Semiconductor Physics Division
Fachverband Halbleiterphysik (HL)

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Overview of Invited Talks and Sessions

(lecture rooms ER 270, ER 164, EW 201, EW 202 and EW 203; Poster D)

Invited Talks

HL 1.1	Mon	9:30–10:15	ER 270	**Electrically driven single quantum dot emitter operating at room temperature** — •Tilmar Kümmell, Robert Arians, Gerd Bacher, Arne Gust, Carsten Kruse, Detlef Hommel
HL 2.1	Mon	10:15–11:00	ER 270	**Theory of Ultrafast Dynamics of Electron-Phonon Interactions: Semiconductor Quantum Wells, Surfaces and Graphene** — •Andreas Knorr, Stefan Butscher, Norbert Bücking, Marten Richter, Frank Milde, Peter Kratzer, Matthias Scheffler, Carsten Weber
HL 4.1	Mon	14:00–14:45	ER 270	**Optical spectroscopy of wide-gap semiconductors: Is our picture of van Hove singularities still valid?** — •Rüdiger Goldhahn
HL 18.1	Tue	9:30–10:15	ER 270	**Quantum Spin Hall Insulator State in HgTe Quantum Wells** — •Hartmut Buhmann, Markus König, Steffen Wiedmann, Christoph Brüne, Andreas Roth, Laurens W. Molenkamp, Xiao-Liang Qi, Shou-Cheng Zhang
HL 20.1	Tue	14:15–15:00	ER 270	**Y-branched nanojunctions as nanoelectronic logic elements, memory devices and sensors** — •Lukas Worschech, David Hartmann, Christian Müller, Alfred Forchel
HL 37.1	Thu	9:30–10:15	ER 270	**Terahertz detection of many-body signatures in semiconductor heterostructures** — •Sangam Chatterjee, Torben Grunwald, David Köhler, Tilmann G. Jung, Daniel Golde, Mackillo Kira, Stephan W. Koch
HL 38.1	Thu	10:15–11:00	ER 270	**Spin dynamics in high-mobility 2D electron systems: effects of electron-electron interaction and anisotropy** — •Tobias Korn, Dominik Stich, Natalie Steffek, Dieter Schuh, Werner Wegscheider, Ming-Wei Wu, Christian Schüller
HL 40.1	Thu	14:00–14:45	ER 270	**Charge transport in organic molecular crystals** — •Karsten Hannewald

Internal Symposium: Nanostructured Photonic Materials

Organisation: Prof. Dr. Ralf Wehrspohn (Universität Halle-Wittenberg)

HL 5.1	Mon	15:00–15:30	ER 270	**FDTD method in nanophotonics: 2D and 3D photonic crystals and lasing** — •Andrei Lavrinenko
HL 5.2	Mon	15:30–16:00	ER 270	**Efficient Coupling into Photonic-Crystal Cavities and Waveguides** — •Solomon Assefa, William Green, Fengnian Xia, Yurii Vlasov
HL 5.3	Mon	16:00–16:30	ER 270	**Optical Super Lens: From Near-Field to Far Field** — •Xiang Zhang
HL 5.4	Mon	16:45–17:15	ER 270	**Nanoplasmonics for field enhancement and subwavelength guiding** — •Sergey I. Bozhevolnyi
HL 5.5	Mon	17:15–17:45	ER 270	**Scaling left-handed materials towards optical frequencies** — •Maria Kafesaki, Raluca Penciu, Thomas Koschny, Eleftherios Economou, Costas Soukoulis
HL 5.6	Mon	17:45–18:15	ER 270	**Engineering optical space with metamaterials** — •Vladimir Shalaev

Internal Symposium: Spin Effects in Semiconductors of Reduced Dimensionality

Organisation: Prof. Dr. Werner Wegscheider (Universität Regensburg)

HL 19.1	Tue	10:30–11:00	ER 270	**Novel devices using local control of magnetic anisotropies in (Ga,Mn)As.** — •Charles Gould, Jan Wenisch, Silvia Hümpfner, Katrin Pappert, Manuel Schmidt, Christian Kumpf, Karl Brunner, Georg Schmidt, Laurens W. Molenkamp
HL 19.2	Tue	11:00–11:30	ER 270	**Local spin manipulation in a semiconductor by nanostructured ferromagnets** — Patric Hohage, Simon Halm, Jörg Nannen, •Gerd Bacher
HL 19.3	Tue	11:30–12:00	ER 270	**Nonequilibrium nuclear-electron spin dynamics in semiconductor quantum dots** — •Fritz Henneberger, Ilya Akimov
HL 19.4	Tue	12:00–12:30	ER 270	**Electrical spin injection into single InGaAs quantum dots** — •Michael Hetterich, Wolfgang Löffler, Thorsten Passow, Dimitri Litvinov, Dagmar Gerthsen, Heinz Kalt
HL 19.5	Tue	12:30–13:00	ER 270	**Transport in 2DEGs and Graphene: Electron Spin vs. Sublattice Spin** — •Maxim Trushin, John Schliemann

Internal Symposium: Semiconductor Nanowires

Organisation: Prof. Dr. Klaus Ensslin (ETH Zürich)

HL 21.1	Tue	15:15–15:45	ER 270	**Electron Transport in InAs Nanowire Quantum Dots** — •Andreas Fuhrer, Carina Fasth, Lars Samuelson
HL 21.2	Tue	15:45–16:15	ER 270	**Electronic properties of gate defined and etched quantum dots in InAs nanowires** — •Ivan Shorubalko, Andreas Pfund, Simon Gustavsson, Renaud Leturcq, Silke Schön, Klaus Ensslin
HL 21.3	Tue	16:15–16:45	ER 270	**prismatic quantum heterostructures on MBE grown GaAs nanowires** — •Anna Fontcuberta i Morral
HL 21.4	Tue	16:45–17:15	ER 270	**From ordered arrays of nanowires to controlled solid state reactions** — •Margit Zacharias
HL 21.5	Tue	17:15–17:45	ER 270	**Top-Down and Bottom-Up: Nanophotonics with ZnO and Silica Nanowires** — •Tobias Voss

Internal Symposium: Semiconducting Nanoparticles for Nano-Optics and Optoelectronics

Organisation: Prof. Dr. Axel Lorke (Universität Duisburg)

HL 52.1	Fri	10:30–11:00	ER 270	**Semiconducting nanoparticles in industrial applications** — •Martin Trocha, André Ebbers, Anna Prodi-Schwab, Heiko Thiem
HL 52.2	Fri	11:00–11:30	ER 270	**Silicon and Germanium Nanoparticles: Spectroscopy and Electronic transport** — •Cedrik Meier, Stephan Lüttjohann, Matthias Offer, Sonja Hartner, Hartmut Wiggers, Axel Lorke
HL 52.3	Fri	11:30–12:00	ER 270	**Photoluminescence Spectroscopy of Semiconductor Nanorods and Their Hybrid Structures** — •Andrey Rogach
HL 52.4	Fri	12:00–12:30	ER 270	**Charge carrier dynamics of surface modified semiconductor nanocrystals** — •Alf Mews, Ma Xuedan, Jessica Völker, Maxime Tchaya, Herbert Kneppe
HL 52.5	Fri	12:30–13:00	ER 270	**Ultrafast Exciton Relaxation Dynamics in Silicon Quantum Dots** — •Carola Kryschi, Volker Kuntermann, Carla Cimpean, Vincent Groenewegen, Anja Sommer

Sessions

HL 0.1–0.3	Sun	14:00–17:00	ER 270	**Tutorial: Graphene**
HL 1.1–1.1	Mon	9:30–10:15	ER 270	**Invited Talk Kümmell**
HL 2.1–2.1	Mon	10:15–11:00	ER 270	**Invited Talk Knorr**
HL 3.1–3.7	Mon	11:15–13:00	ER 270	**Quantum dots: Microcavities and photonic crystals**
HL 4.1–4.1	Mon	14:00–14:45	ER 270	**Invited Talk Goldhahn**
HL 5.1–5.6	Mon	15:00–18:15	ER 270	**Symposium Nanostructured Photonic Materials**
HL 6.1–6.8	Mon	9:30–11:30	EW 201	**Photonic crystals I**
HL 7.1–7.6	Mon	11:30–13:00	EW 201	**II-VI semiconductors**

HL 8.1–8.4	Mon	14:00–15:00	EW 201	**Interfaces/ surfaces**
HL 9.1–9.13	Mon	15:00–18:30	EW 201	**ZnO: Preparation and characterization I**
HL 10.1–10.5	Mon	9:30–10:45	EW 202	**Preparation and characterization**
HL 11.1–11.8	Mon	11:00–13:00	EW 202	**C/diamond**
HL 12.1–12.9	Mon	14:00–16:15	EW 202	**Photovoltaic**
HL 13.1–13.5	Mon	16:15–17:30	EW 202	**Theory of electronic structure**
HL 14.1–14.7	Mon	9:30–11:15	ER 164	**Heterostructures**
HL 15.1–15.7	Mon	11:15–13:00	ER 164	**Devices**
HL 16.1–16.12	Mon	14:00–17:15	ER 164	**Quantum dots and wires: Optical properties I**
HL 17.1–17.53	Mon	16:30–19:00	Poster D	**Poster I**
HL 18.1–18.1	Tue	9:30–10:15	ER 270	**Invited Talk Buhmann**
HL 19.1–19.5	Tue	10:30–13:00	ER 270	**Symposium Spin Effects in Semiconductors of Reduced Dimensionality**
HL 20.1–20.1	Tue	14:15–15:00	ER 270	**Invited Talk Worschech**
HL 21.1–21.5	Tue	15:15–17:45	ER 270	**Symposium Semiconductor Nanowires**
HL 22.1–22.6	Tue	9:30–11:00	EW 201	**Hybrid systems**
HL 23.1–23.8	Tue	11:00–13:00	EW 201	**Quantum dots and wires: Transport properties I**
HL 24.1–24.14	Tue	9:30–13:15	EW 202	**Photonic crystals II**
HL 25.1–25.5	Tue	14:15–15:30	EW 202	**Spin controlled transport I**
HL 26.1–26.10	Tue	15:45–18:15	EW 202	**III-V semiconductors I**
HL 27.1–27.11	Tue	16:00–19:00	EW 203	**Photonic crystals III**
HL 28.1–28.10	Tue	9:30–12:00	ER 164	**Transport properties**
HL 29.1–29.5	Tue	12:00–13:15	ER 164	**New materials**
HL 30.1–30.13	Tue	14:15–17:45	ER 164	**Quantum dots and wires: Transport properties II**
HL 31.1–31.69	Tue	16:30–19:00	Poster D	**Poster II**
HL 32.1–32.13	Wed	14:15–17:45	ER 270	**Quantum dots and wires: preparation and characterization I**
HL 33.1–33.15	Wed	14:15–18:30	EW 201	**III-V semiconductors II**
HL 34.1–34.12	Wed	14:15–17:30	EW 202	**Semiconductor Laser**
HL 35.1–35.13	Wed	14:15–17:45	ER 164	**Spin controlled transport II**
HL 36.1–36.45	Wed	16:30–19:00	Poster D	**Poster III**
HL 37.1–37.1	Thu	9:30–10:15	ER 270	**Invited Talk Chatterjee**
HL 38.1–38.1	Thu	10:15–11:00	ER 270	**Invited Talk Korn**
HL 39.1–39.7	Thu	11:15–13:00	ER 270	**Ultra fast phenomena**
HL 40.1–40.1	Thu	14:00–14:45	ER 270	**Invited Talk Hannewald**
HL 41.1–41.9	Thu	15:00–17:30	ER 270	**Organic semiconductors**
HL 42.1–42.12	Thu	9:30–13:00	EW 201	**Optical Properties of Quantum dots: Theory and Simulation**
HL 43.1–43.9	Thu	14:00–16:30	EW 201	**Quantum dots and wires: Optical properties II**
HL 44.1–44.7	Thu	16:45–18:30	EW 201	**Quantum dots and wires: preparation and characterization II**
HL 45.1–45.9	Thu	9:30–11:45	EW 202	**GaN devices**
HL 46.1–46.4	Thu	11:45–12:45	EW 202	**Transport in high magnetic field/quantum-Hall-effect**
HL 47.1–47.13	Thu	14:00–17:30	EW 202	**GaN: preparation and characterization I**
HL 48.1–48.4	Thu	9:30–10:30	ER 164	**ZnO: Preparation and characterization II**
HL 49.1–49.9	Thu	10:45–13:00	ER 164	**ZnO: Optical properties**
HL 50.1–50.7	Thu	14:00–15:45	ER 164	**ZnO: Tansport**
HL 51.1–51.65	Thu	16:30–19:00	Poster D	**Poster IV**
HL 52.1–52.5	Fri	10:30–13:00	ER 270	**Symposium Semiconducting Nanoparticles for Nano-Optics and Optoelectronics**
HL 53.1–53.13	Fri	10:30–14:00	EW 201	**Optical properties**
HL 54.1–54.17	Fri	10:30–15:00	EW 202	**Si/Ge**
HL 55.1–55.12	Fri	10:30–13:45	ER 164	**GaN: preparation and characterization II**

Annual General Meeting of the Semiconductor Physics Division

Thu 18:00–19:00 ER 164

- Begrüßung und Bericht
- Stichwortkatalog
- Verschiedenes

HL 0: Tutorial: Graphene

Time: Sunday 14:00–17:00 Location: ER 270

Tutorial HL 0.1 Sun 14:00 ER 270

Wandering through the hills of flat carbon: The electronic properties of graphene — •Uli Zeitler — High Field Magnet Laboratory, Institute for Molecules and Materials, Radboud University Nijmegen, NL-6525 ED Nijmegen

Recently a new member joined the family of two-dimensional electron systems, graphene, a single layer of carbon arranged in a wrinkled honeycomb lattice. This 2D form of carbon was long believed to be thermodynamically instable and it took until 2004 to be discovered by Andre Geim's group in Manchester.

Electrons in single graphene behave as massless chiral Dirac fermions, bilayer graphene mimics the properties of relativistic massive chiral particles. These unique electronic properties lead to a plethora of new physics and possible applications. In particular, they enable us to study quantum electrodynamics, a research field hitherto reserved to high-energy physics, in a rather simple solid state system.

In this tutorial I will give an overview on the fascinating electronic and structural properties of graphene. I will show how graphene devices are produced using mechanical exfoliation of graphite. I will relate the bandstructure of single-layer and bilayer graphene to its electronic properties and I will present high-field quantum Hall experiments mimicking quantum electrodynamics. In particular I will show how graphene's unique electronic and structural properties enable the quantum Hall effect (actually a typical low-temperature phenomenon) to surprisingly become observable at room-temperature.

Tutorial HL 0.2 Sun 15:00 ER 270

Electronic Properties of Single and Bilayer Graphene — •Vladimir Falko — Physics Department, Lancaster University, Lancaster LA14YB, United Kingdom

A review will be presented of the bandstructure of atomic monolayer and bilayer of graphite (nowadays, called graphene). It will be shown that charged carriers in graphene are chiral (similarly to relativistic Dirac particles) which will be related to their unusual transport properties and the form of Landau level formed in graphene in a strong magnetic field.

