin (BPhen) or 1,4,5,8-Naphthalene-Tetracarboxylic Acid Dianhydride (NTCDA). Beside the position of the electronic levels the nucleation behavior of the metal contact on the EBL is a critical factor. The second part addresses the comparatively large exciton diffusion lengths in DIP of about 100nm [1]. We performed complementary studies on OPVC photocurrent as well as on photoluminescence (PL)-quenching on layered stacks of similar composition. A strong correlation between the exciton transport characteristics and the crystalline morphology of the DIP layer is demonstrated. Financial support by DFG (project PF385/4) is gratefully acknowledged.

[1] D. Kurrle and J. Pflaum, Appl. Phys. Lett. 92 (2008) 133306

HL 62.9 Thu 18:00 Poster D2

Femtosecond Transient Absorption Spectroscopy of Organic Semiconductors — •Björn Gieseking[1], Daniel Kreier[1], Moritz Liedtke[1,2], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Faculty of Physics and Astronomy, Julius-Maximilians-University Würzburg, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research (ZAE Bayern), D-97074 Würzburg

Organic solar cells based on conjugated polymers exhibit great po-

tential for photovoltaic applications due to their low fabrication costs. Bulk heterojunction devices comprised of regioregular poly(3-hexylthiophene) and the [6,6]-phenyl-C_{61} butyric acid methyl ester fullerene derivative have approached efficiencies of more than 5 %. A further optimization requires a deeper insight into the elementary processes following the photoexcitation of these blends. For such studies a very high time resolution is crucial.

We present investigations applying a transient absorption spectroscopy setup based on two optical parametric amplifiers which are tunable from the visible to the infrared spectral range and provide a sub picosecond time resolution. By probing the different transient species we are able to get a better understanding of photogeneration of free charge carriers and their loss mechanisms in order to improve the performance of organic solar cells.

HL 62.10 Thu 18:00 Poster D2

Recombination kinetics of charge carriers and trap states in P3HT:PCBM blends studied by transient Electron Spin Resonance — •Magdalena Zawadzki[1], Andreas Sperlich[1], Hannes Kraus[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Julius-Maximilians-Universität of Würzburg, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, D-97074 Würzburg

The combination of poly(3-hexylthiophene) (P3HT) and [6,6]-phenyl-C_{61}-butyric acid methylester (PCBM) has shown promising performance in organic solar cells. In order to understand the fate of photoexited charge carriers in P3HT:PCBM blends, cw- and transient electron spin resonance (ESR) were used to investigate the recombination kinetics of the light induced charges. Using cw-ESR the negative and positive polarons and trap states related to impurities and oxygen contamination can be detected as separate signals, while transient ESR allows access to the life and recombination times of the different species, which are in a time scale from μs to minutes. We recorded the ESR signal intensity of the polarons and the decay of the photoluminescence after excitation by a pulsed LED. With the transient ESR technique, in addition to the cw-ESR, more detailed information about the P3HT:PCBM blends could be gained.

HL 62.11 Thu 18:00 Poster D2

Decay of excited species in P3HT:PCBM blends studied by transient absorption — •Matthias Gunz[1], Julien Gorenflot[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research (ZAE Bayern), D-97074 Würzburg

One important parameter for improving the efficiency of organic solar cells is to understand the involved processes of charge generation and recombination, as well as their time dependence. Transient absorption spectroscopy enables us to observe the dynamics of photoexcited species. The investigations are carried out on blends of P3HT:PCBM on a timescale from nanoseconds to milliseconds. Pump intensity and temperature dependencies are studied, as well as the influence of different acceptor materials. The experimental results are compared to the charge carrier continuity equation, accounting for monomolecular and bimolecular recombination.

HL 62.12 Thu 18:00 Poster D2

Charge Transfer States in Polymer:Fullerene Solar Cells — •Michael Binder[1], Daniel Rauh[2], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

In the field of organic photovoltaic power conversion efficiencies as high as 6% have been achieved. One of the key factors is a high exciton dissociation yield. It is crucial to understand the processes involved in charge carrier separation such as the relaxation of the exciton to the so called charge transfer state (CTS). A possibility to investigate those states is to measure the external quantum efficiency (EQE) of solar cells in the near-infrared region as shown by Vandewal et al [1]. With additional EQE measurement of diodes consisting only of the pure acceptor or donor we confirm that the CTS are solely found in donor/acceptor blend systems. The energies we determined from the charge transfer-tails can be directly linked to the open circuit voltage of the solar cell. We investigated the CTS for polythiophene:fullerene blends with varying electron acceptor strength. Furthermore we discuss their energy and magnitude in view of solar cell preparation conditions and the impact on the device performance.

[1] K. Vandewal et al. Adv. Funct. Mater. 2008,18, 2064–2070

HL 62.13 Thu 18:00 Poster D2

Nanotomography of organic heterojunction solar cells — •Mario Zerson[1], Andreas Sperlich[2], Hannes Kraus[2], Carsten Deibel[2], Vladimir Dyakonov[2], and Robert Magerle[1] — [1]Chemische Physik, TU Chemnitz, D-09107 Chemnitz — [2]Experimental Physics VI, Julius-Maximilians-University Würzburg, D-97074 Würzburg

The morphology of organic heterojunction solar cells based on blends of P3HT and PCBM is an important factor determining the power conversion efficiency. For a good charge carrier generation the interface between the two components should be as large as possible. Furthermore, bicontinuous networks of both components are required for an efficient charge carrier extraction. We investigate the three-dimensional structure of P3HT and blends of P3HT and PCBM with Nanotomography based on scanning force microscopy (SFM). The specimen is ablated layer by layer using plasma etching and imaged with tapping mode SFM after each etching step. From the resulting series of images the three-dimensional structure is reconstructed. We will present first volume images of P3HT:PCBM blends and discuss the structure of the interface between donor and acceptor components in view of the charge generation efficiency. Furthermore we investigate the morphology of P3HT and P3HT/PCBM blends using SFM with super-sharp tips and the electro-optical properties at the same samples. We aim at comparing the microstructure of the polymer with the photoluminescence-detected magnetic resonance (PLDMR) which provides information on the recombination kinetics of photoinduced charges.

HL 62.14 Thu 18:00 Poster D2

The effect of a cathode interlayer on the performance of polymer-fullerene bulk heterojunction solar cells — •Antonietta De Sio, Elizabeth von Hauff, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Institute of Physics, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany

We report on the impact of different cathode configurations on the performances of polymer-fullerene photovoltaic devices. The operation of the standard bulk heterojunction solar cell structure, in which the active layer consists of a blend of poly-3-hexylthiophene (P3HT) and [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) 1:1 in weight ratio and the metal cathode is a 150nm thick Al layer, was first recorded as the reference. The electrical behavior of the devices upon inserting an interlayer between the organic active layer and the metal cathode was investigated. We also explored the effect of different kinds of interlayers on device performance, i.e. conductive materials like Ca and Mg, as well as insulating materials such as LiF. The effect of the interlayer is reflected in the solar cell parameters, in particular on the open circuit voltage.

HL 62.15 Thu 18:00 Poster D2

From organic single carrier diodes to bulk heterojunction solar cells: an electrical characterization by impedance spectroscopy — •Bernhard Ecker, Elizabeth von Hauff, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Institute of Physics, University of Oldenburg, 26129 Oldenburg, Germany

Impedance spectroscopy is a widely used and powerful tool for investigating electrical characteristics on the frequency scale of batteries, fuel cells and solar cells. For new materials and novel devices impedance spectroscopy can be used to gain information about material parameters as well as interface characteristics. We aim to understand polymer-fullerene bulk heterojunction solar cells using this method. In this study we first investigate single carrier diodes consisting of P3HT or PCBM to supply the understanding of the P3HT:PCBM heterojunction, which is a promising candidate for highly efficient organic solar cells. The characterization of the materials gives insight to the dielectric behavior and provides understanding of the resistive and capacitive response of the devices. Here we present results from impedance spectroscopy measurements on the single carrier devices.

HL 62.16 Thu 18:00 Poster D2

Charge Transport Investigations of P3HT:PCPM Bulk Heterojunction Solar Cells using the CELIV Method — •Ralph Huber, Antonietta De Sio, Elizabeth von Hauff, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

The performance of organic solar cells is strongly influenced by the charge transport properties of the active layer. In this study we employed the charge extraction by linearly increasing voltage (CELIV) method to investigate charge carrier mobilities in blends of regioregular poly(3-hexylthiophene) (P3HT) and [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM). The CELIV method allows for mobility measurements on the solar cell device directly. The field dependence of the charge carrier mobility and the conductivity of P3HT:PCBM blends was investigated. The CELIV results are presented along with the results from the solar cells.

HL 62.17 Thu 18:00 Poster D2

Study of poly(3-hexylthiophene) by cyclic voltammetry — •Sabrina Jüchter, Holger Borchert, Joanna Kolny-Olesiak, Elizabeth von Hauff, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, 26111 Oldenburg

The working principle of organic solar cells involves charge transfer reactions at a donor/acceptor interface as one important elementary step of the energy conversion process. Both the absolute and relative positions of the HOMO and LUMO energy levels of the donor and acceptor material are of importance for successful charge transfer. Cyclic voltammetry is an electrochemical method suitable to study redox reactions. One can obtain information on the absolute values of HOMO and LUMO levels, the thermodynamics, the kinetics of electron transfer reactions and downstream chemical reactions. The possibility of the investigation of electron transfer reactions is especially important for photovoltaics. In the work to be presented here, a measurement place for cyclic voltammetry was set up, including the design of the measurement cell. First measurements were performed with different samples of the electron donor material poly(3-hexylthiophene) (P3HT), in order to investigate if the HOMO and LUMO levels can be influenced by the molecular weight or different impurities. The P3HT is processed from solution to thin films by spin-coating. Another part of the work is the measurement of HOMO and LUMO levels in inorganic semiconductor nanoparticles of CdSe that can be used as electron acceptor material in organic-based solar cells.

HL 62.18 Thu 18:00 Poster D2

The influence of the morphology of the active layer on inorganic/organic hybrid solar cells studied by electron spin resonance — •Florian Witt, Nicolay Radychev, Irina Lokteva, Joanna Kolny-Olesiak, Holger Borchert, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory (EHF), 26111 Oldenburg, Germany

In the last decade the method of exchanging the fullerene acceptors in organic bulk heterojunction solar cells by inorganic semiconducting nanocrystals has been studied to improve their performance. So far only few promising results in such structures, especially related to power conversion efficiencies, were achieved. One of the main factors for this lack of functionality is connected to the poor morphology in comparison pure organic cells. By consequence, the percolation pathways for charge transport are not well pronounced, and the interface area for charge carrier generation is reduced. It was shown that the generation of charge carriers on light excitation can be characterized by light induced electron spin resonance. With this technique the amount of long living polaron states in the donor polymer can be observed over time, with and without light excitation. This method is suitable to show the influence of the materials morphology to its charge generation and recombination dynamics. At deep temperatures also an analysis of polaron trap states in the material blends is possible. The results of comparative studies of P3HT/CdSe nanoparticle layers with different morphologies as well as of P3HT:PCBM blends will be presented.