Tutorial HL 0.3 Sun 16:00 ER 270

Epitaxial Graphene — •Thomas Seyller — Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

Graphene, a single monolayer of sp^2-bonded carbon, is a very unique 2-dimensional electron gas system with electronic properties fundamentally different to other 2DEG systems. Due to its peculiar band structure, charge carriers in graphene are described by the relativistic Dirac equation for massless particles. This results in extraordinary transport properties which have recently attracted considerable attention. From a practical point of view, the observation of e.g. large and robust carrier mobility and ballistic transport has raised the hope that graphene will find its way into application in electronic devices.

While many exciting results have been obtained with exfoliated graphene, technological applications demand methods suitable for producing large area graphene layers. The possibility to grow epitaxial graphene and ultra-thin graphite layers (so-called few layer graphene, FLG) on the basal plane surfaces of the wide band gap semiconductor silicon carbide (SiC) is a promising approach.

The 2-dimensional nature of epitaxial graphene and FLG layers make them an ideal subject for surface science methods such as photo electron spectroscopy (XPS, ARPES), scanning probe microscopy (AFM, STM), and electron diffraction (LEED). The presentation gives an overview over recent studies of epitaxial graphene and FLG layers on SiC surfaces covering their growth, electronic structure, and structural properties.

HL 1: Invited Talk Kümmell

Time: Monday 9:30–10:15 Location: ER 270

Invited Talk HL 1.1 Mon 9:30 ER 270

Electrically driven single quantum dot emitter operating at room temperature — •Tilmar Kümmell[1], Robert Arians[1], Gerd Bacher[1], Arne Gust[2], Carsten Kruse[2], and Detlef Hommel[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Duisburg — [2]Institut für Festkörperphysik, Universität Bremen, Bremen

Single self-organized semiconductor quantum dots are regarded as one of the most interesting approaches for realizing single photon sources. Although several device concepts have been presented, their applicability was limited to low temperatures up to now. Here, we present electrically driven emission from one single quantum dot at room temperature.

The single quantum dot emitter is based on epitaxially grown CdSe/ZnSSe quantum dots. By sandwiching the active area between MgS barriers, access to room temperature photoluminescence from a single quantum dot became possible [1]. Choosing an appropriate thickness, the MgS barriers do not hamper an electrically driven operation. Embedding the quantum dot active layer into a p-i-n diode, we succeeded in obtaining room temperature electroluminescence from one single quantum dot at a voltage of U = 2.6 V. We observe no significant loss of quantum efficiency with respect to 4 K. The emission linewidth at T = 300 K is about 25 meV and is thus not exceeding the biexciton binding energy, a crucial point for an operation as a single photon emitter.

[1] R. Arians et. al, Appl. Phys. Lett. 90, 101114 (2007)

HL 2: Invited Talk Knorr

Time: Monday 10:15–11:00 Location: ER 270

Invited Talk HL 2.1 Mon 10:15 ER 270

Theory of Ultrafast Dynamics of Electron-Phonon Interactions: Semiconductor Quantum Wells, Surfaces and Graphene — •Andreas Knorr[1], Stefan Butscher[1], Norbert Bücking[1], Marten Richter[1], Frank Milde[1], Peter Kratzer[2], Matthias Scheffler[3], and Carsten Weber[4] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Fachbereich Physik, Universität Dortmund — [3]Firtz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [4]Mathematical Physics, Lund University

Nanostructured semiconductors are ideal model systems to investigate the dynamics of the electron-phonon coupling in different confinement potentials.

In this talk, the simultaneous quantum dynamics of electrons and phonons is described within a Liouville space formalism for the time evolution of the statistical operator. This approach allows the self-consistent description of non-markovian dynamics and non-perturbative interaction in ultrafast electron transfer and relaxation mechanisms.

Specific systems investigated are ultrafast electron transfer between bulk and surface states at silicon surfaces, strong electron-phonon interaction for intersubband optics in nitride quantum wells and quantum cascade lasers as well as hot phonon dynamics in graphene.

HL 3: Quantum dots: Microcavities and photonic crystals

Time: Monday 11:15–13:00 Location: ER 270

HL 3.1 Mon 11:15 ER 270

Optical properties of ZnSe-based quantum dot pillar microcavities at elevated temperatures — •Joachim Kalden, Henning Lohmeyer, Kathrin Sebald, Thomas Meeser, Jürgen Gutowski, Carsten Kruse, Arne Gust, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

II-IV quantum dots (QDs) are of high interest for emission in the green spectral region. CdSe QDs are embedded in monolithic ZnSe-based VCSEL structures grown by molecular beam epitaxy. In these structures the CdSe QDs are embedded inbetween MgS barriers which enhance the high temperature stability up to room temperature [1]. Pillar microcavities (MCs) with diameters down to 715 nm are prepared by focused-ion-beam (FIB) etching and optically characterized by micro-photoluminescence (μ-PL) measurements. Due to the three-dimensional optical confinement discrete mode spectra are detected and studied with regard to polarization and temperature, respectively. Experimental findings correspond to theoretical calculations [2]. Quality factors beyond 3000 are deduced from the spectral width of the fundamental MC mode (FM). Furthermore, the coupling between the single-QD emission and the FM is discussed. In this context we demonstrate how to tune the QD emission into resonance with the FM via temperature adjustment or post fabrication FIB etching. Thus, 5-fold PL intensity enhancement is achieved for individual QDs.

[1] R. Arians et al., Appl. Phys. Lett. **90**, 101114 (2007)
[2] H. Lohmeyer et al., Appl. Phys. Lett. **88**, 051101 (2006)

HL 3.2 Mon 11:30 ER 270

Electrically driven high–Q quantum dot–micropillar cavities — •Caroline Kistner[1], Carolin Böckler[1], Stephan Reitzenstein[1], Ralph Debusmann[1], Andreas Löffler[1], Takayuki Kida[1], Sven Höfling[1], Alfred Forchel[1], Laurent Grenouillet[2], Julien Claudon[2], and Jean-Michel Gérad[2] — [1]Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]CEA-CNRS-UJF Nanophysics and Semiconductors Laboratory, CEA/DRFMC/SP2M, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France

In recent years generating non-classical light and exploring Cavity Quantum Electrodynamic (CQED) effects in semiconductor quantum dot microcavity systems has become an active field of research due to possible applications in the field of quantum computing and cryptography. Here, we report on electrically driven high-Q quantum-dot micropillar cavities which are attractive in order to realize, e.g. compact and efficient single photon sources. In particular, a special lateral current injection scheme is presented which ensures an efficient light outcoupling through the uncapped upper facet of the micropillar. Applying this approach, quality factors up to 16000 were achieved for a 4 μm diameter microcavity. Furthermore, the structures feature excellent single quantum dot CQED effects with a Purcell enhancement larger than 10 for a micropillar with 2.5 μm diameter.

HL 3.3 Mon 11:45 ER 270

Observation of Non-Resonant Dot-Cavity Coupling in Two-Dimensional Photonic Crystal Nanocavities — •Michael Kaniber, Arne Laucht, Andre Neumann, Max Bichler, and Jonathan J. Finley — Walter Schottky Institut, TU-München, Am Coulombwall 3, D-85748 Garching

We report the observation of non-resonant coupling between a single quantum dot (QD) and a photonic crystal (PC) nanocavity. Low density self-assembled $In_{0.50}Ga_{0.50}As$ QDs were grown by MBE at the midpoint of a GaAs slab. Nanocavities with $\omega_{cav}/\Delta\omega \sim 800 - 4000$ are formed by introducing point defects into the PC. Photon auto- and cross-correlation measurements were performed on different transitions from the same QD with a small spectral detuning ($|\Delta| < 2\omega$) from the cavity mode. These measurements were then repeated after Δ was increased up to $+10\Delta\omega$ by the adsorption of molecular nitrogen. For weak detuning different transitions from the same QD exhibit pronounced photon anti-bunching in both auto- and cross-correlation measurements, demonstrating that the different transitions arise from the same dot. The auto-correlation anti-bunching dip is shallower for transitions with smaller Δ due to the presence of an additional cavity mode background emission. Upon increasing the detuning to $\sim 10\Delta\omega$ the depth of the anti-bunching recovers. Most remarkably, cross-correlation measurements between the QD and the strongly detuned mode reveal correlated emission. This observation indicates the presence of a coupling mechanism between the spectrally detuned QD and the cavity. We discuss likely mechanisms mediating the remote coupling process.

HL 3.4 Mon 12:00 ER 270

Influence of the Spontaneous Emission Factor β on the Coherence Time of Semiconductor Microcavity Lasers — •Serkan Ateş[1], Christopher Gies[2], Sven M. Ulrich[1], Jan Wiersig[2], Stephan Reitzenstein[3], Andreas Loeffler[3], Alfred Forchel[3], Frank Jahnke[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Germany — [2]Institut für Theoretische Physik, Universität Bremen, Germany — [3]Technische Physik, Universität Würzburg, Germany

We present experimental and theoretical investigations on the coherence properties of (In,Ga)As/GaAs quantum dot (QD) based high-β ($\beta = 0.01$ to 0.05) semiconductor micropillar lasers. Power-dependent $g^{(1)}(\tau)$ first-order correlation function measurements have been performed by Michelson interferometry to investigate the coherence properties of the fundamental mode emission. A nonlinear increase of the coherence time (i.e., from $\tau_c \approx 30$ ps to ≈ 990 ps for a $\beta = 0.01$ micropillar) is found in the transition regime from spontaneous to dominantly stimulated emission. This increase is accompanied by a qualitative change in $g^{(1)}(\tau)$ measurements from a Gaussian-like profile to an exponential-type behavior. In addition, the emission coherence time of different diameter micropillars at comparable excitation conditions is found to be strongly influenced by the β factor. Devices with larger β exhibit shorter coherence times due to a stronger contribution of spontaneous processes coupled into the laser mode. The measurements are compared to results of a microscopic theory for coupled light-matter dynamics that describes the lasing properties of QD micropillars.

HL 3.5 Mon 12:15 ER 270

Realization of Electrically Tunable Single Quantum Dot - Cavity Systems — Felix Hofbauer, •Jakob Angele, Michael Kaniber, Gerhard Böhm, and Jonathan J. Finley — Walter Schottky Institut, TU München, 85748 Garching, Germany

We present studies of the radiative coupling of single $In_{0.4}Ga_{0.6}As$ self-assembled quantum dots to both extended and strongly localised optical modes in electrically contacted 2D photonic crystal (PhC) nanostructures. The samples investigated consist of a 180nm thick, free-standing GaAs membrane into which PhC are formed by etching a triangular lattice of air holes. Low mode-volume ($V < (\frac{\lambda}{n})^3$) and high $Q \sim 8000$ nanocavities are realised by introducing point defects into the PhC and the structures are electrically contacted via 30nm thick p- and n- doped contact layers in the membrane. These structures enable us to apply static electric field perturbations to the dots in the nanocavity and continuously vary the detuning (Δ) between the exciton and cavity using the quantum confined Stark effect.

The structures were studied using spatially resolved photoluminescence (PL) and photocurrent (PC) absorption spectroscopy. Our results show that Δ can be tuned in-situ by ~ 4 meV in the PL regime. Investigations of the PL intensity and spontaneous emission dynamics as a function of Δ reveal an increase in PL intensity by a factor of 1.5x and a twofold decrease of in spontaneous emission lifetime due to the Purcell effect. Using PC we observe enhanced optical in-coupling to the structures when exciting close to the cavity modes and can detect absorption from a single dot-cavity system.

HL 3.6 Mon 12:30 ER 270

Hybrid microcavities with embedded CdHgTe quantum dots — •David Zingelmann[1], Johannes Renner[1], Lukas Worschech[1], Andreas Löffler[1], Matthias Schäfer[2], Charles Becker[2], Laurens Molenkamp[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg — [2]Experimentelle Physik III, Universität Würzburg

We have realized a hybrid optical microcavity for the near infrared spectral range. The cavity is based on three different material systems. The central cavity layers are made of II-VI semiconductors, namely CdTe with embedded CdHgTe quantum dots as active mate-

rial, formed by MBE growth and subsequent thermal annealing. The bottom mirror is implemented as high-quality III-V semiconductor distributed Bragg reflector (GaAs/AlAs), whereas the top mirror is built up by dielectric materials (SiO_2/Si). From this structure micropillars with diameters of a few μm have been fabricated by reactive ion etching. By means of photoluminescence and reflectivity measurements we demonstrated 1- and 3-dimensional optical confinement in planar structures and micropillar cavities, respectively.

HL 3.7 Mon 12:45 ER 270

Efficient single photon generation using single quantum dots in two-dimensional photonic crystals — •Arne Laucht, Michael Kaniber, Andre Neumann, Max Bichler, and Jonathan J. Finley — Walter Schottky Institut, TU-München, Am Coulombwall 3, D-85748 Garching

We present comparative investigations of single photon generation from self-assembled quantum dots (QDs) emitting into (i) a two-dimensional photonic bandgap (PBG) or (ii) a homogeneous photonic environment. The sample investigated consisted of a single layer of $In_{0.50}Ga_{0.50}As$ QDs embedded within a 180nm thick GaAs membrane. Specific regions of this air-GaAs-air waveguide were patterned using electron-beam lithography and reactive ion etching to form photonic crystal (PC) nanostructures with a PBG enclosing the QD emission. By probing QDs within, or next to, the PC nanostructures we examine the influence of the PBG on the single photon emission rate and external quantum efficiency. Optical measurements were performed using low temperature confocal microscopy. We observe strong photon antibunching with a low multi photon probability both for dots in the unpatterned membrane and the PC of less than 10%. Remarkably, the 2D PBG is shown to enhance the relative photon extraction efficiency by a factor of $\sim 16\times$. From measurements under pulsed excitation we estimate the absolute external quantum efficiency of $26 \pm 3\%$ for dots in the PC to be much larger than the one for dots in the unpatterned GaAs of $1.6 \pm 0.2\%$. Hence, we conclude that a 2D PBG may provide a simple route towards highly efficient QD based single photon sources.

HL 4: Invited Talk Goldhahn

Time: Monday 14:00–14:45 Location: ER 270

Invited Talk HL 4.1 Mon 14:00 ER 270

Optical spectroscopy of wide-gap semiconductors: Is our picture of van Hove singularities still valid? — •Rüdiger Goldhahn — TU Ilmenau, Institut f. Physik, PF 100565, 98684 Ilmenau

The current understanding of the spectral dependence of the dielectric function (DF) for the nitride semiconductors InN, GaN, and AlN is rather scanty. The shape of the DF closely related to the band structure of the materials, i.e. it shows peculiarities in the vicinity of the critical points (CP), the so-called van Hove singularities. Ellipsometry was applied in order to determine both the ordinary and extraordinary dielectric tensor components for all binary compounds up to 10 eV. The experimental results are compared to the results of theoretical calculations. Density functional theory in the local density approximation leads to independent-particle DFs which emphasize the observed optical anisotropy, but the peaks are found at higher energies with respect to the experimental data. If instead the electron-hole Hamiltonian (exciton effects) is employed for the calculations the overall agreement is strongly improved, i.e. the comparison of both calculated DFs yields the size of the peak shift for the high-energy CPs caused by the final state interaction. In the second part of the talk, the influence of electric fields on the electron-hole correlated DF will be discussed in detail.