HL 62.19 Thu 18:00 Poster D2

Recombination in P3HT based solar cells with different acceptor materials — •Sebastian Hafner[1], Andreas Baumann[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, D-97074 Würzburg, Germany — [2]Functional Materials for Energy Technology, Bavarian Centre for Applied Energy Research (ZAE Bayern), D-97074 Würzburg

In order to improve the performance of organic solar cells, it is indispensable to understand the recombination mechanisms in those devices. In previous investigations, a reduced Langevin polaron recombination could be observed [1]. We apply the experimental technique of Photo-CELIV (Charge Carrier Extraction by Linearly Increasing Voltage) to study the recombination dynamics in organic bulk heterojuction solar cells. With this technique, the charge carrier concentration and the mobility of the carriers can be determined simultaneously.The recombination processes in the material system of P3HT with different fullerene acceptors (PC[61]BM, bis-PC[61]BM, PC[71]BM) was investigated in dependence on the temperature and laser intensity. We relate our experimental findings concerning recombination to the performance of polymer:fullerene solar cells.

[1] C. Deibel, A. Baumann, V. Dyakonov: Polaron recombination in pristine and annealed bulk heterojunction solar cells, Applied Physics Letter 93, 163303 (2008)

HL 62.20 Thu 18:00 Poster D2

Limits for the efficiency improvement of hybrid dye- microcrystalline silicon solar cells — •Sven Burdorf[1], Max Meessen[1], Rudolf Brüggemann[1], Andreas Decker[2], Thomas Mayer[2], Wolfram Jägermann[2], and Gottfried H. Bauer[1] — [1]Institut für Physik, Carl von Ossietzky Universität, 26111 Oldenburg — [2]Fachbereich Materialwissenschaften, Technische Universität Darmstadt, 64287 Darmstadt

Recently hybrid solar cells consisting of dye sensitizers embedded in a microcrystalline silicon thin film matrix have been proposed and even recently processed [1]. The dye sensitizers are introduced to the matrix due to their high absorption coefficients and therefore enhance the absorption of the dye-matrix-system. A microcrystalline silicon matrix is chosen because it is fairly "forgiving" to distortions introduced by the dye molecules and transport properties of charge carriers are still acceptable. In this contribution we present calculations for the efficiency improvement of hybrid dye-microcrystalline silicon solar cells compared to pure microcrystalline solar cells. The calculations were performed for varying thicknesses of the microcrystalline silicon layer, dye concentrations and wavelength of maximum absorption of the dye.

[1] T. Mayer et al., Renewable Energy 33, 262-266 (2008)

HL 62.21 Thu 18:00 Poster D2

Spectrally and angle resolved emission of a Rh6G based fluorescence collector — •Hendrik Sträter[1], Sebastian Knabe[1], Nazila Soleimani[2], Tom Markvart[2], and Gottfried H. Bauer[1] — [1]Institute of Physics, Carl von Ossietzky University Oldenburg, D-26111 Oldenburg — [2]School of Engineering Sciences, University of Southampton, SO17 1BJ, UK

Concentration of light based on the fluorescence of well-chosen dyes offers the possibility to decrease the cost of multispectral solar cells. Unfortunately the theoretical efficiency has not been achieved, mainly because of photon transport losses via the loss cone of emission. With increasing dye concentration the effect of reemission of fluorescence light rises and thereby the losses of photons due to the loss cone.

To understand the reemission as a major loss mechanism we measure the spectrum of the light that leaves the edge of the concentrator as a function of the distance between illumination position and edge when illuminating perpendicularly to the surface. For the measurement we used a thin layer of Rhodamine 6G embedded in a Poly(methyl methacrylate) matrix on a glass substrate. The results of spectrally and angle resolved fluorescence emission are compared with those under homogeneous illumination. We compare our data with the results of a theoretical model, which analytically formulates the effects of absorption and subsequent reemission of fluorescence photons in the collector.

HL 62.22 Thu 18:00 Poster D2

Charge transport in thin layers of nanocrystalline mesoporous Titania — •Steve Albrecht, Sylvia Paul, and Dieter Neher — Universität Potsdam, D-14476 Potsdam, Germany

Nanocrystalline mesoporous Titania (nc-TiO_2) has been shown to function as a very good electron acceptor in combination with common electron-donating polymers like poly(para-phenylene vinylene) or poly(3-hexylthiophene). However, charge transport in nc-TiO_2 layers is not well understood, though it might severely affect the energy conversion efficiency of those hybrid cells. Here, we present measurements of the electron mobility using the technique of charge extraction by linearly increasing voltage (CELIV). Layers of ca. 100 nm in thickness were prepared via dip-coating from a dispersion of 5 nm sized Titania particles. These layers were then annealed at different temperatures to remove the organic compounds. Unexpectedly, a pre-bias needed to be applied during the CELIV-measurements in order to obtain a measurable extraction peak. Apparently, those layers possess a high

density of traps, which requires a certain number of electrons to be accumulated within the layer prior to the injection of mobile carriers. This interpretation was nicely confirmed by results from dark-injection measurements. We observed a significant increase of free carrier mobility with annealing temperature, reaching ca. 10^{-5} cm^2/Vs for a layer annealed at 600°C, while the trap density decreased with temperature. In accordance to these results, the performance of hybrid solar cells improved largely when the nanocrystalline Titania layer was annealed at higher temperatures prior to the deposition of the polymers.

HL 62.23 Thu 18:00 Poster D2

Influence of pyridine treatment on the ligand shell of OA-capped CdSe nanoparticles and the impact on polymer/CdSe hybrid solar cells — •Irina Lokteva, Nikolay Radychev, Holger Borchert, Jürgen Parisi, and Joanna Kolny-Olesiak — University of Oldenburg, Oldenburg, Germany

This study describes the surface modification of the original oleic acid (OA) capped CdSe colloidal quantum dots (QDs) with pyridine molecules and application of the pyridine coated CdSe QDs for the preparation of polymer/CdSe hybrid solar cells.

The composition of the ligand shell was investigated by means of nuclear magnetic resonance (NMR) spectroscopy and thermal gravimetric analysis (TGA). It was shown that after one-fold pyridine treatment some amount of OA was still present in the sample, which motivated us to fulfil repeated steps of the ligand exchange. The absorption spectra after repeated pyridine treatment revealed that no aggregation or oxidation of the nanoparticles in solution occurred. TEM images were used as well to characterize the successive steps of the ligand exchange.

The hybrid CdSe-P3HT solar cells were fabricated using the pyridine capped CdSe QDs and I-V characteristics of these solar cells were collected to characterize the sequential steps of the pyridine treatment. Although repeated ligand exchange was found to have a beneficial effect in the sense that they led to more complete ligand exchange which in turn enabled more efficient charge transfer, the main characteristic parameters of the solar cells were found to deteriorate. Correlations of this behavior with the morphology of the hybrid blends were analyzed.

HL 62.24 Thu 18:00 Poster D2

Transmission electron microscopy analyses of binary and ternary iron silicides in the system Al:Fe:Si — •Patrick Schwager, Doaa Abdelbarey, and Michael Seibt — Georg-August-Universität Göttingen, IV. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen

In order to use low-cost multicrystalline silicon for photovoltaic applications it is essential to eliminate metal impurities. One technique to remove device-degrading impurities is aluminum gettering which exploits segregation of metal impurities into the forming Al:Si liquid for annealing above the eutectic temperature of 577°C. The segregation coefficient can be estimated by consulting the binary Al:M and Si:M phase diagrams where M is the metal impurity, here Fe. Experimental data yield instead values which are lower by two orders of magnitude. It has been proposed that this discrepancy stems from a higher solubility of Fe in Si in equilibrium with the ternary Al-doped $\alpha - FeSi_2 : Al$ compared to that in equilibrium with the binary $\alpha - FeSi_2$ (D.Abdelbarey et al., Appl. Phys. Lett. **94**, 061912 (2009)). Due to the slow Al diffusion in Si, the solution of iron in silicon in equilibrium with a $\alpha - FeSi_2 : Al$ surface layer would be unstable against precipitation into $\alpha - FeSi_2$. In this work, we use transmission electron microscopy techniques to analyze the structure and chemistry of ternary Al:Fe:Si surface layers after high temperature formation as well as extended defects formed in the bulk of the wafers.

HL 62.25 Thu 18:00 Poster D2

Optimization of Cu(In,Ga)Se2 solar cells under different irradiance — •Sebastian Jander[1,2], Stefan Puttnins[1,2], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, 04288 Leipzig, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

$Cu(In,Ga)Se_2$ (CIGSe) solar cells on flexible substrates open up new fields of applications for photovoltaics. This could be building integrated photovoltaics, lightweight construction photovoltaic modules or integrated modules in clothes or pockets for charging iPods, mobile phones or laptops.

Depending on their application these solar cells operate at different irradiances und types of illumination. Therefore real working conditions have to be considered besides the standard test conditions (AM 1.5 spectrum with 1000 W/m^2).

The influences of parallel and series resistance, the diode quality factor and other parameters were evaluated in detail on the basis of measurements and model calculations for different irradiances. Additionally, influences of various production parameters in the manufacturing of solar cells from the Solarion AG were investigated and analyzed. We show correlation between Cu/III ratio of CIGSe, i-ZnO layer thickness and metallic grid design with low light intensity performance.

Using these results optimized solar cells and modules can be manufactured for the mentioned applications and illumination conditions.

HL 62.26 Thu 18:00 Poster D2

Photoelectric characterization of $Cu(In,Ga)S_2$ Photovoltaic Devices with Varying Ga-Content — •Julia Riediger[1], Jan Keller[1], Jörg Ohland[1], Martin Knipper[1], Ingo Riedel[1], Jürgen Parisi[1], Roland Mainz[2], Saoussen Merdes[2], and Alexander Meeder[3] — [1]Uni Oldenburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie Berlin GmbH — [3]SULFURCELL Solartechnik GmbH

An increased efficiency of $CuInS_2$-based solar cells is expected for absorber films doped with gallium which enlarges the band gap and therefore the open circuit voltage (V_{OC}). We investigated $Cu(In,Ga)S_2$ solar cells prepared under different rapid thermal processing (RTP) conditions. Depending on the RTP temperature profile, the films exhibit $CuInS_2/CuGaS_2$ (top/bottom) segregation which is detrimental for a large V_{OC}. Solar cells prepared with different RTP-temperatures were investigated by temperature-/illumination-dependent current-voltage measurements (IV(T)), external quantum efficiency (EQE) and admittance spectroscopy (AS). Only precursors sulfurized at sufficiently high temperatures exhibited the desired interdiffusion of the segregated $CuInS_2/CuGaS_2$ system. The activation energies derived from IV(T) measurements suggest carrier losses due to interface recombination. The current collection in cells with substantial $CuInS_2/CuGaS_2$ segregation is limited over a wide temperature range up to 300K whereas the photocurrent is independent of temperature for T>200K. Admittance spectroscopy revealed a set of defect states, each of them representing different response to variation of the RTP process.

HL 62.27 Thu 18:00 Poster D2

Surface roughness, optical and spectroscopic properties of thin film systems based on $Cu(In,Ga)Se_2$ absorbers — •Oliver Neumann[1], Florian Heidemann[1], Stephan J. Heise[1], Rudolf Brüggemann[1], Wolfram Witte[2], and Gottfried H. Bauer[1] — [1]Institute of Physics, Carl von Ossietzky University Oldenburg, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Stuttgart, Germany

We study the behaviour of the local properties like surface roughness, splitting of the quasi Fermi levels and optical threshold energies of thin film systems based on $Cu(In,Ga)Se_2$ absorbers and consisting of substrate, back electrode, $Cu(In,Ga)Se_2$ absorbers, buffer layer and front electrode. We imitate in-situ experiments with lateral resolution such as afm-topology, spectral transmission/absorption and spectral photoluminescence, which announces the splitting of the quasi-Fermi levels by statistical methods for feature extraction like 2D Fourier transforms and/or Minkowski-operations (opening functions) by analyzing films from different states of the growth process, say of different thicknesses. We moreover correlate the above mentioned lateral features for the identification of the origin of final grainy structures as well as for that of lateral inhomogeneities.

HL 62.28 Thu 18:00 Poster D2

Maximum voltage determined by appropriate superposition of photoluminescence from polycrystalline $Cu(In,Ga)S_2$ absorber layers — •Florian Heidemann[1], Rudolf Brüggemann[1], Saoussen Merdes[2], Alexander Meder[3], and Gottfried H. Bauer[1] — [1]Institute of Physics, CvO University Oldenburg, Germany — [2]SE2, Helmholtz-Zentrum Berlin, Germany — [3]SULFURCELL Solartechnik GmbH, Berlin, Germany

Thin film solar cells based on the chalcopyrite $Cu(In,Ga)S_2$ offer an alternative to the predominant $Cu(In,Ga)Se_2$ with the benefit of higher band-gap and thus of nominal higher open circuit voltage V_{oc}. We have performed calibrated photoluminescence (PL) studies on absorbers to characterize their optoelectronic quality. To record spectrally resolved PL with sufficient photon fluxes we collect PL signals from a homogeneously illuminated area of 1 mm^2. Due to absorber polycrystallinity the collected PL-signal is composed of contributions of individual sites in the μm-scale varying in intensity and spectral shape. Since the splitting of quasi-Fermi levels ($E_{Fn} - E_{Fp}$) according to Planck's gen-

eralized law is derived from the logarithm of the spectral PL yield, measuring without sufficient local resolution leads to an overestimation of $E_{Fn} - E_{Fp}$. With a second confocal setup we analyze spectrally resolved PL with a lateral resolution of less than 1 μm. For detection limitations we need excitation fluxes in the order of 10^4 AM1.5 to extrapolate from distribution functions of PL signals recorded at 300 K and high excitation towards AM1.5. We correct $E_{Fn} - E_{Fp}$ from the calibrated setup, which corresponds to the maximum achievable V_{oc}.

HL 62.29 Thu 18:00 Poster D2

Investigations of defects after indiffusion of iron and nickel into float-zone silicon — •Philipp Saring, Nils Hildebrand, Marie Aylin Falkenberg, and Michael Seibt — IV.Physikalisches Institut der Georg-August-Universität, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

The electrical properties of silicon are strongly influenced by fast diffusing transition metal impurities such as iron, nickel and copper, which are unintentionally brought into and distributed inside the material during high temperature treatments. Under certain conditions these metals cluster by forming recombination active silicide precipitates. Whereas homogeneous precipitation has been observed for nickel or copper, iron precipitation generally requires the presence of preexisting nucleation sites. Recent studies deal with the simultaneous coprecipitation of these elements.

In this work we focus on the distribution of the electrically active defects after indiffusion of nickel and iron into float-zone silicon. We investigate the recombination properties of these defects by LBIC- and EBIC-measurements as well as their concentration and majority charge carrier kinetics by DLTS experiments. By suitable annealing conditions we established quite small concentrations of precipitates ($< 10^8 \mathrm{cm}^{-3}$) and metal denuded zones below the sample surfaces. Single precipitates were extracted by Focussed-Ion-Beam technique for TEM-investigations.

HL 62.30 Thu 18:00 Poster D2

Defect characterisation of thin a-Si:H- and μc-Si:H-films with FTPS ("Fourier Transform Photocurrent Spectroscopy") — •Dominik Schael[1], Armin Brechling[1], Ulrich Heinzmann[1], Thomas Westerwalbesloh[2], and Helmut Stiebig[2] — [1]Molecular and Surface Physics, Bielefeld University, Germany — [2]Malibu GmbH & Co. KG, Bielefeld, Germany

An important characteristic of silicon semiconductors is the defect concentration. Acting as recombination centers, defects lead to a reduced carrier lifetime, which strongly influences the performance of a solar cell. One way to get information about the defect concentration is the determination of the optical absorption coefficient $\alpha(E)$ in the subband range. Obtaining $\alpha(E)$ of thin a-Si:H- and μc-Si:H-layers is a challenge since $\alpha(E)$ varies over several orders of magnitude. A very sensitive method to determine the absorption coefficient is the Fourier Transform Photocurrent Spectroscopy. Here, the a-Si:H- or μc-Si:H-sample acts as an external detector in a FTIR setup, which enables very fast measurements. By calibrating the FTPS-signal with reflectance and transmittance data, absolute values for $\alpha(E)$ are obtained. Depending on the characteristics of $\alpha(E)$, a defect concentration can be calculated.

We will present the measurement setup and will discuss the subband gap distribution of different Si based (a-Si:H, μc-Si:H and c-Si) samples.

HL 62.31 Thu 18:00 Poster D2

Morphological studies of microcrystalline silicon for thin-film solar cells by raman spectroscopy and TEM — •Vitalij Schmidt[1], Daniel Janzen[2], Wiebke Hachmann[1], Marc Sacher[1], Stefan Gruss[2], Helmut Stiebig[2], and Ulrich Heinzmann[1] — [1]University of Bielefeld, 33615 Bielefeld — [2]Malibu GmbH & Co. KG, 33609 Bielefeld

Thin-film amorphous and microcrystalline silicon are promising materials for photovoltaics as they have the potential to reduce the solar cell costs. In case of microcrystalline silicon the crystalline volume fraction is an important issue for the quality of solar cells as it is related to the microstructure of the material and the defect density.

Using an AKT PECVD system optimized for amorphous silicon layer deposition we deposited microcrystalline silicon diodes on 1300 mm $\times$1100 mm glas-TCO superstrates under variation of deposition time, RF power, silane concentration and distance of the electrodes.

Focusing on the crystalline fraction and especially its lateral homogenity over the $1,4$ m^2 area we analyzed the intrinsic layer by Raman spectroscopy on different positions. Two excitation wavelength (473 nm and 633 nm) are used in ordner to get depth dependent information of the crystallinity. TEM observations of cross-section of chosen samples confirmed the spectroscopy given results.

Based on the lateral information achieved the process was optimized and a correlation between crystalline volume fraction and local cell efficiency will be disussed.

HL 62.32 Thu 18:00 Poster D2

Estimation of excess carrier depth profile from spectral photoluminescence yield in c-Si absorbers — •Sebastian Knabe and Gottfried H. Bauer — Institure of Physics, University Oldenburg, Germany

The photoluminescence (PL) emitted from excited semiconductors provides access to parameters like the splitting of quasi-Fermi-levels, optical absorption, etc and is based on the recombination of excess carrier. In this study we show one strategy to estimate parameters like excess carrier lifetime, surface recombination velocity, etc. of the excess carrier density depth profile from photoluminescence measurements in the model system crystalline silicon. We simulate the spectral PL and fit these results to experimental ones with respect to an optimally selected carrier depth profile with a Nelder-Mead algorithm.

HL 62.33 Thu 18:00 Poster D2

Verbesserung der Materialqualität von Galliumindiumnitridarsenid (GaInNAs) durch Ausheilen zur Optimierung von hocheffizienten III-V-Mehrfachsolarzellen — •Sebastian Rönsch, Elke Welser, Tobias Roesener, Frank Dimroth und Andreas W. Bett — Fraunhofer Institut für Solare Energiesysteme (ISE), Freiburg

Hocheffiziente Mehrfachsolarzellen aus III-V-Verbindungshalbleitern werden bereits für die Weltraumanwendung und für die Verwendung in terrestrischen Konzentratorsystemen industriell gefertigt. Der theoretische Wirkungsgrad der etablierten, gitterangepassten $Ga_{0,50}In_{0,50}P/Ga_{0,99}In_{0,01}As/Ge$-Dreifachsolarzelle wird durch Erweiterung mit einer $Ga_{0,92}In_{0,08}N_{0,03}As_{0,97}$-Teilsolarzelle unter extraterrestrischen AM0 Standardbedingungen und einfacher Sonnenlichtkonzentration von 40,6 % auf 52,3 % deutlich gesteigert. Diese vielversprechende Vierfachsolarzelle wird derzeit durch die geringe Materialqualität des GaInNAs stark limitiert. Zur Verbesserung der Materialqualität wurde das thermische Ausheilen wachstumsbedingter Defekte mittels Photolumineszenzmessungen (PL), elektronenstrahlinduzierten Strommessungen (EBIC) und kapazitiver Transientenspektroskopie (DLTS) untersucht. Mit EBIC konnten im GaInNAs ausgeprägte, punktförmige Defektstrukturen im Mikrometerbereich beobachtet werden. Ein Hochtemperaturschritt löst die Defektstrukturen auf. Gleichzeitig nimmt der EBIC-Strom zu, die PL-Intensität steigt und der mit DLTS bestimmte Einfangquerschnitt der Defekte nimmt um mehrere Größenordnungen ab.

HL 62.34 Thu 18:00 Poster D2

Entwicklung alternativer Prozesstechnologien zur Herstellung monolithisch integriert serienverschalteter Konzentratorsolarzellen (MIMs) — •Henning Helmers[1], Eduard Oliva[1], Wolfgang Bronner[2], Frank Dimroth[1] und Andreas W. Bett[1] — [1]Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg — [2]Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Freiburg

Monolithisch integriert serienverschaltete Module (MIMs) sind großflächige Solarzellbauelemente für den Einsatz unter hohen Lichtintensitäten in konzentrierenden Photovoltaiksystemen. MIMs bestehen aus mehreren III-V basierten Solarzellsegmenten, die während der Prozessierung durch Verschaltungsgräben in Serie verschaltet werden. Die Breite dieser Gräben, sowie der damit verbundene Verlust an aktiver Solarzellfläche sind durch die verwendete Herstellungstechnologie limitiert.

Es wurden verschiedene Prozesstechniken zur Minimierung dieser Verluste untersucht. Neben einer optimierten herkömmlichen Technologie, mit nasschemischem Ätzen und photostrukturiertem Polyimid als Dielektrikum zur Isolation der pn-Übergänge, wurde ein alternativer Trockenätzprozess mittels RIE-ICP sowie ein Prozess zur Strukturierung von Siliziumnitrid als Dielektrikum entwickelt. Damit wurden die Grabenbreiten von über 100 μm auf 57 μm reduziert. Dies entspricht nahezu einer Halbierung der Flächenverluste von 11% auf unter 6%. Der höchste erzielte Wirkungsgrad beträgt für eine Tandemstruktur η=24,7% bei einer Einstrahlung von 1037 MW/m^2. Dabei wurden folgende Kenngrößen gemessen: V_{oc}=53,7 V, I_{sc}=2,60 A, FF=80,1%.