HL 5: Symposium Nanostructured Photonic Materials

Time: Monday 15:00–18:15 Location: ER 270

Invited Talk HL 5.1 Mon 15:00 ER 270

FDTD method in nanophotonics: 2D and 3D photonic crystals and lasing — •Andrei Lavrinenko — Building 345V, Oersted Plads

2D photonic crystals are treated in verious regimes: transmission bands, TE-TM conversion and slow light regime. The Si inverted-opals based 3D photonic crystals are explored as hosts for effective air-channel waveguides served as parts of photonic circuits. The influence of imperfections on the existence of photonic band gaps as the principle mechanism for waveguiding in such channels is studied. High appropriateness and precision of employed numerical method * 3D FDTD * is validated in the direct comparison with forward scattering experiments in thin opal films. A process of the seeding two coupled defects in photonic crystals filled by gain medium with a symmetric or antisymmetric pulse is shown to act as an ultrafast switchable mechanism for lasing. The generic idea is valid for different photonic applications.

Invited Talk HL 5.2 Mon 15:30 ER 270

Efficient Coupling into Photonic-Crystal Cavities and Waveguides — •Solomon Assefa, William Green, Fengnian Xia, and Yurii Vlasov — IBM Research Center, Yorktown Heights, NY 10589, USA

Photonic-crystals (PhC) provide a compact platform attractive for potential applications such as delay lines, all-optical buffers, highly nonlinear devices, and light-matter interaction. To this end, extensive studies are currently in progress to achieve low group-velocity in PhC waveguides while maintaining low chromatic dispersion. Additionally, on-going research on the confinement and enhancement of quantum-dot emission has increased interest in high-Q PhC cavities.

The W1 waveguide and the microcavity designs both require efficient coupling in order to explore the frequency regimes of interest. We will present experimental results focusing on efficient coupling to W1 waveguides and microcavities fabricated in SOI membrane. Coupling schemes such as group-index tapering and surface-state optimization are explored by making reliable phase information measurements in order to study coupling coefficients and high-order dispersion. We investigate strategies for efficient coupling into a suspended PhC microcavity that is side-coupled to a suspended photonic wire via PhC surface state engineering.

Invited Talk HL 5.3 Mon 16:00 ER 270

Optical Super Lens: From Near-Field to Far Field — •Xiang Zhang — University of California, Berkeley, USA

Recent theory predicted a new class of meta structures made of engineered sub wavelength entities - meta atoms and molecules which enable the unprecedented electromagnetic properties that do not exist in the nature. For example, artificial plasma and artificial magnetism, and super lens that focuses far below the diffraction limit. The metamaterials may have profound impact in wide range of applications such as nano-scale imaging, nanolithography, and integrated nano photonics.

I will discuss a few recent experiments that demonstrated these intriguing phenomena. We showed, for the first time, the high frequency magnetic activity at THz generated by artificially structured meta molecule resonance, as well as the artificial plasma. Our experiment also confirmed the key proposition of super lens theory by using surface plasmon. We indeed observed optical superlensing which breaks down so called diffraction limit. I will also discuss nano plasmonics for imaging and bio-sensing. The surface plasmon indeed promises an exciting engineering paradigm of x-ray wavelength at optical frequency.

15 min. break

Invited Talk HL 5.4 Mon 16:45 ER 270

Nanoplasmonics for field enhancement and subwavelength

guiding — •Sergey I. Bozhevolnyi — Department of Physics and Nanotechnology, Aalborg University, Skjernvej 4A, Aalborg, Denmark

The explosive progress in nanoscience has led to uncovering and exploring numerous physical phenomena occurring at nanoscale. One of the main research directions in nano-optics is the search for configurations that efficiently interconvert propagating and strongly localized (nm-sized) optical fields resulting in strongly enhanced local fields indispensable for optical characterization, sensing and manipulation at nanoscale. After briefly reviewing various configurations used for creating enhanced optical fields, a novel route exploiting retardation-based resonances involving (slow) surface plasmon polaritons (SPPs) supported by metal nanostructures is considered in detail.

Photonic components are superior to electronic ones in terms of operational bandwidth but suffer from the diffraction limit that constitutes a major problem on the way towards miniaturization and high density integration of optical circuits. The main approach to circumvent this problem is to take advantage of hybrid nature of SPPs whose subwavelength confinement is achieved due to very short (nm-long) penetration of light in metals. After briefly reviewing various SPP guiding configuration, the results of our investigations of subwavelength photonic components utilizing SPP modes propagating along channels cut into gold films are overviewed demonstrating first examples of ultracompact plasmonic components.

Invited Talk HL 5.5 Mon 17:15 ER 270

Scaling left-handed materials towards optical frequencies — •Maria Kafesaki[1], Raluca Penciu[1], Thomas Koschny[1,2], Eleftherios Economou[1], and Costas Soukoulis[1,2] — [1]Foundation for Research and Technology Hellas (FORTH), Institute of Electronic Structure and Laser (IESL), P.O. Box 1527, 71110 Heraklion, Crete, Greece, and University of Crete, Greece — [2]Ames Laboratory, and Dept. of Physics and Astronomy, Iowa State University, Ames, Iowa

Left-handed materials (LHMs), i.e. materials with electrical permittivity and magnetic permeability both negative over a common frequency band, have been a subject of increasing interest in the last seven years. This is mainly due to their novel and unique properties (like backwards propagation, negative refraction, superlensing, etc) which entail new capabilities in the manipulation of electromagnetic waves.

A large part of the current efforts in the LHMs research is to achieve left-handed behavior beyond the microwave regime (where this behavior was initially demonstrated), and mainly in the optical regime, exploiting the unique capabilities of LHMs in applications like telecommunications and imaging. A common approach to obtain optical LHMs is the scaling down of well established microwave designs. In this talk we discuss the behavior of specific, well-established in microwaves left-handed designs as they are scaled down into the nanoscale, targeting optical frequencies. Particular attention will be given in the understanding of the scaling behavior of the effective permeability and permittivity, the magnetic resonance frequency and the losses in those designs.

Invited Talk HL 5.6 Mon 17:45 ER 270

Engineering optical space with metamaterials — •Vladimir Shalaev — Purdue University, West Lafayette, IN, USA

Metamaterials are expected to open a gateway to unprecedented electromagnetic properties and functionality unattainable from naturally occurring materials, thus enabling a family of new *meta-devices*. We review this new emerging field and significant progress in developing metamaterials for the optical part of the spectrum. Specifically, we describe recently demonstrated artificial magnetism across the whole visible, negative-index in the optical range, and challenges along with promising approaches for accomplishing optical cloaking. The new paradigm of engineering space for light with transformation optics will be also discussed.

HL 6: Photonic crystals I

Time: Monday 9:30–11:30 Location: EW 201

HL 6.1 Mon 9:30 EW 201

Ultrafast nonlinear switching dynamics in metallic photonic crystals — •Tolga Ergin[1,2], Tilman Höner zu Siederdissen[1,2], Markus Lippitz[1,2], and Harald Giessen[2] — [1]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart

We investigate one-dimensional photonic crystals consisting of periodically arranged alternating layers of a metal and a dielectric. Spectral windows of high transmission in these structures allow the exploitation of the nonlinear transmissive properties of the sample. Recent experiments suggest the possibility of suppressing these windows with a sub-picosecond response and picosecond recovery time by intense pulsed laser pumping. Our research deals with the temporal dynamics as well as intensity and wavelength dependencies of this effect. Understanding these yet unknown issues is essential for maximization of the differential transmission and thus for possible switching applications.

HL 6.2 Mon 9:45 EW 201

Tailoring the polaritonic stop gap in metallo-dielectric photonic crystal superlattices — •Tobias Utikal[1], Thomas Zentgraf[1], André Christ[2], Sergei G. Tikhodeev[3], Nikolai A. Gippius[3], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, Germany — [2]École Polytechnique Fédérale de Lausanne, Switzerland — [3]General Physics Institute, Moscow, Russia

We experimentally and theoretically investigate the influence of the superlattice parameters on the polaritonic stop gap in metallo-dielectric photonic crystal superlattices. We show that the stop gap can be tailored by structuring the elementary unit cells of the superlattice.

Our model system consists of periodically arranged metal nanowires on top of a dielectric slab waveguide. With normal light incidence, a collective electron oscillation in the wires as well as a photonic mode in the waveguide slab can be excited. These modes form a waveguide plasmon polariton in the strong coupling regime. By tilting the angle of incidence of the light, the in-plane wavevector is changed, hence allowing to measure k-dependent dispersion as well as the size of the stop gap. For our specific superlattice case, we constructed metallic photonic crystal slabs by creating supercells from standard metallic photonic crystal building blocks and varied the superlattice parameters such as cell size and inter-cell distance. The optical properties were studied by conventional angle-resolved white-light transmission measurements.

We were able to explain the experiments using a miniband model and reproduced the results by scattering matrix based calculations.

HL 6.3 Mon 10:00 EW 201

Nonlinear and bistable transmission of high quality factor GaAs photonic crystal cavities — •Martin Garbos, Thomas Sünner, Thomas Schlereth, Sven Höfling, Martin Kamp, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg

Two-dimensional photonic crystal (PhC) cavities can localize light in small modal volumes with high quality factors. This leads to a strong enhancement of the field in the cavities, allowing an observation of nonlinear effects at very low power levels of a few μW. We have studied the nonlinear transmission of PhC cavities based on GaAs membranes. The cavities are realized by small local changes of the geometry (e.g. lattice period or hole diameter) of PhC waveguides. A tunable laser source at $1.55\mu m$ was used to probe the structures.

The transmission of the cavities has a Lorentzian shape with quality factors of up to 200000 at low power levels. At higher power levels, two photon absorption (TPA) becomes more and more dominant. Most of the generated carriers recombine non-radiatively, leading to an increase of the temperature and the refractice index. The corresponding redshift of the cavity resonance results in an apparent broadening of the cavity transmission when the tunable laser is swept over the resonance. At a detuning of +10 pm from the resonance, a hysteretic behavious was found when the input power was modulated.

HL 6.4 Mon 10:15 EW 201

Gas sensing using photonic crystal cavities — •Thomas Stichel, Thomas Sünner, Thomas Schlereth, Sven Höfling, Soon-Hong Kwon, Martin Kamp, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg

Cavities in two-dimensional photonic crystals (PhC) can localize light

in mode volumes on the order of a cubic wavelength. Due to the high quality factor of the cavities, which can be as high as 10^6, the spectral position of the resonance can be a very sensitive probe for local changes of the refractive index.

We have studied the dependence of the resonance wavelength of PhC cavities on the type and pressure of the ambient gas. The cavities are based on photonic crystals etched into GaAs membranes. A small change of the lattice constant or the width of a W1 PhC waveguide over a few lattice constants is used to provide the optical confinement. The transmission measurements were performed in a box that can be evacuated or filled with different gases. Light from a tunable laser source at $1.55\mu m$ is used to probe the resonance of the cavities. Measurements of the cavity resonance in different gaseous environments (N_2, SF_6, He) show a a clear dependence of the resonance on the refractive index and the pressure of the gas. Changes of the refractive index on the order of $2 * 10^{-4}$ can be readily detected and are in good agreement with three dimensional finite difference time domain calculations.

HL 6.5 Mon 10:30 EW 201

Coupling of Photonic Resonators with Liquid Crystals — •Karoline A. Piegdon[1], Heiner Matthias[2], Heinz-S. Kitzerow[2], and Cedrik Meier[1] — [1]Experimental Physics, Group NanoPhox, University of Duisburg-Essen — [2]Faculty of Science, Physical Chemistry, University of Paderborn

In order to achieve resonance between a photonic resonator with high quality factor and an emitter with narrow bandwidth, continuous tuning of the resonance frequency is desirable. However, in a semiconductor cavity, it is very difficult to alter the optical path length for this purpose. Matching the frequency of the emitter only by adjusting the device geometry is nearly impossible since even small fabrication imperfections affect the resonance frequency of the cavity considerably. Liquid crystals (LC) are promising candidates to make semiconductor devices tuneable since their refractive indices depend strongly on temperature and external fields.

Here, we report about GaAs microdisks (MD) with InAs quantum dots as built-in light emitters. The MD are embedded in the LC 5CB. The LC was aligned by surface treatment and an electric field. Subsequently, the temperature induced spectral shift of a cavity mode was monitored. The peak wavelength was shifted by 7.5 nm with increasing temperature at the nematic-isotropic phase transition. FDTD simulations and theoretical estimates are in agreement with this shift value. The mode shift was also monitored in situ while the LC was aligned in an electric field. In conclusion, a novel hybrid photonic device is presented that can be tuned by temperature and external fields.

HL 6.6 Mon 10:45 EW 201

Silicon-based low-loss photonic crystal waveguides — •Daniel Pergande[1], Peter Nolte[1], Alexey Milenin[2], and Ralf B. Wehrspohn[1] — [1]Institut of Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle — [2]Max-Planck-Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Silicon is the dominating material in today's microelectronics, especially in modern telecommunications, and therefore a lot of experience in microstructuring of silicon exists. Its high dielectric constant makes it a promising candidate for PhC (Photonic Crystal) fabrication. Furthermore, the possibility of integrating electronics and optics on one chip is of great advantage for silicon-based PhC devices.

We present ridge waveguides and PhC waveguides etched in a high-index-contrast SOI-material made of a thin silicon slab embedded in two silica layers. Hence fully symmetrical structures can be realized and two important conditions for low-loss guiding of light in PhC waveguides can be matched: The symmetry avoids polarization mixing and the high index contrast leads to strong confinement of light, so the PhC waveguides allow theoretically lossless guiding of light because of operating completely below the lightcone.

Since the PhC-structures are formed by air pores in the SOI-material, a great degree of freedom consists in the infiltration of the pores. This leads to a new approach for designing PhC-based devices.

HL 6.7 Mon 11:00 EW 201

implementation of adaptive spatial resolution in the scattering matrix approach: towards improvement of convergence for two dimensional photonic crystal slabs — •Thomas Weiss[1], Sergei Tikhodeev[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, Germany — [2]General Physics Institute, Moscow, Russia

Many attempts have been made to improve the convergence of Fourier modal methods to calculate the optical properties of slabs of 2D-periodic metallic photonic crystals and metamaterials. A key reason for the bad convergence is the discontinuity of the permittivity in patterned structures which results in fictitious localized plasmons on the distortions of the truncated Fourier transformed permittivity.

In numerical simulations with Fourier modal methods we have to truncate the Fourier expansions. If the truncation order is too small then additional resonance-artefacts may occur. Hence it is important to take a sufficient number of modes into account. However, especially for 2D structures we are limited by the operations and memory of computers. Therefore, an adaptive spatial resolution was suggested in order to increase the resolution at the transition between different materials. Hence, higher order modes will be included even if the truncation order is small.

We implemented such a coordinate transformation in the scattering matrix approach (up to now for one-dimensionaly-periodic structures) and are going to present results demonstrating improvement of convergence as well as analytical investigation of the scheme.

HL 6.8 Mon 11:15 EW 201

Optical properties of bowtie slot antennas — •Hongcang Guo[1], Thomas Zentgraf[1], Todd Meyrath[1], Na Liu[1], Liwei Fu[1], Heinz Schweizer[1], Stefan Kaiser[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany — [2]1st Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

Optical nanoantennas recently have gained considerable attention[1,2] due to their potential of localizing optical fields on a subwavelength scale. We study the geometrical dependence of the resonant properties of bowtie slot antennas in the optical regime by experiments and numerical simulations. Two types of transmission resonances in the visible and near infrared range are observed for the subwavelength scale antennas. For slot antennas of several ten nanometers thickness, only localized plasmonic resonances are observed and the resonant wavelength shows a linear dependence on the bowtie aperture perimeter. As for several hundred nanometer thick slot antennas, in addition to localized plasmonic resonances, Fabry-Perot-like resonances are excited at the shorter wavelength range, and the resonant wavelength shows a strong dependence on antenna thickness.