HL 63: III-V Semiconductors

Time: Friday 10:15–13:00 Location: H13

HL 63.1 Fri 10:15 H13

Theoretical Description of optical properties in III-V Semiconductor Nanostructures — •Marc Landmann, Eva Rauls, and Wolf Gero Schmidt — Universität Paderborn

We present a density functional theory (DFT) study of the electronical and optical properties of GaAs and AlAs bulk and AlAs/GaAs superlattices. Thereby, we emphasize that the DFT calculation of band offsets already yields results in quantitative agreement with the experiment. For a general description of optical properties (e.g. band structure and optical absorption) we outline the limitations of a pure independent particle (DFT) description and contrast these results with data obtained from the many body pertubation theory based independent quasiparticle approximation (GWA) and Coulomb-correlated quasiparticle approximation (BSE). [1]

[1] W. G. Schmidt et al., PRB 67, 085307 (2003)

HL 63.2 Fri 10:30 H13

Band structure and effective mass calculations for III-V compound semiconductors using hybrid functionals and optimized local potentials — •Yoon-Suk Kim, Martijn Marsman, and Georg Kresse — Faculty of Physics, University of Vienna, Austria

The band structures of III-V semiconductors (InP, InAs, InSb, GaAs, and GaSb) are calculated using the HSE06 hybrid functional, GW, and local potentials optimized for the description of band gaps. We show that the inclusion of a quarter of the exact HF exchange allows to predict accurate direct band gaps for InP, InAs, and InSb, i.e., 1.48, 0.42, 0.28 eV,[1] in good agreement with recent experiments, i.e., 1.42, 0.42, 0.24 eV,[2] respectively. The calculated effective masses and Luttinger parameters are also in reasonable agreement with experiment, although a tendency towards underestimation is observed with increasing anion mass. In order to find more efficient methods than hybrid functionals, the modified Becke-Johnson exchange potential[3] is also employed to calculate the effective masses. The agreement of the effective masses with experiment is comparable to the one obtained with the HSE06 hybrid functional. Therefore, this opens a way to model band structures of much large systems than possible using hybrid functionals.

[1] Y.-S. Kim, K. Hummer, and G. Kresse, Phys. Rev. B **80**, 35203 (2009).

[2] I. Vurgaftman, J.R. Meyer, and L.R. Ram-Mohan, J. Appl. Phys. **89**, 5815 (2001).

[3] F. Tran and P. Blaha, Phys. Rev. Lett. **102**, 226401 (2009).

HL 63.3 Fri 10:45 H13

Damping processes on coherent zero field spin oscillations in high mobility, two-dimensional electron systems — •Michael Griesbeck[1], Mikhail Glazov[2], Tobias Korn[1], Dominik Waller[1], Dieter Schuh[1], Werner Wegscheider[1], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Peterburg, Russia

We present time-resolved studies of two-dimensional electron systems with high mobility, where at low temperatures the weak-scattering regime of the D'yakonov-Perel spin relaxation mechanism is accessible. Using the all-optical time-resolved Faraday rotation technique, coherent oscillations of the optically-excited spin ensemble about the intrinsic spin-orbit field are observable. The lifetimes of these oscillations are limited by scattering mechanisms, which change the electrons k vector or an anisotropy of the k-dependent effective spin-orbit field. By investigating samples with different mobilities of 1.5 million cm^2/Vs and 15 million cm^2/Vs, temperature dependent measurements showed that in the lower mobility sample the momentum scattering time τ_p limits the lifetime of the zero field oscillations, whereas in the sample with the ultra high mobility the limiting processes are electron-electron scattering events. Lowering the excitation density led to a lower temperature of the electron system and due to increasing e-e-scattering times to an increasing lifetime of the observed spin beats.

HL 63.4 Fri 11:00 H13

Optically detected cyclotron-resonance in $GaAs/Al_{0.3}Ga_{0.7}As$ heterojunction — •Claudia Zens[1], G. Bartsch[1], B.M. Ashkinadze[2], D.R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Solid State Institute, Technion-Israel Institute of Technology, Haifa 3200, Israel

We study the effective electron mass of a high mobility two-dimensional electron gas in a $GaAs/Al_{0.3}Ga_{0.7}As$ heterojunction. The effective mass is measured by changes in the photoluminescence, induced by far infrared radiation (FIR) under conditions of the electron cyclotron resonance. Additional illumination above the $Al_{0.3}Ga_{0.7}As$ barrier band gap allows flexible control of the carrier concentration, which was tuned in the range from 0.5 to $2{\cdot}10^{11}cm^{-2}$ in the very same sample. We have found a systematic increase of the electron effective mass with growing carrier concentration, and for higher FIR photon energies. Both trends are in qualitative agreement with the behavior expected due to conduction band nonparabolicity.

HL 63.5 Fri 11:15 H13

Engineering ultralong spin coherence in 2D hole systems at sub-Kelvin temperatures — •Kugler Michael, Korn Tobias, Griesbeck Michael, Schulz Robert, Hirmer Marika, Schuh Dieter, Wegscheider Werner, and Schüller Christian — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

For the realisation of scalable solid-state quantum-bit systems, spins in semiconductor quantum dots are promising candidates. A key requirement is a sufficiently long coherence time of the spin system. Recently, hole spins in III-V-based quantum dots were discussed as alternatives to electron spins, since the hole spin is not affected by contact hyperfine interaction with the nuclear spins.

Here, we report a breakthrough in the spin coherence times of hole ensembles, confined in so called natural quantum dots, in narrow GaAs/AlGaAs quantum wells at sub-Kelvin temperatures. Consistently, time-resolved Faraday rotation and resonant spin amplification techniques deliver hole-spin coherence times, which approach in the low magnetic field limit values above 70 ns. The optical initialisation of the hole spin polarisation, as well as the interconnected electron and hole spin dynamics in our samples are well reproduced using a rate equation model [1].

Furthermore, electric control of the hole g factor could be achieved via application of a gate voltage, resulting in a shift of more than 50 % in the value of the g factor [2].

[1] Korn et al., cond-mat0909.3711v2, submitted.

[2] M. Kugler et al., Phys. Rev. B 80, 035325 (2009).

15 Min. Coffee Break

HL 63.6 Fri 11:45 H13

Carbon doped GaAs/AlGaAs heterostructures with high mobility two dimensional hole gas — •Marika Hirmer[1], Dieter Schuh[1], and Werner Wegscheider[1,2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg, Germany — [2]present address Laboratorium für Festkörperphysik, ETH Zürich, Schafmattstr. 16, 8093 Zürich, Switzerland

Two dimensional hole gases (2DHG) with high carrier mobilities are required for both fundamental research and possible future ultrafast devices.

Here, two different types of GaAs/AlGaAs heterostructures hosting a 2DHG were investigated. The first structure is a GaAs QW embedded in AlGaAs barrier grown by molecular beam epitaxy with carbon-doping only at one side of the QW (single side doped, ssd), while the second structure is similar but with symmetrically arranged doping layers on both sides of the QW (double side doped, dsd).

The ssd-structure shows mobilities up to $1.2 * 10^6 cm^2/Vs$ which are achieved only after illumination, while the dsd-structure hosts a 2DHG with mobility up to $1.6 * 10^6 cm^2/Vs$. In addition, mobility and density is not affected by illuminating this sample. Both samples showed distinct Shubnikov-de-Haas oscillations in magnetotransport experiments done at 350mK, indicating the high quality of the material. Further, the influence of different temperature profiles during growth and the influence of the Al content of the barrier $Al_xGa_{1-x}As$ on carrier concentration and mobility were investigated.

HL 63.7 Fri 12:00 H13

Ferromagnetic and transport properties of very thin (Ga,Mn)As layers — •Lars Ebel, Stefan Mark, Michael Freitag, Tsvetelina Naydenova, Charles Gould, Karl Brunner, and Laurens W. Molenkamp — Physikalisches Institut (EP III), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We have fabricated by low-temperature molecular beam epitaxy series of typically 4nm thin (Ga,Mn)As layers with homogeneous or parabolically graded Manganese content on un-GaAs(001). The average Mn content was varied between 2 and 10%. The samples have been studied by RHEED, SQUID, room- and low-temperature magneto-transport measurements. The results as well as self consistent model calculations by "nextnano" show a strong influence of hole compensation and band bending caused by LT-GaAs and surface defects. Thin layers with graded Mn content reveal better conductivity and higher Curie temperatures (up to about Tc=71K, as-grown) compared to homogeneous layers. Thus, such layer with moderate hole density but well-controlled transport and ferromagnetic behavior may be used for novel spintronic devices with large tunability by a gate voltage.

HL 63.8 Fri 12:15 H13

Quantitative analysis of III-V on Si(100) anti-phase domains — •Henning Döscher[1], Benjamin Borkenhagen[2], Peter Kleinschmidt[1], Sebastian Brückner[1], Anja Dobrich[1], Oliver Supplie[1], Gerhard Lilienkamp[2], Ulrike Bloeck[1], Winfried Daum[2], and Thomas Hannappel[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin — [2]IEPT, TU Clausthal, Leibnizstr. 4, 38678 Clausthal-Zellerfeld

GaP growth on Si(100) is considered as an important model system for polar on non-polar epitaxy required for the combination of opto- and microelectronic devices. Anti-phase disorder according to the step structure of the substrate surface prior to III-V deposition has been identified as a major challenge. Destructive techniques such as anisotropic etching or adequate post growth annealing can highlight anti-phase boundaries (APBs) as height contrast. Transmission electron microscopy (TEM) is able to visualize APBs in high resolution images and even anti-phase domains (APDs) directly, if proper dark field imaging conditions are applied.

The influence of anti-phase disorder on surface reconstructions enables alternative concepts for direct APD investigation with non-destructive surface sensitive instruments: Reflectance anisotropy spectroscopy (RAS) integrates over large surface areas (cm scale) and provides a quantitative in situ access to the APD content of a sample. Low-energy electron microscopy (LEEM) allows the lateral resolution of APDs in GaP/Si(100) samples via dark field imaging with related higher order diffraction spots from the surface.

HL 63.9 Fri 12:30 H13

Identification of the character of ferromagnetic Mn in Epitaxial Fe/GaMnAs heterostructures by XMCD and XRMS measurements — •Marcello Soda[1], Francesco Maccherozzi[2], Matthias Sperl[1], Dieter Schuh[1], Günther Bayreuther[1], Werner Wegscheider[1,4], Giancarlo Panaccione[3], and Christian Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Deutschland — [2]Soleil Synchrotron, L'Orme des Merisiers Saint-Aubin, BP 48, F- 91192 Gif-sur-Yvette , France — [3]Laboratorio Nazionale TASC, INFM-CNR, in Area Science Park, S.S. 14, Km 163.5, I-34012, Trieste, Italy — [4]Laboratorium für Festkörperphysik, Schafmattstr. 16, 8093 Zürich, Switzerland

We demonstrate that the growth of Fe/(Ga,Mn)As heterointerfaces can be efficiently controlled by epitaxy, and that robust ferromagnetism of the interfacial Mn atoms is induced at room temperature by the proximity effect. X-ray magnetic circular dichroism and X-ray resonant reflectivity data, supported by theoretical calculations, were used to monitor both the temperature and the magnetic field dependence of the Mn magnetic moment in the semiconducting host. We identify distinct Mn populations, each of them with specific magnetic character.

HL 63.10 Fri 12:45 H13

GHz Spin Noise Spectroscopy in n-Doped Bulk GaAs — •Georg Müller, Michael Römer, Jens Hübner, and Michael Oestreich — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We advance spin noise spectroscopy (SNS) to GHz frequencies in order to resolve high frequency spin dynamics in n-doped bulk GaAs [1]. SNS relies on the statistical imbalance of electron spins in thermodynamical equilibrium, which is detected by below band gap Faraday rotation. Hence, SNS is an ideal experimental tool to deliver intrinsic spin lifetimes. In the past, these advantages could not be exploited to full extend since the bandwidth of the detection system ($\lesssim 1$ GHz) has capped SNS to slow spin dynamics at relatively low frequencies. In the advanced experimental method of GHz SNS, ps laser pulses are utilized as probe light. The spin dynamics in the sample at the Larmor frequency is sampled by the repetition rate of the laser such that spin noise at frequencies above 10 GHz can be detected without any loss of sensitivity. With this new measurement technique at hand, we study the magnetic field dependence up to 3 T of the electron Landé-g-factor g^* and the spin dephasing time T_2^* of two n-doped bulk GaAs samples at and above the metal-to-insulator transition (MIT). Our findings reveal in conjecture with high aperture SNS, which allows depth resolved SNS measurements, that the observed inhomogeneous broadening of the spin dephasing rate at the MIT originates from a local g-factor variation in the sample due to surface electron depletion.

[1] G. M. Müller *et al.*, arXiv:0909.3406 (2009).

HL 64: Quantum Dots and Wires: Optical Properties VI

Time: Friday 10:15–13:00 Location: H14

HL 64.1 Fri 10:15 H14

Elastic strain engineering of quantum dot excitonic emission in nanomembranes and optical resonators — •Fei Ding[1], Ranber Singh[2], Johannes Plumhof[1], Tim Zander[2], Gabriel Bester[2], Armando Rastelli[1], and Oliver Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Max-Planck-Institut fuer Festkoerperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

We study the effect of an external biaxial stress on the light emission of single InGaAs/GaAs (001) quantum dots (QD) embedded in a 200 nm-thick-membrane. Reversible and bi-directional spectral tuning of QD excitonic emission is demonstrated via a simple electro-mechanical device. The most intriguing finding is that biaxial strain is a reliable tool to engineer the QD electronic structure and reach color coincidence between exciton and biexciton emission, providing a vital prerequisite for the generation of polarization entangled photon pairs through a time reordering strategy. The physical origin of this new phenomenon is discussed based on the empirical pseudopotential calculations.

With similar technique we study the effect of biaxial stress on single QDs embedded in microring resonators. The microrings can be reversibly stretched or squeezed, resulting in a controllable engineering of both QD emissions and optical modes. Our results open up a new tuning strategy to study cQED with semiconductor quantum dots.

HL 64.2 Fri 10:30 H14

Effect of substrate thickness on uniaxial strain–induced single quantum dot emission energy tuning — •Klaus D. Jöns[1], Robert Hafenbrak[1], Sven M. Ulrich[1], Lijuan Wang[2], Fei Ding[2], Johannes D. Plumhof[2], Armando Rastelli[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

The ability to tailor the optical properties of epitaxially grown quantum dots (QDs) is one of the huge advantages of these kind of solid state quantum emitters. In particular, the possibility to tune the emission energy is an important prerequisite to generate indistinguishable photons from two different quantum emitters. In our work we present in–situ emission energy tuning of self–assembled InGaAs/GaAs QDs by uniaxial strain. For this purpose we glued the sample tightly on a piezo stack. Our technique allows to apply tunable tensile and compressive uniaxial strain along the [110] crystal axis perpendicular to the growth direction. The applied strain changes the emission energy of the QD by enlarging respectively reducing the lattice constant

and thus the band gap. Micro–photoluminescence measurements at $T = 10\,K$ show that the spectral emission of the QDs can be reversibly shifted in a controlled way. We use different substrate thinning techniques to increase the uniaxial strain at the lattice plane of the QDs. This leads to an increased tuning range of the emission energy. Samples with completely removed substrate show an emission tuning range up to 2.8 meV.

HL 64.3 Fri 10:45 H14

Strain tuneable photoluminescence from natural InAs quantum dots — •Matthias Klingbeil, Matthias Grave, Sven Wildfang, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik,Jungiusstr 11, 20355 Hamburg

The growth of self-assembled InAs-quantum dots on a GaAs substrate is inherently connected to the formation of an InAs wetting layer. Recently it was shown that fluctuations in the composition and thickness of this wetting layer lead to the formation of shallow zero dimensional confinements [1], so called natural InAs quantum dots [nQD]. The photoluminescence of these nQD is typically located in the low energy tail of the wetting layer emission. Here, we show that the nQD emission can be shifted away from the wetting layer and increased in intensity by the application of stress. For this purpose we embed the nQD in free standing lamellae that can be bent by a glass needle during the photoluminescence experiment. In the unstrained state all nQDs exhibit a low intensity. The application of strain amplifies the luminescence of certain nQDs and red shifts their emission away from the wetting layer signal by up to 40 meV.

[1] Babinski et al., Appl. Phys. Lett. 92, 171104 (2008).

HL 64.4 Fri 11:00 H14

Effect of biaxial stress on single particle states and binding energies of charged excitons and biexciton in In(Ga)As/GaAs(001) self-assembled quantum dots — •Ranber Singh[1], Fei Ding[2], Johannes Plumhof[2], Tim Zander[2], Gabriel Bester[1], Armando Rastelli[2], and Oliver Schmidt[2] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr 20, D-01069 Dresden, Germany

We study the effect of an external biaxial stress on single particle states and binding energies of charged excitons and biexciton relative to that of neutral exciton in In(Ga)As/GaAs(001) quantum dots. We performed million-atom empirical pseudopotential calculations on *realistic* In(Ga)As/GaAs(001) quantum dots. We find that compressive biaxial stress increases the electron localization and hole delocalization. The binding energies of the positive trion and biexciton increase under compressive stress. Depending upon the value of binding energy of biexciton and available biaxial stress, the binding energy of biexciton can be tuned to zero which allows for the generation of entagnled photon pairs across generations in biexciton cascade process in In(Ga)As/GaAs(001) self-assembled quantum dots.

HL 64.5 Fri 11:15 H14

Cascaded exciton emission of an individual strain-induced quantum dot — •Florian J. R. Schülein[1], A. Laucht[2], M. Mattila[3], J. Riikonen[3], M. Sopanen[3], H. Lipsanen[3], J. J. Finley[2], A. Wixforth[1], and H. J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg, Germany — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [3]Department of Micro and Nanosciences, Micronova, Helsinki University of Technology, P.O. Box 3500, FIN-02015 TKK, Finland

Individual strain-induced quantum dots defined by InP stressors in an InGaAs/GaAs quantum well are isolated by electron beam lithography and selective wet chemical etching of stressors from an ensemble. Single exciton (1X) and biexciton (2X) are identified by power-dependent photoluminescence spectroscopy and do not show any finestructure splitting. Time-resolved PL spectroscopy performed at different excitation powers shows clear indications of cascaded emission of unpolarized photons in the transition from the triexciton back to the crystal ground state: The onset of the 1X emission is delayed with respect to the laser excitation pulse and the decay of the higher exciton levels at higher excitation powers. The decay time of one transition agrees with the rising time of the next lower transition of the cascade. This observation is characteristic for a the cascaded emission of single photons. Furthermore, we can reproduce this behavior using a rate equation model for a three-step cascade. Our system is a potential candidate for a source of polarization entangled photon pairs.

15 Min. Coffee Break

HL 64.6 Fri 11:45 H14

Optical properties of GaAs quantum dots fabricated by filling of self-assembled nanoholes — •Christian Heyn[1], Andrea Stemmann[1], Tim Köppen[1], Christian Strelow[1], Tobias Kipp[1], Matthias Grave[1], Matthias Klingbeil[1], Stefan Mendach[1], Andreas Schramm[2], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik,Jungiusstr 11, 20355 Hamburg — [2]Optoelectronics Research Centre, Tampere University of Technology, Finnland

Local droplet etching (LDE) is a very powerful technique which allows the self-assembled patterning of GaAs or AlGaAs surfaces without any lithographic steps. The LDE process starts with the generation of Ga, Al, or In droplets on the surface. Using appropriate process temperatures, deep nanoholes are drilled beneath the liquid droplets into the substrate. The method was introduced by Wang et al. [1] for etching of GaAs surfaces with Ga droplets. We have expanded the range of materials [2] and studied the time evolution of the LDE process [3]. By filling of nanoholes in AlGaAs with GaAs, we have fabricated GaAs quantum dots (QDs).[4] Dependent on the process parameters, ensembles of these LDE QDs show either broadband optical emission or very sharp lines up to room temperature. Furthermore, the optical fine-structure of single LDE QDs is studied.

[1] Zh. M. Wang et al., Appl. Phys. Lett. 90, 113120 (2007).
[2] A. Stemmann et al., Appl. Phys. Lett. 93, 123108 (2008).
[3] Ch. Heyn et al., Appl. Phys. Lett. 95, 173110 (2009)
[4] Ch. Heyn et al., Appl. Phys. Lett. 94, 183113 (2009).

HL 64.7 Fri 12:00 H14

Nuclear spin-polarization of InGaAs quantum dots due to electrical spin-injection — Pablo Asshoff, •Andreas Merz, Gunter Wüst, Heinz Kalt, and Michael Hetterich — Karlsruhe Institute of Technology (KIT) and DFG Center for Functional Nanostructures (CFN), 76131 Karlsruhe, Germany

For quantum information processing, the electronic spin states in semiconductor quantum dots can be used as two-level systems. Polarization of the nuclei resulting from spin-flip processes of the electrons is regarded to be detrimental to this. On the other hand, this interaction provides an easy access to the spin states of the nuclei. In this contribution, we demonstrate that electrical pumping of the quantum dots with spin-polarized electrons in a spin-injection light-emitting diode (spin-LED, [1]) can be used to achieve a nuclear spin polarization.

[1] M. Hetterich et al., in Advances in Solid State Physics, edited by R. Haug (Springer, Berlin, 2009), Vol. 48, p. 103

HL 64.8 Fri 12:15 H14

Proposal for a nanowire-based terahertz quantum cascade laser — •Thomas Grange and Peter Vogl — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

In spite of many efforts of optimization in the past few years, operation of terahertz quantum cascade laser (THz QCL) is still limited to cryogenic temperature. In THz QCLs, the lasing transition occurs between two subbands which are separated by less than the optical phonon energy. As the temperature increases, electrons gain sufficient in-plane kinetic energy in order to scatter efficiently between subbands by emitting optical phonons, reducing drastically the population inversion. An efficient way to circumvent this limitation is to use a structure in which the lateral motion of electrons is quantized. The use of an array of nanowires seems an appealing solution. In the present work, we calculate the transport and optical gain in nanowire heterostructures. Our calculation is made in the non-equilibrium green function (NEGF) framework. We incorporate scattering mechanisms due to interaction with phonons. Anharmonic interaction between phonons is also taken into account since it leads to scattering between the polaron states formed by electrons interacting with polar optical phonons [1,2]. We propose a structure that yields optical gain up beyond room temperature in the THz range. We highlight the physical differences with usual QCLs based on homogeneous 2-D layers.

[1] T. Grange, R. Ferreira and G. Bastard, Phys. Rev. B **76**, 241304(R) (2007).
[2] E. A. Zibik *et al.*, Nature Materials **8**, 803 (2009).

HL 64.9 Fri 12:30 H14

Light Harvesting in SC Core-Shell Nanocrystals — •Peter

Lemmens[1], Hongdan Yan[1], Abhinandan Makhal[2], and Samir Kumar Pal[2] — [1]IPKM, TU-BS, Braunschweig — [2]SNBC, Kolkata, India

The effect of capping and functionalization of core/shell type CdSe/ZnS semiconductor QDs is investigated by coupling/complexation with benzoquinone and TiO_2 nanoparticles using ps resolved time correlated single photon counting and fs carrier dynamics. Our aim is to improve photostability and understand energy transfer involved in light harvesting. Work supported by DFG.