[1] P. Mühlschlegel et al., Science 308, 1607 (2005) [2] L. Novotny, Phys. Rev. Lett. 98, 266802 (2007)

HL 7: II-VI semiconductors

Time: Monday 11:30–13:00 Location: EW 201

HL 7.1 Mon 11:30 EW 201

Gate induced transition from n to p conduction in HgTe quantum wells — •Christoph Brüne, Markus König, Steffen Wiedmann, Andreas Roth, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut, Lehrstuhl für Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

HgTe/HgCdTe quantum well (QW) structures became very interesting for electronical applications due the good electrical properties and the unique band structure (which e.g. enabled the observation of the quantum spin hall effect [1]). In low density n-type QWs and as a consequence of the narrow bandgap it becomes possible to deplete the conduction band completely and introduce p-type conduction. The depletion can be realised by using a gate electrode to lower the fermi level in the QW. The n-to-p transition is observed in magneto transport measurements on hallbar structures. Clear SdH oscillations and hall plateus are observed in the p-type regime even though the contact regions are n-type, which leads to an additional p-n junction resistance. This Esaki-type tunnel resistance is deduced from the

measurements. It turned out that the resistance and mobility changes are mainly due to a change of the effective band mass of the carriers.

[1] M. König *et al.* Science 318, 766 (2007).

HL 7.2 Mon 11:45 EW 201

First principles calculations of CdSe nanowires — •Marcel Mohr and Christian Thomsen — Institut für Festkörperphysik, TU Berlin

We present first principles calculations of CdSe nanowires with diameters of up to 25 Å. Their atomic structure and their electronic and vibrational properties are investigated. We verify the strong band gap dependence on nanowire diameter. In addition, passivating the surface dangling bonds increases the band gap. The phonon modes that correspond to bulk modes show a redshift with smaller diameter. A shortening of the bond lengths of surface atoms gives rise to high-energy surface modes. Surface termination induces lattice contraction and a shift of the phonon frequencies.

HL 7.3 Mon 12:00 EW 201

Lithographical fabrication of HgTe quantum well structures for spin Hall effect measurements — •Andreas Roth, Moritz Leberecht, Markus König, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut, Lehrstuhl für Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Large Rashba energies and high carrier mobilities make HgTe quantum wells structures an interesting material for spintronics applications. The electric detection of the spin Hall current without an external magnetic field requires structures with a special geometry [1]. Due to the low growth temperature standard nano fabrication processes can not be used. It was necessary to develop specific low temperature lithographic processes. Here we present measurements on structures which are fabricated with different geometries and various contact configurations. The Rashba-coupling strength was controlled separately for injector and detector in a non-local measurement configuration. The results provide an all-electronic detection of spin-currents.

[1] E. M. Hankiewicz *et al.*, Phys. Rev. B 70, 241301(R) (2004).

HL 7.4 Mon 12:15 EW 201

Diffusion von Co und Au in CdZnTe — •Jörg Kronenberg[1], Frank Wagner[1], Herbert Wolf[1], Thomas Wichert[1] und CERN ISOLDE collaboration[2] — [1]Technische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]CERN, PH Department, CH-1211 Geneva 23, Switzerland

Nach Implantation der Gruppe-IB-Metalle ^{111}Ag und ^{67}Cu in die II-VI Halbleiter CdTe, CdZnTe und ZnTe mit 60 keV und nachfolgender Diffusion bei ca. 800 K unter dem Dampfdruck der Metallkomponente werden symmetrische Profilformen beobachtet, die in der Mitte des Kristalls eine hohe und in den bis zu 250 μm tiefen Randzonen eine niedrige Ag bzw. Cu Konzentration zeigen [1]. Ähnlich ist auch das Diffusionsverhalten von Na in CdZnTe. Die Diffusionsprofile unterscheiden sich drastisch von gewöhnlichen Diffusionsprofilen, welche sich in einer monotonen Abnahme der Konzentration äußern. In den hier vorgestellten Experimenten wurde untersucht, ob in CdZnTe auch das Edelmetall Au oder das ferromagnetische Dotieratom Co ungewöhnliche Diffusionseigenschaften zeigen. Hierfür wurden an ISOLDE/CERN ^{191}Au und ^{61}Co mit 60 keV in 500 μm dicke CdZnTe Einkristalle implantiert und diese anschließend zwischen 700 K und 900 K getempert. Während die ^{61}Co Diffusion ebenfalls ungewöhnlich, dabei aber deutlich unterschiedlich zur Ag oder Cu Diffusion verläuft, wurden für ^{191}Au keine ungewöhnlichen Diffusionsprofile beobachtet.
Gefördert durch das BMBF, Prokjekte 05KK7TS1 und CZE 03/002.
[1]H. Wolf *et al.*, Phys. Rev. Lett. 94 (2005) 125901

HL 7.5 Mon 12:30 EW 201

Radiation induced coupling of semimagnetic quantum dots — •Thomas Schmidt[1], Fabian Spielberger[1], Lukas Worschech[1], Alfred Forchel[1], Taras Slobodskyy[2], and Laurens Molenkamp[2] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

In 1954 R. H. Dicke pointed out that the particles of a spontaneously radiating gas can not be regarded as independent as long as they interact with a common radiation field [1]. Here we present optical studies performed with CdMnSe quantum dots (QDs), which indicates that due to Mn not only the nonradiative decay because of the internal Mn transition is altered but also the radiative decay undergoes a change associated with a Mn enhanced coupling of quantum dots by their radiation field [2]. The range of such a radiant coupling is in the order of the emission wavelength. By analyzing the photoluminescence intensity and the decay rate of quantum dots for differently sized mesas, it was observed that the quantum yield is larger for quantum dots embedded in large mesas with many quantum dots. Removing QDs slows down the PL decay associated with a cooperative radiation of the QDs. Interestingly, by comparison of different excitation conditions it was found that incorporation of Mn into the samples enhances the far-field coupling.

[1] R. H. Dicke, Physical Review 93, 99 (1954)
[2] M. Scheibner, et al., Nature Physics 3, 106 (2007).

HL 7.6 Mon 12:45 EW 201

Interface phonons in CdSe/Zns core/shell-nanorods — •Holger Lange[1], Maria Machon[1], Mikhail Artemyev[2], Ulrike Woggon[3], and Christian Thomsen[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Fachbereich Physik, Universität Dortmund — [3]Institute for Physico-Chemical Problems of Belorusian State University, Minsk

We discuss surface optical phonon modes and interface optical phonons in plain CdSe nanorods of different sizes and CdSe nanorods with an epitaxial grown ZnS shell. The related Raman bands are not only influenced by the geometry of the nanorod, but also by the presence and structure of the shell.

HL 8: Interfaces/ surfaces

Time: Monday 14:00–15:00 Location: EW 201

HL 8.1 Mon 14:00 EW 201

Influence of group-V exchange processes and Sb segregation on the interface quality of GaSb/GaAs quantum wells — •Rainer Timm[1], Andrea Lenz[1], Lena Ivanova[1], Holger Eisele[1], Ian Farrer[2], David A. Ritchie[2], Ganesh Balakrishnan[3], Diana L. Huffaker[3], and Mario Dähne[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Deutschland — [2]Cavendish Laboratory, University of Cambridge, UK — [3]Center for High Technology Materials, University of New Mexico, Albuquerque, USA

GaSb nanostructures in GaAs show a staggered type-II band alignment with a large hole confinement, making them very promising for optoelectronic and charge storage device applications. For such devices, however, the correct chemical composition of the nanostructures and the abruptness of their interfaces are both crucial and challenging [1]: While intermixing at the GaSb-on-GaAs interface can partly be controlled using an Sb soaking step, atomic exchange processes leading to strong Sb segregation upon GaAs overgrowth of a GaSb layer are even more difficult to avoid.

Using cross-sectional scanning tunneling microscopy [2], we were able to study the interfaces of various MBE-grown GaSb/GaAs quantum wells at the atomic level, including the wetting layers between quantum dots. By systematically varying the growth conditions, the influences of Sb soaking, intermixing effects, As-for-Sb exchange upon GaAs overgrowth, and Sb acting as surfactant could be distinguished.

[1] I. Farrer et al., J. Crystal Growth **251**, 771 (2003).
[2] R. Timm et al., Appl. Phys. Lett. **85**, 5890 (2004).

HL 8.2 Mon 14:15 EW 201

Nano- and atomic-scale potential fluctuations in two-dimensional semiconductors — •Sebastian Landrock[1], Ying Jiang[1], Kehui Wu[2], Enge Wang[2], Knut Urban[1], and Philipp Ebert[1] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Chinese Academy of Science

As the size of semiconductor devices is shrinking, not only the posi-

tioning of dopants is challenging, but also the knowledge on nanoscale potential fluctuations induced by inhomogeneities and the discrete nature of dopant atoms is becoming most critical. Therefore, we used scanning tunneling microscopy to measure the magnitude and extent of local potential fluctuations in a two-dimensional semiconductor with atomic resolution. On the one hand, we were able to prove that the limit of a macroscopic description of local nanoscale potential fluctuations is about 6×10^{13} dopants/cm^2. On the other hand, we found significant deviations from a microscopic description based on screened Coulomb potentials only. The potential consists rather of the superposition of extended potential fluctuations, defined by the charge carrier distribution in the bands, and local deviations from the spatial average of the screened Coulomb potentials arising from electron-electron interactions.

HL 8.3 Mon 14:30 EW 201

Deoxidation and surface structure of InGaN(0001) — •C. Friedrich[1], V. Hoffmann[2], N. Esser[3], M. Kneissl[1], and P. Vogt[1] — [1]TU Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchoff-Str. 4, 12489 Berlin, Germany — [3]ISAS-Berlin, Albert-Einstein Str. 9, 12489 Berlin, Germany

$In_xGa_{1-x}N$ alloys have attracted considerable interest due to their wide range of applications in optoelectronic devices, e.g. blue and green lasers. Although the quality of In-rich epitaxial layers has improved in recent years, there is still not much known about the atomic structure of $In_xGa_{1-x}N$ surfaces. The influence of the surface structure on the growth of $In_xGa_{1-x}N$ layers and on the interface formation in hetero-structures remains unclear. Here we present our results on $In_xGa_{1-x}N$ surface properties after deoxidation under ultra high vacuum (UHV) conditions. Auger Electron Spectroscopy measurements of the chemical surface composition confirm residual contaminations such as carbon and oxygen even after annealing up to 600 °C. Further annealing at higher temperatures leads to a strong reduction of carbon and oxygen and LEED reveals a (3×3)-surface periodicity. Scanning tunnelling microscopy (STM) measurements on such prepared surfaces show atomically flat terraces and both more metallic-like and more semi-conducting areas. Based on these results surface structure models are discussed.

HL 8.4 Mon 14:45 EW 201

Schottky Barrier Height Engineering of NiSi/Si Contacts by Dopant Segregation — Christoph Urban, •Qing-Tai Zhao, Marcel Müller, Christian Sandow, and Siegfried Mantl — Institute of Bio- and Nanosystems (IBN1-IT), and CNI - Center of Nanoelectronic Systems for Information Technology, Forschungszentrum Jülich, D-52425 Jülich, Germany

Schottky barrier MOSFETs become more and more attractive for device downscaling, especially due to very low parasitic S/D resistances. However, the performance of such devices suffers from the on-current limitation due to tunneling through the high Schottky barrier at the source. The performance of such a device would be drastically improved if the effective Schottky barrier height (SBH) between the S/D metal and the semiconductor in the channel could be eliminated. A successful approach of SBH engineering is the silicidation induced dopant segregation (DS) where a thin highly doped layer is formed at the silicide-silicon interface. In this work we present a systematic study of effective SBH lowering by DS during Ni silicidation of activated and non-activated As and B implanted Si. The current-voltage characteristics of fabricated NiSi Schottky diodes show higher reverse saturation currents compared with Schottky diodes without DS. This confirms the distinct Schottky barrier lowering due to the silicide induced DS. Diodes where the dopants were not activated before silicidation show a minimum SBH of Φ=0.13eV for As and of Φ=0.14eV for B. Moreover, we observe that the diodes with dopants activated prior to silicidation show a remarkably lower SBH by about 35%.

HL 9: ZnO: Preparation and characterization I

Time: Monday 15:00–18:30 Location: EW 201

HL 9.1 Mon 15:00 EW 201

Magnetische und Strukturelle Untersuchung von Mangandotierten Zinkselenid-Halbleiternanopartikeln — •Andreas Hofmann[1], Christina Graf[1], Thomas Ackermann[2], Christine Boeglin[3], Xiaogang Peng[4], Ranjani Viswanatha[4], Arantxa Fraile-Rodriguez[5], Frithjof Nolting[5] und Eckart Rühl[1] — [1]Institut für Chemie und Biochemie, Freie Universität Berlin, 14195 Berlin — [2]Institut für Physikalische Chemie, Universität Würzburg, 97074 Würzburg — [3]Institute de Physique et Chimie des Materiaux de Strasbourg, 67034 Strasbourg — [4]Department of Chemistry and Biochemistry, University of Arkansas, 72701 Fayetteville — [5]Paul Scherrer Institut, SLS, 5232 Villigen

Mn-dotierte ZnSe Nanopartikel sowie ZnSe-Partikel mit einem MnSe-Kern wurden mit chemischen Hochtemperaturverfahren synthetisiert. Die Mn-Konzentration betrug dabei $0.2 - 5\%$ bei einer Partikelgröße von $2.8 - 7.5$ nm. Um die elektronische Struktur und die magnetischen Eigenschaften der Mangan-Atome näher zu untersuchen, wurden an den Nanopartikeln magnetische Röntgenzirkulardichroismus-Messungen (XMCD) durchgeführt. Dabei konnte für alle Proben gezeigt werden, dass die Mn-Atome im Inneren der Nanopartikel lokalisiert sind und nicht oxidiert vorliegen. Die Polarisierung der Mn-Atome beträgt im Falle der isolierten Mn-Atome bis zu 80% des theoretischen Wertes eines freien d^5-Zustandes. Die Partikel mit einer MnSe/ZnSe Kern-Schale-Struktur zeigen in Abhängigkeit der Mn-Konzentration eine verminderte Polarisierung von etwa 50%.

HL 9.2 Mon 15:15 EW 201

ZnO-nanowire as a nanogenerator? — •Markus Andreas Schubert, Stephan Senz, Marin Alexe, and Ulrich Gösele — Max Planck Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

Recently nanogenerators for powering nanodevices were reported [1] in which ZnO-nanowire arrays convert mechanical energy in electrical energy by bending the ZnO-nanowires.

We simulate the experiments in which the ZnO nanowires were bent by AFM tip [2] by FEM-calculations for an ideal nonconducting piezoelectric ZnO-nanowire with a length of 600 nm and a diameter of 50 nm fixed perpendicular to a substrate. The top part of this nanowire was bent about 140 nm by a force applied at the top of the nanowire. At the point of the applied force the electrical potential has a maximum of +1.3 V. In the rest of the nanowire the electrical potential is +0.3 V for the stretched side and -0.3 V for the compressed. The piezoelectric charge generate the signal on the capacitance between the two sides, which is about 10^{-5} pF for the whole wire. A lower value of 10^{-7} pF is estimated for the AFM point contact.

However, most ZnO-nanowires are n-doped semiconductors with a typically resistivity of 1 Ωcm. One consequence is a very fast discharging of the piezoelectric generate charge in the order of magnitude of 1 ps. Even, in the case of an ideal nonconducting nanowire, the voltage at the input capacity of any preamplifier (∼1-5 pF) would be of the order of 10^{-7} V, which corresponds to a charge of about one electron.

[1] Y. Gao and Z.L. Wang, Nano Letters **7**, 2499–2505 (2007)
[2] Z.L. Wang and J. Song, Science **312**, 242–246 (2006)

HL 9.3 Mon 15:30 EW 201

Homoepitaxial growth of ZnO thin film by pulsed laser deposition (PLD) — •Matthias Brandt[1], Holger von Wenckstern[1], Holger Hochmuth[1], Michael Lorenz[1], Gisela Biehne[1], Gabriele Benndorf[1], Christoph Meinecke[1], Tilman Butz[1], Heidemarie Schmidt[1,2], Andreas Rahm[1,3], and Marius Grundmann[1] — [1]Universität Leipzig, Semiconductor Physics Group, Institut für ExperimentellePhysik II, Leipzig, Germany — [2]now at Forschungszentrum Dresden–Rossendorf, Dresden, Germany — [3]now at Solarion AG, Leipzig, Germany

Homoepitaxy has proven to improve the structural quality of ZnO thin films considerably compared to heteroepitaxy [1]. In this work the transport properties of phosphorous doped ZnO thin films, grown by pulsed–laser deposition (PLD) on thermally pretreated hydrothermally grown ZnO single crystal substrates are reported. Atomic force microscopy (AFM), high resolution X–ray diffraction and Rutherford backscattering (RBS) channeling measurements have been employed to analyse the morphological and structural properties of the ZnO:P thin films. Steps of height $c/2$ are visible in AFM images of all samples.

For an oxygen partial pressure of 0.1 mbar two–dimensional growth was found. RBS–Channeling of a ZnO:P film shows a minimum yield of 0.034 which is comparable to that of an annealed substrate (0.033). Hall effect measurements revealed that all as–grown ZnO:P thin films are n–type. Peak mobilities of 800 cm^2/Vs have been observed around 70 K, being in line with the high structural quality of the samples.
[1] H. v. Wenckstern et al.: phys. stat. sol. (RRL) **1**, 129 (2007).

HL 9.4 Mon 15:45 EW 201

Cathodoluminescence on homoepitaxially grown phosphorus doped ZnO epilayers — •Jan Zippel, Holger von Wenckstern, Gabriele Benndorf, Matthias Brandt, Michael Lorenz, Christoph Meinicke, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Phosphorus doped ZnO thin films were grown homoepitaxially by pulsed-laser deposition (PLD). The hydrothermal ZnO substrates were heat treated in oxygen ambient (850 mbar) at 1000°C for 2 h which results in a vicinal surface perfectly suited for epitaxy [1]. PLD-targets with different content of phosphorus were used(1 wt.%, 0.1 wt.%, 0.01 wt.%) for thin film deposition. Additionally we change the oxygen partial pressure systematically from 0.0003 mbar to 0.1 mbar. All samples were annealed (800 W, 10 min, 700 mbar N2).

In this contribution we compare low temperature (10K) cathodoluminescence (CL) of the as-grown and the annealed state in dependence on the phosphorus content and the oxygen partial pressure. Typical CL spectra are dominated by peaks related to the band edge and peaks related to deep impurities, respectively. We find that the red band dominates the spectra for high oxygen partial pressure independent of the phosphorus content whereas the green band is significant for low oxygen partial pressure and high phosphorus content.

[1] H. von Wenckstern, H. Schmidt, C. Hanisch, M. Brandt, C. Czekalla, G. Benndorf, G. Biehne, A. Rahm, H. Hochmuth, M. Lorenz and M. Grundmann, phys. stat. sol. (RRL) {1}, 129 (2007)

HL 9.5 Mon 16:00 EW 201

Structural and electronic properties of ZnO nanowires and nanotubes — •Andreia Luisa da Rosa[1], Hu Xu[2], Wei Fan[2], Fei Zhan[2], Xiaohong Zhang[2], Ruiqin Zhang[3], and Thomas Frauenheim[1] — [1]BCCMS, Universität Bremen, Am Fallturm 1, 28359, Bremen, Germany — [2]Nano-organic Photoelectronic Laboratory, Technical Institute of Physics and Chemistry, Beijing 100101, China — [3]COSDAF, Department of Physics and Materials Science, City University of Hong Kong SAR, China

ZnO is a well known semiconductor with potential applications in electronics and optoelectronics. ZnO has a direct wide band gap of 3.3 eV and a large exciton binding energy making it promising for high-efficiency blue and ultra-violet devices. Recently, the successful growth of highly ordered nanowires has expanded the list of potential applications. In this work we employ density functional theory to investigate ZnO nanowires and nanotubes. We find that relaxations on the facets are very similar to the ones in non-polar ZnO surfaces. While bare and completely passivated wires are semiconducting, wires with intermediate hydrogen passivation exhibit metallic behavior. We therefore suggest that hydrogenation leads to drastic changes in the ZnO nanowire electrical properties. We have also investigated ZnO nanotubes with round and hexagonal shapes. The calculated strain energy of round ZnO nanotubes follows a classical strain law. All the ZnO nanotubes were found to be direct band gap semiconductors with the band gap decreasing as their diameter increases.

HL 9.6 Mon 16:15 EW 201

Growth and doping of ZnO — •Stefan Lautenschläger, Joachim Sann, Niklas Volbers, Jan E. Stehr, Andreas Laufer, Thomas Leichtweiss, and Bruno K. Meyer — I.Physikalisches Institut, Justus Liebig Universität Gießen, Deutschland

The so far not reliably resolved acceptor doping of ZnO is clearly the main obstacle for the successful development of working devices based on ZnO. We report on the possibilities of acceptor doping during the CVD growth of ZnO. To achieve the incorporation of an acceptor we used the group V elements arsenic and nitrogen. We investigated mainly epitaxially grown thin films, some comparison with Ion- implanted samples have been undertaken. All the samples have been analyzed using photoluminescence spectroscopy, secondary ion mass spectrometry, atomic force microscopy, X-Ray photoelectron spectroscopy (XPS) and scanning electron microscopy. Especially the As- doped and implanted samples have been investigated with XPS to obtain information about the lattice site the dopant occupies.

15 min. break

HL 9.7 Mon 16:45 EW 201

Thermal and flash lamp annealing of nitrogen–implanted ZnO thin films. — •Thomas Lüder[1], Christian Czekalla[1], Gabriele Benndorf[1], Matthias Schmidt[2], Wolfgang Anwand[2], Gerhard Brauer[2], Wolfgang Skorupa[2], Manfred Helm[2], and Marius Grundmann[1] — [1]Universität Leipzig, Leipzig, Germany — [2]Forschungszentrum Dresden – Rossendorf e.V., Dresden, Germany

pn–junctions in ZnO have already been built by implantation of nitrogen ions. Post–annealing methods are used in order to activate the N_O acceptor and reduce defects caused by implantation processes. However out–diffusion of nitrogen during thermal annealing reduces the acceptor concentration and might lead to a loss of p–type conductivity. Recent success in using flash lamp annealing on Fe implanted ZnO single crystals[1] encouraged us to apply this post–annealing method to nitrogen–implanted ZnO thin films grown by pulsed laser deposition on sapphire substrates. The short annealing time of this process should minimize the diffusion of nitrogen.

Our samples have been annealed under three different flash lamp annealing conditions and are compared to thermally annealed samples.

The samples have been investigated by electrical and optical methods. We used low temperature photoluminescence and Raman–spectroscopy to prove the incorporation of nitrogen on oxygen sites. To finally get results of the electrical activity of the N_O acceptors, the samples have been examined by current–voltage measurements.

[1] K. Potzger et al.: J. Appl. Phys. **101**, 033906 (2007).

HL 9.8 Mon 17:00 EW 201

Hydrogen motion in the Cu-H complex in ZnO — •Felix Börrnert, E. V. Lavrov, and J. Weber — Technische Universität Dresden, 01062 Dresden, Germany

The Cu-H complex in ZnO consists of Cu on Zn site and a hydrogen atom bound to a nearby O atom with the O–H bond oriented in the basal plane of the hexagonal lattice to the c axis. The motion of hydrogen in the Cu-H complex is studied by the stress-induced dichroism. Stress applied at room temperature along $[10\bar{1}0]$ results in an alignment of the Cu-H bond. The reorientation process was found to be thermally activated with the activation energy of 0.52 ± 0.04 eV. The connection of the hydrogen movement in the Cu-H complex with the hydrogen diffusion in ZnO is discussed and consequences for the existence of interstitial hydrogen in ZnO at room temperature are presented.

HL 9.9 Mon 17:15 EW 201

Sputtered Silver Contacs on Zinc Oxide — •A. Lajn, H. von Wenckstern, M. Schmidt, M. Brandt, G. Biehne, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für ExperimentellePhysik II, Leipzig, Germany

Rectifying metal-semiconductor contacts are an adequate tool for investigating the electrical properties of semiconductors by means of, e.g., current-voltage- (IV) or capacitance-voltage-characterisation (CV) or thermal admittance spectroscopy (TAS). Reactive sputtering of silver in an oxygen atmosphere is a reproducible method to realize contacts on zinc oxide single crystals with excellent rectification properties [1]. In this contribution we investigate the properties of such contacts on hydrothermally grown ZnO bulk single crystals and on ZnO thin films grown by pulsed-laser deposition (PLD). The contacts realized on PLD thin films have a rectification ratio I(1V)/I(-1V) of 10^6, the typical rectification ratio for contacts on bulk crystals is 10^5. Both IV and CV characteristics confirm the formation of Schottky contacts. The barrier heights are about 0.9 V and the ideality factors are below 1.3 for thin films and about 1.6 for single crystals. Further the contact properties were investigated by temperature-dependent IV measurements confirmimg the usability of the contacts for semiconductor defect characterisation. As example TAS measurements on various electronic defects are presented.

[1] M. W. Allen, S. M. Durbin and J. B. Metson, Appl. Phys. Lett. **91**, 053512 (2007).

HL 9.10 Mon 17:30 EW 201

Implantationsuntersuchungen an polaren und unpolaren ZnO Einkristallen — •Patrick Kessler und Reiner Vianden —

Helmholtz- Institut für Strahlen- und Kernphysik, Nußallee 14-16, 53115 Bonn

Untersucht wurden in verschiedene Richtungen orientierte ZnO Kristalle mit der Methode der gestörten γ - γ Winkelkorrelation (PAC). Dabei wurden die Kristalle mit ^{111}In als Sondenatomen dotiert, die bevorzugt auf Zink Gitterplätze eingebunden werden. Deren direkte Umgebung kann mit der gewählten Messmethode dadurch hochaufgelöst studiert werden.

Um einen möglichen Effekt der Polarität und der daraus resultierenden Oberflächenterminierung auf das Ausheilverhalten der Implantationsschäden zu untersuchen wurde ein vergleichendes isochrones Temperprogramm an $\langle 0001\rangle$, $\langle 10\bar{1}0\rangle$ und $\langle 11\bar{2}0\rangle$ orientierten ZnO Einkristallen durchgeführt.

HL 9.11 Mon 17:45 EW 201

Properties of Li doped ZnO nanocrystals prepared from organometallic precursors — •Christian Rauch[1], Markus R. Wagner[1], Ronny Kirste[1], Wolfgang Gelhoff[1], Axel Hoffmann[1], Michael Lehmann[1], Matthias Driess[1], Andrey Orlov[2], and Sebastian Polarz[2] — [1]Technische Universität Berlin — [2]Universität Konstanz

Applying a special organometallic precursor system, ZnO nanocrystals with considerable Li incorporation were produced. The structural, optical and electronic properties of the Li doped ZnO nanocrystals with lithium concentrations between 0.1 and 12 percent are studied by x-ray diffraction (XRD), photoluminescence (PL) and electron paramagnetic resonance (EPR) spectroscopy. The XRD patterns demonstrate that ZnO solely crystallises in the wurtzite structure, with no other phases present. The ZnO particles are of similar size (70-80nm) with no considerable strain. However, a deviation of the lattice parameters for Li containing ZnO samples could be observed. The incorporation of lithium in the lattice, the g-values and the charge transfer processes are studied by photo-excited EPR. The successful lithium incorporation on the Zn site leads to a reduction of the Fermi level compared to undoped ZnO. The PL spectra at helium temperature show a bound exciton transition in the range of I_8, a luminescence band around 3.31eV with strong dependence on the Li concentration and a significant donor-acceptor-pair luminescence for medium lithium concentrations. The experimental data are discussed concerning the effectiveness of the shallow Li acceptor towards p-conductive ZnO nanocrystals.

HL 9.12 Mon 18:00 EW 201

ZnO nanocolumns grown by catalyst-free plasma assisted molecular beam epitaxy — •Thomas Andreas Wassner, Bernhard Laumer, Stefan Maier, Jochen Bruckbauer, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

ZnO nanocolumns were grown on (11-20)-sapphire by plasma assisted molecular beam epitaxy without the use of a catalyst. The influence of the II-VI ratio and the substrate temperature during growth on the density and shape of the nanocolumns was investigated. The epitaxial relationship was found to be $Al_2O_3[0001]\|ZnO[11\text{-}20]$, as determined by high resolution X-ray diffraction. Transmission electron microscopy images and Raman measurements will be presented in order to discuss the structural quality of the ZnO-nanorods. Optical properties, probed by photoluminescence spectroscopy are compared with those of continuous ZnO epitaxial films.

HL 9.13 Mon 18:15 EW 201

Chemical nature of N incorporated into ZnO during epitaxial film growth — •Patrick Hoffmann, Christian Pettenkofer, and Stefan Andres — Hahn-Meitner-Institut, Glienicker Straße 100, 14109 Berlin

ZnO is a wide band gap semiconductor (gap=3.4eV) which is unintentionally n doped by nature. In the last years it has been shown that ZnO can be p doped by incorporation of nitrogen. Nevertheless, some puzzling results suggest that just incorporation of nitrogen not simply leads to p doped ZnO. Investigations have shown that nitrogen can replace oxygen (N_O, p doping), but can also be incorporated as molecular N_2 ($[N_2]_O$, n doping), and can be bonded to oxygen. Therefore, this investigation concentrates on the chemical nature of the incorporated nitrogen during ZnO growth. The ZnO films are grown by metal-organic MBE (MOMBE) on sapphire substrate (r plane), while nitrogen is supplied by an ion source. Additionally, a mass filter between the ion source and the sample gives the opportunity to minimise the influence of the neutrals (e.g. N_2), and to select certain ions and ion fractions (e.g. N_2^+, N^+). The obtained films were investigated by means of XPS and NEXAFS. A comparison of the differently prepared films will be given.