HL 64.10 Fri 12:45 H14

Electroluminescence from silicon nanoparticles — •Jens Theis[1], Cedrik Meier[2], Axel Lorke[1], and Hartmut Wiggers[3] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen — [2]Nanophotonics & Nanomaterials Group, University Paderborn — [3]Institute of Combustion and Gas Dynamics and CeNIDE, University of Duisburg-Essen

We have fabricated an electroluminescence device based on silicon nanoparticles on a micropatterned GaAs heterostructure. The Si nanoparticles have been synthesized from the gas phase in a low-pressure microwave plasma using SiH_4 as a precursor. The nanoparticles were dispersed from an aqueous solution onto the patterned GaAs sample. For carrier injection, the particle layer was incorporated into a capacitor-like structure, where a transparent ITO layer served as the top-electrode. An AC-voltage accelerates electrons from the top gate to the GaAs-back contact. These electrons generate secondary electrons and holes by impact ionization and thus induce electron-hole pair recombination in the nanoparticles. For further analysis an optical, high resolution two-dimensional scans of the electroluminescence device was performed in a μ-Photoluminescence setup. Additionally, we study the influence that waveform, frequency and amplitude of the AC voltage on the electroluminescence. PL measurements made on separate samples of the same nanoparticles were also conducted. As a result, we conclude that the electroluminescence light around 700 nm and around 850 nm arise from the nanoparticles and the GaAs substrate, respectively.

HL 65: GaN-based Devices

Time: Friday 10:15–12:45 Location: H15

HL 65.1 Fri 10:15 H15

Calculation of optical eigenmodes and gain in semipolar and nonpolar InGaN/GaN laser diodes — •Wolfgang Scheibenzuber and Ulrich Schwarz — Fraunhofer IAF, Freiburg, Deutschland

Growth on semipolar and nonpolar crystal planes poses a possibility to reduce polarization fields and thereby enhance stimulated emission in (Al,In)GaN laser diodes. In this case the anisotropic optical properties of wurtzite (Al,In)GaN influence the optical eigenmodes of the laser waveguide and the optical gain .

This contribution reports the calculation of the optical eigenmodes in semipolar and nonpolar laser diodes taking into account the birefringence of GaN. Furthermore it shows calculations of the optical gain in such devices based on self-consistent 6x6 k*p valence band calculations.

Depending on the orientation of the laser diode's ridge waveguide relative to the c-axis, the eigenmodes of the laser diode are TE-/TM-modes or extraordinary/ordinary modes polarized along the crystal directions. The polarization of the eigenmodes then enters the calculation of the optical gain. Resulting spectra for c-plane, semipolar and nonpolar structures are compared at different charge carrier densities. It is found that for high indium concentrations the gain can be significantly increased by going from the c-plane to a semipolar or nonpolar crystal orientation. However, due to birefringence and composition of the topmost valence band wavefunction, the ridge has to be oriented along the projection of the c-axis on the growth plane.

HL 65.2 Fri 10:30 H15

Anisotropy in semipolar InGaN laser diodes: Consequences for resonator design and facet formation — •Jens Rass[1], Tim Wernicke[2], Wilfred John[2], Sven Einfeldt[2], Patrick Vogt[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universitaet Berlin, Institute of Solid State Physics, Hardenbergstrasse 36, 10623 Berlin — [2]Ferdinand-Braun-Institut fuer Hoechstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

For InAlGaN-based light emitting devices on nonpolar and semipolar substrate orientations the polarization fields can be reduced. Birefringence and gain anisotropy influence the optical modes of semipolar separate confinement hetero structures. We have investigated the threshold for amplified spontaneous emission and the optical polarization state of the eigenmodes for laser resonators with different orientations on various semipolar and nonpolar substrates. We found that semipolar resonators along the projection of the c-axis onto the surface have a lower threshold and the light is TE-polarized. Nonpolar resonators perpendicular to the c-axis on the other hand have elevated thresholds and hence a lower gain as well as a tilted linear optical polarization with the electric field nearly parallel to the c-axis of the crystal.

In order to obtain devices with low threshold and maximum performance, laser resonators on semipolar substrates have to be oriented along the semipolar orientation, posing a challenge for the fabrication of laser facets. Technologies such as laser assisted cleaving, chemical dry etching and wet chemical post processing are presented and their suitability for the generation of smooth vertical facets is discussed.

HL 65.3 Fri 10:45 H15

GaN-based laser structure with semipolar InGaN QWs realized by selective area epitaxy — •Thomas Wunderer[1], Johannes Biskupek[2], Andrey Chuvilin[2], Ute Kaiser[2], Yakiv Men[3], Junjun Wang[1], Frank Lipski[1], Stephan Schwaiger[1], Kamran Forghani[1], and Ferdinand Scholz[1] — [1]Institute of Optoelectronics, Ulm University, Germany — [2]Central Electron Microscopy Facility, Ulm University, Germany — [3]Institute of Electron Devices and Circuits, Ulm University, Germany

It was shown that by the use of selective area epitaxy three dimensional (3D) GaN structures can be realized providing semipolar surfaces. Using this technique a high material quality can be achieved on low-cost full 2 inch c-oriented sapphire wafers. It was shown that InGaN/GaN MQWs or even complete light emitting diode (LED) structures can be realized by growing the respective layers on these facets.

Now, we successively reduced the size of the 3D GaN structures in order to implement the semipolar QWs in a conventionally grown, well working laser structure. Therefore, the mask period of the structures were reduced to a lateral dimension of just 240nm using electron beam lithography and sputter coating of SiO2 mask deposited on the lower AlGaN cladding layer. Then, the active area consisting of an InGaN QW is grown on the 3D GaN structures and planarized by GaN grown under 2D conditions. The GaN layers, representing a waveguide layer, and the zigzag grown semipolar QW are embedded in planar AlGaN cladding layers as known from standard devices. Detailed structural analyses including TEM as well as optical properties will be presented.

HL 65.4 Fri 11:00 H15

Heterostructure design optimisation of (In)AlGaN deep ultraviolet light emitting diodes — •T. Kolbe[1], T. Sembdner[1], A. Knauer[2], V. Küller[2], H. Rodriguez[2], S. Einfeldt[2], P. Vogt[1], M. Weyers[2], and M. Kneissl[1,2] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Ultraviolet (UV) light emitting diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. However, due to weak carrier confinement, strong piezoelectric fields and high defect densities the external quantum efficiency of UV LEDs is still only a few percent.

We have investigated 316 nm (In)AlGaN LEDs with one, three, five and seven quantum wells (QWs). The carrier injection in the devices is simulated and compared to electroluminescence measurements. The emission power of all devices is nearly the same due to a strongly inhomogeneous carrier distribution between the wells. In the second series (In)AlGaN multi-quantum-well UV LEDs with a varying QW thickness of 1.5 nm, 2.2 nm and 3.2 nm have been investigated. We could show that the light output power depends strongly on the QW thickness. The highest output power was obtained for the LEDs with a QW thickness of 2.2 nm. This effect is attributed to the interplay between electron and hole wave function overlap and carrier concentration in the active region.

HL 65.5 Fri 11:15 H15

GaN-based LEDs on 200 mm diameter substrates — Adam Boyd[1], Hannes Behmenburg[1,2], Olaf Rockenfeller[1], Bernd Schineller[1], and •Michael Heuken[1,2] — [1]AIXTRON AG, Herzogenrath, Germany — [2]Inst. f. Theoretische Elektrotechnik, RWTH-Aachen, Aachen, Germany

We report on the growth of GaN-based structures on 200 mm sapphire and silicon by MOCVD using a CRIUS® Close Coupled Showerhead® reactor. The temperature profile was monitored in real time using an ARGUS pyrometer scanner and continuously adapted by adjusting the power to the three radial heater zones. A deflectometer was used to monitor the wafer curvature in the radial direction. To gauge the uniformity of a GaN nucleation layer on sapphire a thick layer was grown under nucleation layer growth conditions (530°C growth temperature, 900 mbar total pressure, 1 h duration). Ex-situ white-light interference measurements yielded a standard deviation of the thickness uniformity of 0.25% (6 mm edge exclusion). Under these conditions the uniformity approaches that of the gas phase delivery. Similar mapping of an LED structure gave 5.34 μm total thickness with a standard deviation over the wafer of 2.1%. The InGaN / GaN multiple quantum well peak wavelength uniformity was assessed by photoluminescence and indicated an average of 502 nm peak wavelength with a standard deviation of 10.7 nm. Results from an iteration of the edge design of the wafer recess as well as additional in-situ data and post growth material assessment will also be presented.

15 Min. Coffee Break

HL 65.6 Fri 11:45 H15

Electrical and Optical Characteristics of GaN based MSM Photodetectors — •Martin Martens[1], Jessica Schlegel[1], Patrick Vogt[1], Frank Brunner[2], Richard Lossy[2], Joachim Würfl[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

GaN metal-semiconductor-metal (MSM) structures are attractive candidates for ultraviolet (UV) photodetectors because of their fabrication simplicity and their potentially high quantum efficiency, high UV/VIS contrast and high speed. We have characterized MSM UV photodetectors fabricated on semi-insulating GaN by photocurrent spectroscopy and current-voltage (I-V) measurements. The responsivity spectra show a sharp cut-off at 365 nm according to the GaN band gap and high response at shorter wavelengths. Under UV-VIS illumination we measured photocurrents up to 1 mA depending on the applied bias. These high currents indicate an internal gain mechanism which was investigated by photocurrent measurements for different bias and light intensities. After switching off the light the photocurrent decays slowly indicating a persistent photoconductivity (PPC) effect. Therefore the dark I-V characteristics were measured after the samples had been kept in the dark for several hours. Under these conditions the dark current is in the range of 10 nA at 50 V. Subsequent I-V measurements show a degradation in the I-V characteristics suggesting a trap-related effect to cause this behaviour.

HL 65.7 Fri 12:00 H15

Quantum corrections to the Drude conductivity in $Al_xGa_{1-x}N$/GaN two-dimensional electron gas — •Stepan Shvarkov, Andreas Jupe, Dirk Reuter, and Andreas D. Wieck — Ruhr-Universität Bochum, Deutschland

The magnitotransport properties of Gd-implanted $Al_xGa_{1-x}N$/GaN heterostructures are studied. We observe an increase of the longitudinal resistance with decreasng temperature < 80 K. This is atributed to both electron-electron interactions and weak localization. The presence of Gd atoms in the sample makes Kondo effect also possible, but due to the fact that the behavior of the Kondo effect and weak localization with temperature and magnetic field change are very similar, further studies of these effects in $Al_xGa_{1-x}N$/GaN are necessary and currently under way.

HL 65.8 Fri 12:15 H15

Long term investigations of neuronal cell cultures with AlGaN/GaN-based HEMTs — •H. Witte[1], C. Warnke[1], T. Voigt[2], A. de Lima[2], and A. Krost[1] — [1]Inst. of Experimental Physics, University of Magdeburg, Magdeburg — [2]Inst. of Physiology, University of Magdeburg, Magdeburg

Planar devices based on metal layers or Si-devices are widely used for the detection of electrical activity of neuron cells. As an alternative more and more AlGaN/GaN- based devices are applied for analysis of biological molecules and single cells. Otherwise, the use of AlGaN/GaN based high electron transistors (HEMTs) as sensors for biological networks are seldom up to now. We have applied AlGaN/GaN HEMTs for monitoring the growth behavior of neurons from embryonic rat cerebral cortex form active networks after one week in vitro. Both, the source-drain current at 0.1 V bias as well as the frequency dependent impedance at zero voltage were measured within the time regime of culturing during some days. From these investigations we can distinguish the culture medium and the changes due to the growing neuron cell network. Results from long term investigations will be compared with phenomena of long term stimulation using a gold electrode / neuron network interface with respect to damaging processes by electrical fields. This knowledge is the basic for the detection of mechanism, e.g. of the energy metabolism.