HL 10: Preparation and characterization

Time: Monday 9:30–10:45 Location: EW 202

HL 10.1 Mon 9:30 EW 202

Defect cores investigated by x-ray scattering close to forbidden reflections in silicon — •Till H. Metzger[1], Marie-Ingrid Richard[2], Vaclav Holy[3], and Kai Nordlund[4] — [1]ESRF, Grenoble, France — [2]ESRF/CEA, Grenoble, France — [3]Charles University, Prague, Czech Republic — [4]University of Helsinki, Finland

Characterizing the structure of point defects and dislocations and understanding their properties are of great importance in semiconductor technology. In silicon implantation, the interaction of defects and impurities play a crucial role in the doping of silicon. The most important extended defects observed in such systems are stacking faults, "311" defects and perfect dislocation loops. A new x-ray scattering method is presented making possible the detection of defects and the investigation of the structure of their cores. The method uses diffuse x-ray scattering measured close to the (200) forbidden diffraction peak, in which the intensity scattered from the distorted crystal lattice around the defects is minimized. As an example of this non-destructive method we demonstrate how the local compression of the extra {111} double planes in extrinsic stacking faults in Si can be probed and quantified using a continuum approach for the simulation of the core displacements. The experimental results are found to be in a very good agreement with atomistic simulations [1]. [1] M.I. Richard, T. H. Metzger, V. Holy and K. Nordlund, accepted for publication in Phys. Rev. Lett. 2007

HL 10.2 Mon 9:45 EW 202

Application of evolutionary strategies to the analysis of defects in semiconductors — •Silvia Schumann[1] and Torsten Hahn[2] — [1]TU Bergakademie Freiberg, Institute for Theoretical Physics, Leipziger Str. 23, 09599 Freiberg, Germany — [2]TU Bergakademie Freiberg, Institute for Experimental Physics, Leipziger Str. 23, 09599 Freiberg, Germany

This work presents an application of evolutionary strategies to the analysis of defects in semiconductors. Experimental Photo-Induced Current Transient Spectroscopy (PICTS) measurements have been simulated at different levels of optical excitation. These simulations give access to various physical properties like e.g. the minority carrier lifetimes. This enables us to compare directly the simulated data to quasi steady state photoconductance and PICTS-measurements at different injection levels. The evolutionary strategy was chosen because of the high dimension of the problem and the unknown landscape of the objective function. The application of the evolutionary algorithm provides the defect configurations, where each defect is characterized by its energy, concentration, and capture cross-section. Suitable configurations in very good agreement with experimental data can be obtained already after a few generations. The evolutionary algorithm avoids trapping in local minima and provides information on the range of possible solutions.

HL 10.3 Mon 10:00 EW 202

Probing the free charge carrier distribution with non-contact and contact AFM — •A.-D. Müller[1], F. Müller[1], S. Jänsch[2], C. Henkel[2], P. Pelzing[3], A. Möller[3], and H. Schmidt[4] — [1]Anfatec Instruments AG, Melanchthonstrasse 28, D-08606 Oelsnitz — [2]Universität Leipzig, Institut für Experimentelle Physik II, D-04103 Leipzig — [3]SGS Institut Fresenius GmbH, D-01109 Dresden — [4]Forschungszentrum Dresden-Rossendorf e.V., D-01314 Dresden

We address the issue of extracting the dopant profile information on

the nanoscale by electrostatic force microscopy (EFM) in non-contact and Scanning Capacitance Microscopy (SCM) in contact mode. Cross sections prepared of Si epilayers on Si substrates were investigated with highly-doped conductive tips in complementary SPM techniques with a lateral resolution limited by the Debye length. Frequency and tip-sample distance dependent surface work functions were obtained by Kelvin Probe Force Microscopy (KPFM) with a voltage resolution better than 10 meV. Surface band structures in the frequency range between 10 kHz and 300 kHz are acquired by non-contact capacitance detection in dynamic EFM, while high-frequency tip-sample capacitance-voltage characteristics have been detected by a SCM sensor and enable the determination of dopant concentration. The comparison between these techniques is completed by numerical simulations of voltage dependent tip-sample capacitances to improve the understanding of the contrast. The recorded KPFM and SCM data are complementary with respect to surface and depth resolution, respectively, and together they give a more complete impression of the sample's electronic structure.

HL 10.4 Mon 10:15 EW 202

Preparation and tunneling characteristics of MOS structures for Si-based IR light emitters — •Stephan Suckow[1], Martin Kittler[1,2], Winfried Seifert[1,2], Tzanimir Arguirov[1,2], Manfred Schmidt[3], Bert Stegemann[3], and Heike Angermann[3] — [1]IHP/BTU JointLab, Konrad-Wachsmann-Allee 1, 03046 Cottbus, Germany — [2]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [3]Hahn-Meitner-Institut Berlin, Kekuléstraße 5, 12489 Berlin, Germany

Si based light emitters, such as MOS structures based on dislocation networks, are attractive candidates for the generation of electroluminescence in the IR spectral range to be applied e.g. in optical on-chip interconnects. In the present work the preparation of an appropriate MOS structure that facilitates efficient charge carrier injection is explored and its charge carrier tunneling and recombination characteristics are analyzed. In this respect MOS structures with ultra-thin tunnel oxides fabricated by wet-chemical oxidation of Si wafers and thermally deposited Ti contacts turned out to produce the most efficient and reliable results. Moreover, electroluminescence measurements revealed an anomalous temperature behavior of band-to-band recombination with enhanced intensity at higher temperature (300 K). As photoluminescence intensity inversely increases with decreasing temperature, this effect is clearly correlated to efficient minority charge carrier injection via the MOS contact and points towards an application as room temperature IR light emitter.

HL 10.5 Mon 10:30 EW 202

Photoelectrochemical Formation and Shaping of Silicon Nanostructures Controlled by in-situ Brewster-Angle Reflectometry — •Michael Lublow and Hans-Joachim Lewerenz — Hahn-Meitner-Institut Berlin GmbH, Glienicker Str. 100, 14109 Berlin

Silicon nanostructures were produced and manipulated in ammonium fluoride containing solutions at small potentials positive from the open-circuit potential (OCP). In diluted solutions, either divalent or tetravalent electrochemical reactions can be induced by light intensity variations which consequently alter the OCP and therefore the resulting overpotential. During photon flux variation, formation and selective oxidation of the structures were monitored in real-time by the surface sensitive signal of Brewster-angle reflectometry. After subsequent oxide removal, varied aspect ratios and densities of the nanostructures were obtained. Structure alignment effects were analyzed by Atomic Force Microscopy and could be related to the wafer-miscut dependent topographies of the initially H-terminated surfaces. Results for varying miscut angles from 0° to 4° will be presented. The influence of solution concentration and different surface orientations towards (111), (100) and (113) direction will be discussed.

HL 11: C/diamond

Time: Monday 11:00–13:00 Location: EW 202

HL 11.1 Mon 11:00 EW 202

Discontinuity of the loss function at large momentum transfers in graphite. — •Ralf Hambach[1,2], Christine Giorgetti[1], Frank Ortmann[2], Karsten Hannewald[2], Francesco Sottile[1], Apostolos G. Marinopoulos[3], Friedhelm Bechstedt[2], and Lucia Reining[1] — [1]Laboratoire des Solides Irradiés, CEA-CNRS UMR 7642-Ecole Polytechnique, 91128 Palaiseau Cedex, France and European Theoretical Spectroscopy Facility (ETSF), Palaiseau, France — [2]IFTO, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — [3]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA

The loss function of graphite was studied for momentum transfers q beyond the first Brillouin zone. Surprisingly, near Bragg reflexes, the spectra are highly dependent upon very small changes in q, which reminds the non-analyticity of the loss function in the optical limit ($q \to 0$). The effect is investigated by means of first principle calculations within the random phase approximation (RPA). We find crystal local field effects to be crucial and propose a simple 2×2 model dielectric function.

HL 11.2 Mon 11:15 EW 202

Optical properties and electronic structure of size- and shape-selected nanodiamonds — •Lasse Landt[1], Kathrin Klünder[1], Trevor Willey[2], Tony van Buuren[2], Jeremy Dahl[3], Robert Carlson[3], Thomas Möller[1], and Christoph Bostedt[1] — [1]Technische Universität Berlin, Germany — [2]Lawrence Livermore National Laboratory, USA — [3]MolecularDiamond Technologies, USA

Diamondoids can be considered the smallest possible cage-like subunits that can be excised from diamond lattice closing the gap between large hydrocarbon molecules and nanodiamonds. Diamondoids are fully sp3-hybridized and show no surface reconstruction due to full hydrogen-passivation.

The optical and electronic properties of perfectly size- and structure-selected, neutral diamondoids ranging in size from 0.5 to 1 nm have been determined by means of PES, XAS, and optical absorption measurements. All data were taken from high purity samples in the gas phase revealing optical gap and band edges with near theoretical purity. We find that the optical properties of the perfectly size- and shape-selected nanocrystals exhibit strong shape dependence unlike band edges or ionization potentials which have also been determined. The observed isomeric dependencies of the optical gap will be discussed and first experimental data on the influence of targeted surface modification (e.g. thiols, alcohols) will be presented.

HL 11.3 Mon 11:30 EW 202

Molecular doping and pseudo Landau levels in graphene — •Tim Wehling and Alexander Lichtenstein — I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Controlling graphene's density of states near the Fermi level is crucial for future applications based on this material. Two mechanisms related to this goal will be addressed, here. Firstly, we present a joint experimental and ab-initio theoretical investigation of adsorbate induced doping of graphene. A general relation between the doping strength and whether or not adsorbates are open- or closed- shell systems is demonstrated with the NO_2-system: The single, open shell NO_2 molecule is found to be a strong acceptor, whereas its closed shell dimer N_2O_4 causes only weak doping. This effect is pronounced by graphene's peculiar density of states (DOS), which is ideal for chemical sensor applications. We explain the recently observed [Schedin et. al., Nat. Mater 6, 652 (2007)] NO_2 single molecule detection.

In addition, we present first principles calculations on midgap states in corrugated graphene: Rippling induces pseudomagnetic fields leading to the formation of flat bands near the Fermi level — so-called pseudo-Landau levels. Especially, the chiral zero-energy pseudo-Landau level gives rise to specific real space signatures like full sublattice polarization and related sublattice stripes observable in any experiment probing the local electronic structure.

In collaboration with A. Balatsky (LANL), A. Geim (U. Manchester), M. Katsnelson (U. Nijmegen) and K. Novoselov (U. Manchester).

HL 11.4 Mon 11:45 EW 202

Synthesis and investigation of iron-filled carbon nanotubes as probes for magnetic force microscopy — •Uhland Weissker, Thomas Mühl, Albrecht Leonhardt, Christine Täschner,

Siegfried Menzel, Franziska Wolny, Christian Müller, and Bernd Büchner — Leibniz Institute for Solid State and Material Research IFW, Dresden

Magnetic force microscopy is a powerful method for imaging magnetic stray fields of magnetic surfaces with high spatial resolution. For magnetic force microscopy a conventional atomic force microscopy tapping mode cantilever is coated with a magnetic layer that interacts with the sample stray field. Using this kind of probes the rather complicated pyramid shape of the probe influences the measurement results. Because of that, a straightforward quantitative interpretation of MFM data is hardly possible. On the other hand, quasi one-dimensional ferromagnetic wire-shaped probes should allow quantitative stray field measurements.

One promising solution is the use of iron-filled carbon nanotubes as scanning tip. The filled nanotubes offer a high aspect ratio, good mechanical properties and are magnetic. We report a chemical vapour deposition method (CVD) for fabrication of in-situ filled carbon nanotubes, which exhibit a long continuous iron-filling of several microns. The nanotube structure is investigated by SEM and TEM, whereas the filling is examined by AGM, XRD and EELS.

HL 11.5 Mon 12:00 EW 202

Scratching Multilayer Graphene with an Atomic Force Microscope — •Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover

The atomic force microscope (AFM) is a well known tool used for structuring devices on different materials. Besides others, one way is to scratch the surface and thus create insulating lines. We used this technique on thin graphite films. In situ measurements of the resistance while the sample was mounted and electrically contacted in the AFM show an astonishing reversible change in the resistance when the sample was scratched with a diamond coated tip. After moving the tip several times across the sample the resistance changes permanently. We contribute the reversible effect to induced and then moving defects in the graphite, whereas the irreversible change indicates that different layers have been cut through.

HL 11.6 Mon 12:15 EW 202

Ab initio calculation of the lattice dynamics of graphene nanoribbons — •Roland Gillen, Marcel Mohr, Janina Maultzsch, and Christian Thomsen — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

During the past decades, graphite-related materials of nanoscale, such as fullerenes and nanotubes, have been subject to scientific interest. Their remarkable optical and electronical properties make them promising for use in future nanotechnology. Recently, another type of nanoscale materials, narrow stripes of graphene (single layer graphite) have been fabricated and were investigated regarding their electrical transport properties. Those graphene nanoribbons are, depending on the direction of their edges, classified into armchair (AGNR), zig-zag (ZGNR) and chiral nanoribbons (CGNR). They correspond to "unrolled" carbon nanotubes, i.e. the model system used in zone-folding calculations of carbon nanotube properties. We use DFT calculations to obtain the band structure and phonon dispersion of various AGNR and ZGNR. Group theory was applied to classify the resulting phonon modes. We show that most of the phonon modes can be interpreted as "overtones" of a few fundamental modes. These overtone frequencies can be understood from zone folding the phonon dispersion of graphene. Shape and size dependences of the phonon frequencies of the nanoribbons are found. Similarities between nanoribbons and carbon nanotubes will be discussed.

HL 11.7 Mon 12:30 EW 202

Phonon symmetries of carbon picotubes — •Nils Rosenkranz[1], María Machón[1], Rainer Herges[2], and Christian Thomsen[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Institut für Organische Chemie, Christian-Albrechts-Universität Kiel, Otto-Hahn-Platz 4, 24098 Kiel, Germany

Picotubes are ring-shaped hydrocarbons closely related to very short carbon nanotubes. They seem to be a promising starting point for the specific synthesis of nanotubes, which is one of the great goals in nanotube research. We identified the symmetries of all main modes in the Raman spectrum of semitrimer picotubes by performing polarization-dependent Raman measurements on crystalline samples. Furthermore, the semitrimer molecule has been subject to ab initio calculations, the results of which agree excellently to the experimental data. By comparing experiment and theory, we can assign phonon eigenvectors to all main Raman peaks.

HL 11.8 Mon 12:45 EW 202

The intermediate frequency modes in the carbon nanotube Raman spectra — •Martin Weiss[1], Hagen Telg[1], Janina Maultzsch[1], Viera Skákalová[2], and Christian Thomsen[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Max Planck Institut for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany

The carbon nanotube Raman spectrum as it is commonly referred to consists of three features, the radial breathing mode (RBM), the high energy modes and the defect induced D mode. These modes are used to gain information on the diameter distribution, the presence of metallic tubes, the defect density and even the precise chiral indices (n_1, n_2) of the tubes in a nanotube sample. However, apart from these three modes the nanotube Raman spectrum contains features in the intermediate frequency range of which the scattering mechanism is not yet consistently understood. These modes in part result from second-order scattering and resemble the phonon density of states. Therefore, they can give information on the phonon dispersion of nanotubes and on Raman inactive modes. We performed resonant Raman measurements of the intermediate frequency modes (IFM) located between ~ 400 and $\sim 1000\ \mathrm{cm}^{-1}$. By comparing the resonance conditions of the IFMs and RBMs we assign the IFMs to certain groups of nanotubes (n_1, n_2). Furthermore we discuss the dependence of the IFMs on excitation energy and their lineshapes with respect to the calculated phonon density of states.

HL 12: Photovoltaic

Time: Monday 14:00–16:15 Location: EW 202

HL 12.1 Mon 14:00 EW 202

Measurement of interstitial iron content in multicrystalline silicon by microwave detected photoconductance decay — •Kevin Lauer[1,2], Abdelazize Laades[1], Alexander Lawerenz[1], Hartmut Übensee[1], and Heinrich Metzner[1] — [1]CiS Institut für Mikrosensorik GmbH, SolarZentrum Erfurt, Konrad-Zuse-Str. 14, 99099 Erfurt, Germany — [2]Institut für Physik, TU-Ilmenau, Weimarer Str. 32, 98693 Ilmenau

A new approach to evaluate the photoconductance decay measured by microwave reflection in thin multicrystalline silicon wafers is presented. The minority carrier lifetime as a function of the excess carrier density is extracted from the photoconductance decay signal. We use this new approach to detect the interstitial iron content with a high spatial resolution. This is done by measurements in the two different states of the meta-stable iron-boron pairs. The limits of this method are discussed and it is shown to be applicable to thin and surface passivated multicrystalline silicon wafers with low minority carrier lifetime. A quantitative comparison to results obtained by means of quasi steady-state photoconductance measurements (QSSPC) is presented.

HL 12.2 Mon 14:15 EW 202

Monolithic III-V- tandem solar cell lattice matched to InP(100) with a GaInAs/GaAsSb tunnel junction — •Nadine Szabó, Ulf Seidel, Erol Sagol, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institut, Glienicker Str. 100, Berlin

At present, III-V triple junction (3J) solar cells are achieving the highest conversion efficiencies (η=40.7%) worldwide. These cells are grown slightly lattice mismatched to Ge(100) and are containing three absorber layers: Ge, GaInAs and GaInP. Even higher efficiencies are possible if more than 3 subcells were used. To obtain this, one can

replace the Ge bottom cell by a GaInAsP/GaInAs tandem cell grown lattice matched to InP. The combination of these low band gap subcells with an established GaAs/GaInP tandem solar cell can be realised by mechanical stacking. The GaAs/GaInP// GaInAsP/GaInAs 4J tandem solar cell has a theoretical conversion efficiency limit of 61% (500 suns), which is clearly higher than the limit of the current world record 3J solar cell (49%). The serial connection of the two subcells of our tandem cell was realised by a tunnel junction. This tunnel junction was composed of a n-GaInAs and a p-GaAsSb layer. Depending on the preparation of the n-GaInAs layer, the p-GaAsSb layer was grown either on III-rich or on V-rich surfaces. Whereas the growth of the GaAsSb layer on a III-rich surface led to a sharper interface. Sun simulator measurements have been performed in order to investigate the influence of the different preparation methods on the cell efficiencies.

HL 12.3 Mon 14:30 EW 202

Photonic intermediate layer for silicon tandem solar cells — •Andreas Bielawny[1], Paul-Tiberiu Miclea[1], Ralf Wehrspohn[1], Seuong-Mo Lee[2], Mato Knez[2], Reinhard Carius[3], Marian Lisca[4], Carsten Rockstuhl[4], and Falk Lederer[4] — [1]Martin-Luther Universität Halle-Wittenberg, Inst. für Physik, Mikro-MD, D-06120 Halle — [2]Max-Planck-Inst. für Mikrostrukturphysik, D-06120 Halle, — [3]Forschungszentrum Jülich, Inst. für Photovoltaik (IEF-5), D-52428 Jülich — [4]Universität Jena, Dept. Physik, D-07743 Jena

The concept of incorporation of a 3D photonic crystal as diffractive spectral filter within a-Si/mc-Si tandem solar cells has been investigated as a promising application. Our intermediate reflective filter enhances the pathway of spectrally selected light within an amorphous silicon top cell in its spectral region of low absorption. From our previous work, we expect a significant improvement of the tandem's efficiency of about 1.2%(absolute). This increases efficiency for a typical silicon tandem cell from 11.2% to 12.4%, as a result of the optical current-matching of the two junctions. Our wavelength-selective optical element is a 3D-structured optical thin-film - prepared by self-organized artificial opal templates and finalized with atomic layer deposition techniques. The resulting samples are highly periodical thin-film inverted opals made of zinc-oxide. We compare recent experimental data on the optical properties with our simulations and photonic bandstructure calculations.

HL 12.4 Mon 14:45 EW 202

Deposition and characterization of (Zn,Mg)O buffer layers on CIGSSe thin film solar cells — •Benjamin Hussmann[1], Felix Erfurth[1], Thomas Niesen[2], Jörg Palm[2], Alexander Grimm[3], Achim Schöll[1], and Eberhard Umbach[1,4] — [1]Universität Würzburg, Experimentelle Physik II — [2]Avancis GmbH, München — [3]Hahn-Meitner-Institut, Berlin — [4]Forschungszentrum Karlsruhe

(Zn, Mg)O buffer layers on Cu(In,Ga)(S,Se)$_2$ (CIGSSe) thin film solar cells are promising alternatives to CdS buffer layers by featuring comparable efficiencies, better environmental compatibility and the possibility to implement the deposition process into a vacuum processing line. The (Zn, Mg)O buffer layers are deposited by radio frequency magnetron co-sputtering from two separate ZnO and MgO ceramic sputter targets to control the Mg-content and therefore the band gap of the buffer layer. In our experimental setup the sputter preparation chamber is connected with a UHV analysis system which allows in-situ characterization with X-ray photoelectron spectroscopy (XPS). The interface between the absorber and the buffer layer is believed to have a major influence on the cell efficiency and is thus of particular interest in this work. This interface has been investigated during layer deposition by sequentially interrupting the sputter process and performing XPS scans. We observed island growth of (Zn,Mg)O on CIGSSe and a strong oxidation of the absorber surface induced by the deposit. In order to complement the chemical and electronic information with structural data, energy dispersive X-ray analysis, X-ray diffraction, and scanning electron microscopy have been applied.

HL 12.5 Mon 15:00 EW 202

Influence of gap state defect passivation on transport properties in SiO_2/Si/SiO_2 quantum layers — •Daniel Sixtensson, Bert Stegemann, and Manfred Schmidt — Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Kekuléstraße 5, 12489 Berlin

The maximum efficiency of standard silicon single bandgap photovoltaic devices is given by the Shockley-Queisser limit of 32.7 %. A major loss source is thermalization of hot photogenerated charge carriers. Novel methods utilizing quantum confinement effects have recently been proposed to circumvent this limit. Si/SiO_2 quantum well structures, utilizing stacked absorbers with different bandgaps, can better be adjusted to the solar spectrum and thus, avoid thermalization losses. However, the interface-to-volume ratio increases tremendously in such structures. Therefore, due to strong interface recombination and Coulomb scattering from charged interface states, the Si/SiO_2 interfaces are a major factor limiting carrier transport. In the present work, the impact of defect passivation by hydrogen treatment on interface gap state defect densities at structurally and chemically well-defined Si/SiO_2 interfaces has been analyzed using surface photovoltage (SPV) measurements and constant final state photoelectron spectroscopy. Moreover, transport properties in single SiO_2/Si/SiO_2 quantum well structures are analyzed and related to interface quality by means of highly sensitive photoconductivity measurements.

HL 12.6 Mon 15:15 EW 202

Angle dependent optics in nano-textured thin-film silicon solar cells — •Rahul Dewan[1], Christian Haase[2], Helmut Stiebig[2], and Dietmar Knipp[1] — [1]School of Engineering and Science, Jacobs University Bremen, D-28759 Bremen, Germany — [2]Institute of Photovoltaics, Research Center Jülich, D-52425 Jülich, Germany

Highly effective light trapping and optical light incoupling concepts are essential in realizing highly efficient thin-film solar cells with absorbers in the range of micrometers. To investigate and optimize both effects, wave propagation in thin-film silicon solar cells with integrated grating couplers was modeled in two and three dimensions solving the Maxwell equations by a Finite Difference Time Domain approach. Simulations were carried out for different wavelengths and angles of incidence of light, keeping the period of the grating structure fixed. Simulation results reveal that for small angles of incidence (close to normal incidence) the absorption of the solar cells with integrated couplers is enhanced in comparison to structures without grating couplers. Such behavior is observed for shorter and longer wavelengths (500 nm and 800 nm). For intermediate angles of incidence (30° - 60°) the absorption of the structures without grating couplers exceeds the absorption attained for structures with integrated couplers. As the wavelength of the incident light increases from 500 nm to 800 nm for structures without couplers, the maxima of the absorption shifts from 60° to 40° angle of incidence. Structures with and without grating couplers exhibit similar absorption behavior for angles of incidence larger than 75°.

HL 12.7 Mon 15:30 EW 202

Locally resolved characterization of CuInS2 thin film solar cells — •Markus Wendt, Jo Klaer, Thomas Unold, and Hans Werner Schock — Hahn-Meitner-Institut Berlin Glienicker Str. 100 14109 Berlin

CuInS2 thin film solar cells were produced by sulfurization of metallic precursor layers using a rapid thermal anneal process. Depending on the processing conditions variations of the total photocurrent were found. At the same time, scanning electron microscopy revealed an inhomogeneous morphology for many of the solar cells processed. To investigate the influence of processing conditions on the photocurrent collection in more detail, laser beam induced current (LBIC) measurements were applied to selected solar cells. The excitation wavelength was 525nm and the local resolution was 1-3 um. The typical scanning range of the experiments was 1sq.mm. LBIC-maps collected at low light-intensities of approximately 1 sun showed variations of 5% in the local photocurrent collection. However, LBIC maps at high intensities of approximately 1000 suns showed very large variations in the local photocurrent collection of nearly a factor of 2-3. We conclude that the local variation of current collection under high illumination is due to current crowding effects caused by inhomogeneities in the morphology of the solar cells.

HL 12.8 Mon 15:45 EW 202

Light-Beam Induced Current-investigations of Copper/Nickel - co-doped, wafer-bonded silicon bicristals — •Philipp Saring, Carsten Rudolf, Oliver Voss, Linda Stolze, and Michael Seibt — IV.Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

Light Beam Induced Current (LBIC)-measurements were performed on samples of Czochralski-silicon, containing a small-angle grain boundary. This dislocation-network is visible on cross-section samples as a line with strong LBIC-contrast. Copper-doped samples exhibit precipitates with polyhedral structure and a strong contrast, whereas the Nickel-doped samples (same indiffusion conditions) do not reveal regions of such strong recombination activity. The samples, co-doped

with Copper and Nickel, exhibit precipitates with LBIC-characteristics comparable to that in the Copper-samples. All samples containing precipitates show a higher concentration of them in one Wafer, probably due to the presence of oxygen related defects acting as nucleation sites. We greatfully acknowledge M. Reiche, Th. Wilhelm for providing bonded silicon wafers. This work was financially supported by Volkswagen foundation (SOBSI-Project).

HL 12.9 Mon 16:00 EW 202

Invenstigation of the Silicon-Oxide-Platinum interface for photoelectrochemical solar cells — •Thomas Stempel Pereira[1], Aggour Mohammed[2], Katarzyna Skorupska[1], Michael Lublow[1], Andres Munoz[1], and Hans-Joachim Lewerenz[1] — [1]Hahn-Meiter-Institut, Devision of Solar Energy, Glienicker Str. 100, 14109 Berlin, Germany — [2]Ibn Tofail University, Rabat, Marocco

Photoelectrochemical solarcells on the basis of Si can be fabricated with standart electrochemical methods. However, corrosion of the semiconductor surface leads to a degeneration of such cells. Attemps have been made to passivate the Si surface with an oxide while allowing charge transfer through metal deposits on the surface. Thus efficiencies of more than 10% can be achived. We present experimental results of various preparation methods of anodic oxides on Si. The deposion of Pt nanoemitters on the electrode through pores in the oxide layer is investigated. The interface density of states was examined by capacitance measurements. Low interface density states can be achived by anodic oxidation in phtalate solutions. Model experiments of electrochemically deposited Pt with synchrotron radiation photoelectron spectroscopy show that Si is oxidized during Pt-deposition, thus reducing the influence of metal induced gap states at the interface.

HL 13: Theory of electronic structure

Time: Monday 16:15–17:30 Location: EW 202

HL 13.1 Mon 16:15 EW 202

GW **Method for *f*-electron Systems: Applications to CeO_2 and ThO_2** — •Hong Jiang[1], Ricardo I. Gomez-Abal[1], Xinzheng Li[1], Patrick Rinke[1,2], and Matthias Scheffler[1] — [1]Fritz-Haber-Institut der MPG, Berlin — [2]University of California at Sant Barbara, CA 93106

Understanding the physics of *f*-electron systems is regarded as a great challenge in condensed-matter physics today. In many of these materials the strong localization of the *f*-electrons gives rise to large many-body exchange and correlation effects and in addition leads to severe self-interaction errors in the local-density approximation (LDA). Many-body perturbation theory in the *GW* approximation offers both a quasiparticle perspective and an exact treatment of exchange. It is therefore a promising approach for investigating these systems. In this work we apply the G_0W_0 method to CeO_2 and ThO_2, the "simplest" *f*-electron systems for which the LDA provides a qualitatively correct description, but underestimates band gaps significantly. For both materials, G_0W_0 based on LDA provides an accurate description for the fundamental (*p*-*d*) band gap. In CeO_2, the highly localized *f*-states fall within the *p*-*d* gap; the G_0W_0 correction increases the *p*-*f* gap and reduces the *f*-band width considerably. The resultant density of states is in good agreement with experiments. In ThO_2, the 5*f*-states are more delocalized and overlap with the Th-6*d* bands; the G_0W_0 correction shifts the 5*f*-bands more than 6*d*-bands, changing the density of unoccupied states considerably. Implications for general *f*-electron systems with partially filled *f*-shell are discussed.

HL 13.2 Mon 16:30 EW 202

Hybrid density functionals for calculating the lattice dynamics of semiconductors — •Kerstin Hummer and Georg Kresse — Vienna University, Sensengasse 8/12, 1090 Vienna, Austria

We present the *ab initio* study of the lattice dynamics of group-IV tetrahedral semiconductors, *i.e.*, cubic diamond, silicon, germanium, and grey tin as well as α-quartz by a frozen phonon approach. The main objective of this work is to examine the performance of the screened hybrid density functional proposed by Heyd, Scuseria and Ernzerhof (HSE03) [1] for calculating phonon dispersion curves. The HSE03 has been very successful in describing the structural, electronic, and thermochemical properties of many solids comprising insulators, semiconductors as well as metals [2]. Within density functional theory (DFT), the widely utilized exchange-correlation functionals LDA and GGA show deficiencies in accurately describing the shallow *d* electrons, which is particularly important in the case of germanium and grey tin. While for both, DFT-LDA yields a wrong (metallic) ground state and considerably underestimated phonon frequencies, the HSE03 functional significantly improves the results regarding the ground state solution, the theoretical lattice constant and thus the lattice dynamics. The presented *ab initio* phonon dispersions are compared to experimental data and reviewed in the context of previously reported theoretical findings, where particular emphasis is also placed on analyzing its sensitivity to the lattice constant utilized in the calculations.