HL 65.9 Fri 12:30 H15

Recording glycolytic oscillations in yeast cells using AlGaN/GaN high electron mobility transistor (HEMT) — •Christian Warnke[1], Hartmut Witte[1], Thomas Mair[2], Marcus J. B. Hauser[2], and Alois Krost[1] — [1]Otto-von-Guericke-Universität Magdeburg, Inst. Exp. Phys., Abt. Halbleiterepitaxie — [2]Otto-von-Guericke-Universität Magdeburg, Inst. Exp. Phys., Abt. Biophysik

Glycolytic oscillations in yeast cells are a well documented example of a macroscopic oscillator in biology. Methods for recording the glycolytic oscillations are the measurement of the NADH-fluorescence and impedance of a planar yeast cell/blank metal electrode interface [1]. As a new approach we used the source-drain-current and the impedance of a gateless AlGaN/GaN High Electron Mobility Transistor (HEMT) with different insulating surface layers. We show that these HEMTs exhibit a strong dependence of their resistance and capacitance when electrolytic solutions with different conductance and pH-values are placed on these HEMTs. We have measured the dielectric behavior of living yeast cells with these HEMTs. The measured period agrees well with results from control measurements via optical methods. We detected that the fluorescence of the yeast cells strongly enhances the signal output of the HEMTs. It was found that this signal enhancement results from photosensitivity of the insulating Durimide layer.

[1] Reiher, A. et al.: Electrical stimulation of the energy metabolism in yeast cells using planar Ti-Au-Electrode interface, J. Bioenerg. Biomembr. 38 (2006), 143-148.

HL 66: ZnO-based Devices

Time: Friday 10:15–11:15 Location: H17

HL 66.1 Fri 10:15 H17

Properties of transparent ZnO-based electronics — •Alexander Lajn, Heiko Frenzel, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

In combination with transparent light emitters, transparent electronics permit the fabrication of fully transparent displays. Thus, new designs allowing higher information content, better ergonomics and new aesthetic aspects are feasible; e.g. in car wind shields, windows, monitors or cell phones. We report on the fabrication of transparent rectifying contacts (TRC) on ZnO thin films and their application in photodetectors, field-effect transistors and inverters. Our TRC can be described as Schottky-diodes and exhibit maximum effective barrier heights of 0.87 eV, ideality factors of 1.47 and rectification ratios of 5×10^6. Visible-blind UV photodetectors with an external quantum efficiency of 32% at 375 nm and an UV-VIS rejection ratio in excess of 10^3 are demonstrated. Metal-semiconductor field-effect

transistors (MESFET) with a channel mobility of 11.4 cm^2/Vs and on/off-ratios of 10^6 were fabricated. An average transmission of 70 % in the visible spectral range was achieved for the Ag_xO-based gate electrodes. Furthermore the MESFETs operate at low voltages, only about $\Delta U = 2.5\,V$ are required to switch between on- and off-state. This advantage of MESFETs (compared to MISFETs) was successfully transferred to integrated inverters, yielding a maximum gain of 200 at a supply voltage of 4 V and a low uncertainty level of 0.3 V.

HL 66.2 Fri 10:30 H17

Properties of transparent ZnO inverters under the influence of light and elevated temperature — •Tobias Diez, Alexander Lajn, Heiko Frenzel, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Transparent electronics is an ambitious technology, which can be applied in transparent displays, e.g., as car wind-shield displays, in cell phones and electronic paper. In order to be able to manufacture these devices, transparent wide band-gap semiconductors, such as ZnO, have to be used. We fabricate normally-on metal-semiconductor field-effect transistors (MESFET) with reactive dc-sputtered Schottky-gate contacts and combine these to transparent inverters. They exhibit a transparency of about 69 % averaged over the device area and the visible spectrum. To explore the application relevant performance we investigate the change of the electrical properties of our transparent ZnO inverters under illumination with visible light. The uncertainty level, indicating the range of the input voltage with a ambiguous logical output, remains constant at about 0.3 V. Also the peak gain value is mainly unaffected by the incident light, except for blue light, for which a reduction of the gain is observed. Furthermore we investigate the temperature dependence of the inverter characteristics.

HL 66.3 Fri 10:45 H17

ZnO-based On-Chip Devices for Cell Potential Measurement — •F. Klüpfel, A. Lajn, H. Frenzel, H. von Wenckstern, G. Biehne, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Abteilung Halbleiterphysik, Linnéstr. 5, 04103 Leipzig

External stimulation causes nerve cells to change their membrane potential. Measuring these electric cell activities is important to improve the understanding of nerve cell communication and has been demonstrated using multi-transistor arrays based on silicon technology [1]. However these devices do not allow transmission microscopy and thus complicate the determination of the cell locations during electric measurements. The development of such structures on transparent substrates like glass or sapphire promises simultaneous recording of cell potential changes and visual observation. We use a chip with transistors based on the transparent semiconductor ZnO grown by pulsed laser deposition and gold electrodes to contact the cells. Our metal-semiconductor field effect transistors (MESFETs) with reactively sputtered AgO Schottky gate contacts are already described in [2] and outperform the amplification properties of ZnO-based metal-insulator-semiconductor field effect transistors by far, making them most suitable for this purpose. In this talk the electrical properties of the MESFETs as well as their applicability for cell potential measurements will be discussed.

[1] A. Lambacher et al., Appl. Phys. A 79, 1607-1611 (2004)
[2] H. Frenzel et al., Appl. Phys. Lett. 92, 192108 (2008)

HL 66.4 Fri 11:00 H17

Appropriate choice of channel ratio in thin-film transistors for the exact determination of field-effect mobility — •Koshi Okamura, Donna Nikolova, Norman Mechau, and Horst Hahn — Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany

For the evaluation of any kind of semiconducting materials for thin-film transistors (TFTs), the most important figure of merit is field-effect mobility. It is, however, sometimes extracted from the TFTs with the active semiconductor area undefined (unpatterned) and in the geometry of the small channel ratio; the effect of the fringing electric field at ends of source/drain electrodes are not taken into account. In this study, therefore, the effect of the fringing electric field on the field-effect mobility is systematically investigated. TFTs in the bottom gate configuration were fabricated by spin-coating a suspension of ZnO nanoparticles, as a function of different channel ratios, such as 2.5, 5.5, 12, 32 and 70. The field-effect mobility extracted from TFTs, with the active ZnO area undefined, at the small channel ratio of 2.5 showed the value by 418 % overestimated. In contrast, the field-effect mobility extracted from TFTs, with the active area defined, at the large channel ratio of 70 was nearly equivalent to the real value. These results reveal that the active semiconductor area of TFTs should be defined for the exact determination of the field-effect mobility; otherwise, the channel ratio should be chosen to be large enough to neglect the effect of the fringing electric field.

HL 67: Organic Semiconductors: Solar Cells II (Joint Session with DS/CPP/O)

Time: Friday 10:15–12:15 Location: H16

HL 67.1 Fri 10:15 H16

Organic-inorganic heterojunction with P3HT and n-type 6H-SiC: Determination of the band alignment and photovoltaic properties — •Roland Dietmüller, Helmut Nesswetter, Sebastian Schöll, Benedikt Hauer, Ian David Sharp, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

The exact band alignment in organic/inorganic semiconductor heterojunctions is influenced by a variety of properties and difficult to predict. For the organic/inorganic heterojunction made of poly(3-hexylthiophene) (P3HT) and n-type 6H-SiC, the band alignment is determined via current-voltage measurements. For this purpose a model equivalent circuit, combining a thermionic emission diode and space-charge limited current effects, is proposed which describes the behavior of the heterojunction very well. From the fitting parameters, the interface barrier height of 1.1 eV between the lowest unoccupied molecular orbital (LUMO) of P3HT and the Fermi level of 6H-SiC can be determined. In addition from the maximum open circuit voltage of the diodes, a distance of 0.9 eV between the HOMO of P3HT and the conduction band (CB) of 6H-SiC can be deduced. These two values determine the Fermi level of 6H-SiC, which is about 120 meV below the CB, relative to the HOMO and LUMO of P3HT. The 6H-SiC/P3HT heterojunction exhibits an open circuit voltage of 0.55 eV at room temperature, which would make such a heterojunction a promising candidate for bulk heterojunction hybrid solar cells with 6H-SiC nanoparticles.

HL 67.2 Fri 10:30 H16

Hybrid solar cells based on semiconductor nanocrystals and poly(3-hexylthiophene) — •Holger Borchert, Florian Witt, Marta Kruszynska, Nikolai Radychev, Irina Lokteva, Folker Zutz, Marc Daniel Heinemann, Elizabeth von Hauff, Joanna Kolny-Olesiak, Ingo Riedel, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

Semiconductor nanoparticles are promising electron acceptor materials for polymer-based bulk heterojunction solar cells. Size-dependent optical properties enable adaptation of the absorption to the solar spectrum, and the possibility to use elongated nanoparticles should be favorable for efficient electron transport. Despite these potential advantages, efficiencies reported for such hybrid solar cells are still below those of organic polymer/fullerene cells. In the work to be presented, CdSe nanoparticles were prepared by colloidal chemistry and their usability for hybrid solar cells in conjunction with poly(3-hexylthiophene) (P3HT) as electron donor material was studied. Systematic studies of correlations between the device performance and blend morphology are presented. Furthermore, charge separation in the donor/acceptor systems was studied in detail by electron spin resonance (ESR) and photoinduced absorption spectroscopy (PIA). The studies revealed the existence of a large amount of trap states which might be the origin of the limitations for the device efficiency. First results with colloidally prepared CuInS2 nanoparticles are presented as well.

HL 67.3 Fri 10:45 H16

Analysis of space charge limited currents in P3HT-PCBM based bulk heterojunction solar cells — •Sidhant Bom and Veit Wagner — School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

The bulk heterojunction organic photovoltaic (OPV) devices have gained attention due to its applicability in large area printing offering a prospect of significant cost reduction. Our work here focuses on modeling of charge carrier transport in P3HT-PCBM based bulk heterojunction OPV devices sandwiched between ITO/PEDOT:PSS and aluminium electrode using glass substrates. For this purpose different blend ratios of P3HT and PCBM were analyzed.

The mobility determined from the space charge limited current is directly correlated to diffusion constant of the charge carriers, which is a crucial parameter in determining the rate of extraction of dissociated charge carriers. Taking into consideration the variation of mobility with charge carrier density at different operating modes of the OPV cell, a charge carrier density dependent mobility was introduced as opposed to constant mobility. This modification not only leads to a more accurate determination of charge carrier mobility but also gives an insight into the morphology of the blend via an energetic disorder parameter. Surprisingly, in comparison to a pure P3HT device, a bulk heterojunction OPV cell showed a significant reduction in this disorder parameter indicating a PCBM induced improvement of the existing P3HT network.

HL 67.4 Fri 11:00 H16

Spectroscopy of PTCDA deposited on an ultra thin optical fiber from a helium nanodroplet beam. — Tobias Knoblauch, •Matthieu Dvorak, and Frank Stienkemeier — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau

Optical nanofibres can be employed for ultra-sensitive surface spectroscopy of deposited molecules [1,2]. This method shows a good signal to noise ratio with surface coverage as small as 1/1000 of a monolayer, the reason of which stems from the strong evanescent field existing at the interface of optical fibres with sub-wavelength diameter.

Helium nanodroplet isolation (HENDI) spectroscopy is a powerful technique to analyze the vibrational structure of molecules as well as excitonic transitions of complexes and nanostructures at low temperatures [3]. In the present case, helium droplets are used to form complexes of PTCDA molecules having organic semiconducting properties and deposit them on an ultra thin fibre. In this way it is expected to link spectroscopic data obtained in the ultra-cold and interaction-free environment and film spectra.

[1] F. Warken et al., Optics Express 15, 11952 (2007)
[2] A. Stiebeiner et al., Optics Express 17, 21704 (2009)
[3] M. Wewer and F. Stienkemeier, Phys. Rev. B 67, 125201 (2003)

15 Min. Coffee Break

HL 67.5 Fri 11:30 H16

Evaporated Mixed Films of Electron Acceptor and Donor Molecules as Model Systems of Bulk Hetero Junction Materials — •André Dragässer, Max Beu, Christopher Keil, and Derck Schlettwein — Institute of Applied Physics, Justus-Liebig-University Giessen, Germany. email:schlettwein@uni-giessen.de

The formation of evaporated blends of organic donor and acceptor molecules has gained interest recently for active interlayers in organic photovoltaic cells and organic field effect structures. For example photovoltaic efficiencies in the 4 % range could be reached recently by research groups in Dresden, Hong Kong or Michigan for mixed blends of C_{60} and PcCu. It is well known that each individual compound is sensitive in its electrical properties to environmental influence (e.g. H_2O, O_2, etc.) and so will be the interplay of the molecules in this complex material. In this contribution we therefore report about the combination of electron donor and acceptor molecules, e.g. C_{60} and PcCu, as evaporated bulk heterojunction in simple model systems. Photovoltaic cells consisting of these layers were built in high vacuum and characterized in-situ with IV-measurements in the dark and under illumination. The influence of oxygen, air and conditioning of the films in vacuum will be discussed.

HL 67.6 Fri 11:45 H16

Role of the Charge Transfer State for Organic Solar Cells — •Carsten Deibel[1], Alexander Wagenpfahl[1], Thomas Strobel[1,2], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Germany — [2](now at Cavendish Laboratory, University of Cambridge, UK) — [3]Functional Materials for Energy Technology, Bavarian Centre for Applied Energy Research (ZAE Bayern), Würzburg, Germany

In organic bulk heterojunction solar cells, the charge transfer (CT) state is the intermediate but crucial step between exciton dissociation and charge transport to the electrodes. It is important for both, open circuit voltage and photocurrent.

The maximum open circuit voltage of organic bulk-heterojunction solar cells was recently shown to be given by the energy of the CT state (Nat. Mater. 8 (2009) 904). For P3HT:PCBM solar cells, it is around 1.1eV, whereas the open circuit voltage is only around 600 mV. This discrepancy was assigned to nonradiative recombination, although the details are still unknown. Performing macroscopic device simulations with input parameters resulting from a comprehensive experimental characterization, we discuss the relative contributions of surface and bulk recombination to this difference. Concerning the impact of the CT state on the photocurrent: we recently performed Monte Carlo simulations of CT dissociation, finding that the fast local charge carrier transport can explain the high quantum yields in polymer solar cells. Also, we were able to show that CT diffusion to the electrodes before complete dissociation is a potential loss mechanism.

HL 67.7 Fri 12:00 H16

Numerical simulation of s-shaped organic bulk-heterojunction solar cell current–voltage characteristics — •Alexander Wagenpfahl[1], Daniel Rauh[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern e.V.), Am Hubland, D-97074 Würzburg

Organic solar cell devices based on semiconducting polymer–fullerene blends occasionally possess current–voltage characteristics showing an s-shaped behavior. A strong effect of this kind easily reduces the solar cells working efficiency to a minimum. The detailed origin of the double diode behavior is still unknown. Using a poly(3-hexylthiophene) : phenyl-C61-butyric acid methyl ester (P3HT:PCBM) blend as active layer, we will present how such an s-shape is experimentally achieved using a plasma etch process on the transparent hole conducting anode (indium tin oxide). By considering a finite surface recombination in a device simulation program, we show that this s-shape can be calculated, only by assuming finite charge extraction velocities from the active layer to the metallic electrodes. The resulting charge carrier accumulation at the surfaces thereby changes the current transport from ohmic to space charge limited. By analyzing the found dependencies we will demonstrate under which conditions this effect influences the solar cell performance.

HL 68: II-VI Semiconductors: mainly Optical Properties

Time: Friday 11:30–12:45 Location: H17

HL 68.1 Fri 11:30 H17

Dynamical control of Mn spin system cooling by photogenerated carriers in (Zn,Mn)Se/BeTe heterostructures — •Daniel Dunker[1], J. Debus[1], A. A. Maksimov[2], D. R. Yakovlev[1], I. I. Tartakovskii[2], and M. Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Institute of Solid State Physics, Russian Academy of Sciences, 142432 Chernogolovka, Russia

We study magnetization dynamics in undoped $Zn_{0.99}Mn_{0.01}Se$/BeTe type-II quantum wells by means of time-resolved pump-probe-control and photoluminescence techniques. Measurements at a magnetic field of 3 T and a temperature of 1.8 K show under pulsed excitation of a control laser a strong decrease of the excitonic giant Zeeman shift which leads to a reduction of the Mn ion spin temperature. Its dynamics was

studied with a nanosecond time resolution.

The band alignment of the type-II heterostructure results in a spatial separation of the thermalized electrons and holes in the (Zn,Mn)Se and BeTe layers, respectively, and this causes long radiative lifetimes of photocreated electrons. The magnetization relaxation of the Mn spin system is accelerated by the efficient transfer of spin and energy from the Mn ions to the lattice via the electrons localized in (Zn,Mn)Se layers. The strength of the laser induced cooling effect is controlled with the optical excitation density. The overall temporal evolution of the Mn spin system cooling is also influenced by the heating impact on the Mn ions of the holes, localized in BeTe, as well as by non-equilibrium phonons.

HL 68.2 Fri 11:45 H17

Optical characterization of CdSe/Cd(S,Se)/ZnS core-shell-shell collodial quantum dots — •Martin Pohl[1], Sergey Skripets[1], Martin Kneip[1], Dmitrii Yakovlev[1], Manfred Bayer[1], Celso Mello-Donega[2] und Daniel Vanmaekelbergh[2] — [1]Experimentelle Physik E2, TU Dortmund, Deutschland — [2]Debye Institut, Universität Utrecht, Niederlande

The optical properties of collodial CdSe/Cd(S,Se)/ZnS core-shell-shell quantum dots with varying dot density were studied by means of optical methods. In these systems, electrons, holes and excitons are strongly confined in the nanocrystal host, resulting in discrete energy levels for these nanocrystals. Investigations were performed in resonant and nonresonant excitation regime over a wide temperature range from 2 up to 300 K with magnetic fields between 0 and 10 T. Furthermore the relaxation time of the photoluminescence was studied in picosecond range by means of streak camera and nanosecond range by means of gated ccd.

The workings were done in the framework of the Herodot-program "heterogeneous quantum rod and quantum dot nanomaterials" at the physics department of the TU Dortmund with samples grown at the University of Utrecht.

HL 68.3 Fri 12:00 H17

Methods for polarized light emission from CdSe quantum dot based monolithic pillar microcavities — •Moritz Seyfried, Joachim Kalden, Kathrin Sebald, Jürgen Gutowski, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

A lifting of the polarization degeneracy of the fundamental cavity mode in pillar microcavities (MCs) would allow for controlling the polarization state of the emitted photons. Therefore, monolithic VCSEL structures were grown by molecular beam epitaxy containing either one CdSe/ZnSSe quantum dot layer or three quantum well layers as active material. By using focused-ion-beam etching, MC pillars with different geometries were prepared out of the planar samples. Among these are circularly shaped pillar MCs with diameters in the range from 500 nm up to 4 μm and quality factors of up to 7860, elliptically shaped MCs, and so-called photonic molecules consisting of circular pillar MCs which are connected by small bars. Polarization dependent photoluminescence investigations of the fundamental cavity mode reveal a lifting of the polarization degeneracy for all three types of MCs. The energy splitting of up to 0.42 meV in the circularly shaped pillar MCs is probably caused by anisotropic strain conditions within the sample and directly dependent on the pillar diameter, whereas the larger energy splitting of up to 0.72 meV for the photonic molecules or even 4.5 meV for the elliptically shaped MC is based on their asymmetric cross sections.

HL 68.4 Fri 12:15 H17

Diffusionsmessungen in CdTe mittels ortsaufgelöster Photolumineszenzspektroskopie — •R. Gerten, F. Strauss, J. Kronenberg, H. Wolf und Th. Wichert — Technische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

In Radiotracer-Experimenten ist gezeigt worden, dass nach Diffusion von Gruppe I Elementen in ca. 800 μm dicken CdTe Kristallen peakförmige, bezüglich des Kristallzentrums symmetrische Konzentrationsprofile beobachtet werden [1]. Motiviert durch diese Ergebnisse wurde eine Apparatur für ortsaufgelöste Photolumineszenzspektroskopie (μPL) aufgebaut, um Defektprofile ohne die Verwendung radioaktiver Isotope und nahezu zerstörungsfrei zu bestimmen. Erste Messungen zeigen an nominell undotierten Proben nach Tempern für 60 Minuten bei 800 K unter Cd-Atmosphäre tiefenaufgelöste PL-Signale mit Intensitätsprofilen, die den Diffusionsprofilen von Gruppe I Elementen nach gleichartiger thermischer Behandlung entsprechen. Dabei zeigt der Verlauf der Intensität für die akzeptor- und donatorgebundenen Exzitonen ein komplementäres Verhalten, ähnlich wie in [2] berichtet. Offensichtlich werden durch interstitiell eindiffundierende Cd Atome pn-Übergänge im Innern des Kristalls erzeugt, wobei die mobilen, elektrisch geladenen Defekte dem Verlauf des Potentials folgen. Damit lassen sich sowohl die Tracer-Diffusionsprofile als auch die μPL-Profile konsistent erklären. Gefördert durch das BMBF, Projekt 05 KK1TSB/5 [1] H. Wolf et al., Phys. Rev. Lett. 94 (2005) 125901 [2] P. Horodyský et al., Phys. Stat. Sol. 2 (2005) 1189

HL 68.5 Fri 12:30 H17

Size-dependent recombination dynamics in ZnO nanowires — •Juan Sebastian Reparaz — Institut für Festkörperphysik - Technische Universität Berlin Hardenbergstr. 36, Sekr. EW 5-1, D-10623 Berlin, Germany

A deep understanding of the recombination dynamics of ZnO nanowires is a natural step for a precise design of on-demand nanostructures based on this material system. In this work we investigate the influence of finite-size on the recombination dynamics of the neutral bound exciton around 3.365 eV for ZnO nanowires with different diameters. We demonstrate that the lifetime of this excitonic transition decreases with increasing the surface-to-volume ratio due to a surface induced recombination process. Furthermore, we have observed two broad transitions around 3.341 and 3.314 eV, which were identified as surface states by studying the dependence of their life time and intensitiy with the NWs dimensions.