[1] J. Heyd *et al.*, J. Chem. Phys. **118**, 8207 (2003)
[2] J. Paier *et al.*, J. Chem. Phys. **124**, 154709 (2006)

HL 13.3 Mon 16:45 EW 202

An efficient approach to bound excitons: Applications to model and *ab initio* band structures. — •Frank Fuchs, Claudia Rödl, André Schleife, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik and European Theoretical Spectroscopy Facility (ETSF), Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena, Germany

The accurate calculation and parameter-free prediction of optical spectra including excitonic effects is highly desirable for both fundamental and applied research. Excitonic effects can be treated in the framework of many-body perturbation theory and the Bethe-Salpeter equation (BSE), by solving an eigenvalue problem for the electron-hole Hamiltonian $\hat{H}$. Although an efficient method for the calculation of excitonic spectra in an extended frequency range is available [1], a comparably efficient approach to bound excitonic states or even dark excitons is lacking. Instead, the diagonalization of $\hat{H}$, with computational costs scaling with the number of pair states N like $O(N^3)$, is required. Thus computational studies are usually limited to well behaved problems and/or are insufficiently converged with respect to N. We present a numerically efficient approach for the calculation of a limited number of excitonic states avoiding the full diagonalization of $\hat{H}$. The approach is tested for its accuracy and performance by numerically solving the BSE for the Wannier-Mott two-band model in **k**-space and real semiconductors like InN and ZnO.

[1] W.G. Schmidt et al. , Phys. Rev. B **67**, 085307 (2003).

HL 13.4 Mon 17:00 EW 202

Charged defects in a supercell formalism: from an empirical to a fully ab-initio treatment of finite-size effects — •Christoph Freysoldt and Jörg Neugebauer — MPI für Eisenforschung, Düsseldorf, Germany

Charged point defects govern the charge carrier densities in semiconductors and are crucial for the performance of electronic devices. However, quantifying the thermodynamical, chemical, electrical, and other properties of such defects is a challenge to both theory and experiment. On the theoretical side, *ab-initio* calculations have proven to be a valuable tool. In these calculations, the defect is usually modelled in a periodic supercell with a few dozen to a few hundred atoms. Unfortunately, the supercell approximation introduces artificial electrostatic interactions between the charged defects. A number of correction schemes such as Makov-Payne corrections, potential alignment, scaling laws, or Coulomb truncation are available in the literature, but the magnitude of these corrections for a specific supercell usually scatters widely. The assumptions behind these schemes are often unclear and all schemes lack a stringent theoretical foundation. From a formal analysis within linear-response theory, we propose a new and simple scheme that combines the strengthes of Makov-Payne corrections and potential alignment. Our scheme requires no empirical parameters or fitting procedures. Its reliability (scatter in formation energies <0.1 eV, charge transition levels <0.05 eV) is demonstrated for the Ga vacancy in GaAs.

HL 13.5 Mon 17:15 EW 202

First-Principles Calculations of Electronic and Optical Properties of MnO and NiO — •Claudia Rödl, Frank Fuchs, Jürgen Furthmüller, and Friedhelm Bechstedt — Institut für

Festkörpertheorie und -optik and European Theoretical Spectroscopy Facility (ETSF), Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

The treatment of the antiferromagnetic transition-metal oxides within many-body perturbation theory (MBPT) remains a challenge. It is well-known for years that density-functional theory (DFT) in the local-density (LDA) and generalized-gradient approximation (GGA) yields very small or even negative gaps for this class of materials. Consequently, quasiparticle calculations using Hedin's GW approximation in the commonly applied one-shot approach underestimate the fundamental gap significantly. That is why we use the non-local HSE03 exchange-correlation functional to obtain a reasonable starting point for a quasiparticle calculation within first-order perturbation theory. We explicitly focus on the compounds MnO and NiO which are usually considered as paradigmatic examples. Furthermore, we examine the optical properties of these materials. We solve the spin-polarized Bethe-Salpeter equation (BSE) and calculate optical absorption spectra including excitonic and local-field effects. In order to keep the computational demand treatable, we utilize the comparably less expensive GGA+U scheme for the subjacent electronic structure calculation.

HL 14: Heterostructures

Time: Monday 9:30–11:15 Location: ER 164

HL 14.1 Mon 9:30 ER 164

The initial growth stages of MBE Ge films on PrO2(111)/Si(111) support systems — •Alessandro Giussani[1], Olaf Seifarth[1], Peter Rodenbach[1], Hans-Joachim Müssig[1], Peter Zaumseil[1], Thomas Weisemöller[2], Carsten Deiter[2], Joachim Wollschläger[2], Peter Storck[3], and Thomas Schroeder[1] — [1]IHP-Microelectronics, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]University of Osnabrück, Barbarastrasse 7, 49076 Osnabrück, Germany — [3]SILTRONIC AG, Hanns-Seidel-Platz 4, 81737 München, Germany

In the framework of epitaxial GeOI heterostructures on Si for CMOS applications and III-V optoelectronic materials integration on the Si platform, the MBE growth of Ge on PrO2(111)/Si(111) heterostacks was studied by means of RHEED, XPS, UPS, GI-XRD. It was shown that in the first deposition stages a GeO2-like layer forms as a result of the interaction with the PrO2 substrate, namely the diffusion of lattice oxygen from the dielectric to the growing semiconductor deposit. In consequence the PrO2(111) buffer is fully reduced to a cubic Pr2O3(111) structure. As no oxidizing species are available in the process anymore, under continuous Ge evaporation the Ge oxide layer converts to GeO, which sublimates at the deposition conditions. The uncovered cubic Pr2O3(111) surface then provides a thermodynamically stable template for the heteroepitaxial growth of elemental Ge, which occurs according to a Volmer-Weber mode and results after island coalescence in the formation of a flat, single crystalline, untwined Ge(111) film.

HL 14.2 Mon 9:45 ER 164

Growth and electrical characterization of c-BN/ZnO-heterostructures — •Marc Brötzmann, Hayo Zutz, Anne-Katrin Nix, Carsten Ronning, and Hans Hofsäss — II. Physikalisches Institut, Universität Göttingen, Germany

In this work we investigated the conduction mechanism of c-BN/ZnO-heterostuctures. For this purpose several c-BN-films with various thicknesses between 80nm and 250nm were grown on ZnO-substrates using Mass Separated Ion Beam Deposition (MSIBD). The parameters during deposition were 450eV substrate-bias and a temperature of 250-300°C. After deposition the BN-thin-films were characterized by in-situ XPS- and EELS as well as ex-situ FTIR-measurements followed by an electrical measurement of each sample. Furthermore, the structure of grown c-BN films was investigated by transmission-electron-microscope (TEM)-measurements. In addition the effect of photon-irradiation on the samples was investigated by performing several photo current measurements at various light intensities. We will discuss the effect of the layered structure of c-BN-thin-films on the conduction mechanism and the results of photo-current-measurements of the c-BN/ZnO-heterostuctures.

HL 14.3 Mon 10:00 ER 164

Anisotropic light emission of single CdSe/CdS tetrapods due to asymmetric electron localization — •Thomas Limmer[1], Christian Mauser[1], Enrico Da Como[1], Andrey Rogach[1], Dmitri V. Talapin[2], and Jochen Feldmann[1] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität München, Munich, Germany — [2]Department of Chemistry, University of Chicago, Chicago, IL, USA

We have recently reported on highly luminescent CdSe/CdS tetrapod heterostructures, where wurtzite CdS arms were grown on CdSe zinc-blend nuclei [1]. Due to the peculiar energy band alignment the holes remain trapped in the CdSe core, whereas electrons in ideal tetrapods are expected to delocalize symmetrically into the four CdS arms. However, polarization dependent photoluminescence experiments on single tetrapods show asymmetric localization effects for electrons. Whereas in optical excitation nearly no polarization anisotropy is observed, high polarization degrees are present in the emission process. Calculations based on the effective mass approximation show that the electron wavefunction confinement is very sensitive to changes in the shape of the tetrapods. Breaking the symmetry by increasing the thickness of one arm gives rise to a strongly asymmetric localization of the electron and leads to high polarization degrees in emission. The related decrease in electron-hole wavefunction overlap results in a correlation between emission intensity and polarization anisotropy in agreement with our experimental findings. [1] D. V. Talapin et al., Nano Lett. 7, 2951 (2007)

HL 14.4 Mon 10:15 ER 164

Tunneling spectroscopy of a p-i-n diode interface — Sebastian Loth[1], •Martin Wenderoth[1], Karen Teichmann[1], Jan Homoth[1], Karolin Löser[1], Rainer G. Ulbrich[1], Stefan Malzer[2], and Gottfried H. Döhler[2] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Universität Erlangen-Nürnberg, Max-Planck-Research Group, Institute of Optics, Information, and Photonics, Germany

The performance of modern semiconductor devices is largely influenced by the spatial distribution of dopants in the device's active region on the nanoscale. Since the late 80's Scanning Tunneling Microscopy (STM) was employed to study the local properties of p-n interfaces [1]. Most studies were carried out on p-n superlattices allowing the investigation of intrinsic features accessible without applied bias across the diode.

Here, a single GaAs p-i-n diode heterostructure is investigated with Cross-Sectional STM (X-STM) in a three-terminal configuration. External source and drain contacts control the electric field across the junction. Then, the diode's active region is mapped with atomic resolution. Local I(V)-spectroscopy (STS) directly resolves the band edge alignment from p to n for different diode bias conditions. The effect of the external electric field on the spatial and spectral images of individual dopant atoms in the active layer is discussed.

This work was supported by the DFG-SPP 1285 and the German National Academic Foundation.

[1] P. Muralt et al., Appl. Phys. Lett. 50, 1352 (1987).

HL 14.5 Mon 10:30 ER 164

PLD growth of ZnO resonators based on all-oxide Bragg reflectors — •Helena Hilmer, Jan Sellmann, Chris Sturm, Rüdiger Schmidt-Grund, Holger Hochmuth, Jesús Zúñiga Pérez, Gregor Zimmermann, Jörg Lenzner, Christian Czekalla, Gabriele Benndorf, Michael Lorenz, Bernd Rheinländer, Anatoli Serghei, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

High quality microcavities are crucial for reaching strong coupling of excitons and photons (exciton-polaritons) and finally to obtain a Bose-Einstein condensate of exciton-polaritons. For this, high reflective mirrors and a cavity with smooth interfaces are necessary. Furthermore, the active medium should be distinguished by a narrow linewidth of the optical emission. For this purpose, ZnO-based microcavity resonators are promising systems.

Planar resonators with ZnO as cavity material and active medium

embedded between ZrO_2/Al_2O_3 Bragg reflectors have been grown on c-plane sapphire substrates by means of pulsed laser deposition. For the Bragg reflectors reflectivity values up to 99.8% at 3.3 eV and smooth interfaces (R_a = 0.5 nm) have been achieved. The structural and optical quality, i.e. smooth interfaces and narrow exciton linewidth, of the ZnO-layer are still a challenge. We discuss the influence of deposition rates, formation of a thin nucleation layer as well as replacing ZrO_2 by YSZ on the properties of the cavity. The optical properties were analysed by spectroscopic ellipsometry and photoluminescence. The structural properties were examined by means of AFM and XRD.

HL 14.6 Mon 10:45 ER 164

Influence of barrier thickness on AlInN/AlN/GaN heterostructure properties — •Lars Rahimzadeh Khoshroo[1], Christof Mauder[1], Ian Booker[1], Wanjiao Zhang[1], Daniel Wamwangi[2], Herbert Horn-Solle[3], Joachim Woitok[4], Matthias Wuttig[2], Andrei Vescan[1], Michael Heuken[1,5], Holger Kalisch[1], and Rolf Jansen[1] — [1]Institut für Theoretische Elektrotechnik, RWTH Aachen, Kopernikusstr. 16, 52074 Aachen — [2]Institute of Physics (1A), RWTH Aachen, Templergraben 55, 52056 Aachen — [3]Lehrstuhl für Lasertechnik, RWTH Aachen, Steinbachstr. 15, 52074 Aachen — [4]PANalytical B.V., P.O. Box 13, 7600 AA ALMELO, The Netherlands — [5]AIXTRON AG, Kackertstr. 15-17, 52072 Aachen

We report on four AlInN/AlN/GaN heterostructures on sapphire substrates with different grown in an AIXTRON metal organic vapor phase epitaxy reactor. High resolution X-Ray diffraction showed 15%In content and X-Ray reflection (XRR) measurements allowed a reliable thickness determination. However, the sample with the thinnest AlInN barrier thickness of 3.2 nm yielded no Hall results due to an increase of sheet resistivity from 372 Ω/* immediately after epitaxy, to 972 Ω/* two weeks later. This increase weakens with increasing barrier thickness. The samples with 4.2 nm, 7.1 nm and 9.3 nm barrier thickness yielded average charge carrier densities and average mobilities (ordered by increasing thickness) of 0.89 x 1013 cm-2, 1.45 x 1013 cm-2, 1.78 x 1013 cm-2 and 1510 cm2/Vs, 1410 cm2/Vs, 1550 cm2/Vs. We assume a stronger detrimental influence on the charge carrier concentration by a changing surface potential at low barrier thicknesses.

HL 14.7 Mon 11:00 ER 164

MOVPE Wachstum und Charakterisierung von AlInN HFET Strukturen — •Christoph Hums, Aniko Gadanecz, Armin Dadgar, Jürgen Bläsing, Thomas Hempel, Hartmut Witte, Annette Diez, Jürgen Christen und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

AlInN / GaN Heterostrukturen werden heute für unterschiedliche elektronische (HFET, Sensoren) und opto-elektronische (RCLED, VCSEL) Bauelemente eingesetzt. Dabei wird zumeist die Möglichkeit genutzt, dass AlInN bei einem Indiumanteil von 17,4% gitterangepasst auf GaN wächst und dadurch verspannungsfreie Strukturen realisiert werden können. Über die Wachstumsbedingungen und die Eigenschaften von $Al_{1-x}In_xN$ mit x > 0,18 ist dagegen wenig bekannt. Das Wachstum ist wegen der unterschiedlichen Wachstumsparameter von AlN und InN eine Herausforderung. In dieser Arbeit wird das MOVPE Wachstum von $Al_{1-x}In_xN$ in einem weiten Konzentrationsbereich ($0{,}09 < x < 1$) beschrieben und die Eigenschaften des ternären Halbleiters mit HR-XRD, AFM und FEREM Messungen untersucht. Es kann gezeigt werden, dass die Mischungslücke kleiner ist als durch theoretische Berechnungen prognostiziert. Die kritische Schichtdicke für pseudomorphes Wachstum wurde in einem Mischungsbereich von $0{,}09 < x < 0.34$ ermittelt. Auf Grund der spontanen- und piezoelektrischen Polarisation wird für x > 0.3 an der Grenzfläche zwischen AlInN und GaN ein 2D Löchergas erwartet, welches aber mit Hall-Effekt Messungen bislang nicht nachgewiesen werden konnte. Es werden verschiedene mögliche Gründe für die Abwesenheit des 2DHG diskutiert.

HL 15: Devices

Time: Monday 11:15–13:00 Location: ER 164

HL 15.1 Mon 11:15 ER 164

Disposable DotFET: Overlay requirements and the accuracy of E-Beam lithography on structures defined by optical lithography — •J. Moers[1], J. Gerharz[1], G. Mussler[1], L.K. Nanver[2], and D. Grützmacher[1] — [1]IBN and CNI, Research Center Jülich, 52425 Jülich, Germany — [2]DIMES, Delft Technical University, Feldmannweg 17, 2628 CT Delft, The Netherlands

Strained silicon enhances carrier mobility and therefore has drawn increasing attention for application in MOSFET devices. While wafer size processes for SiGe pseudosubstrates need either thick epitaxial layers or sophisticated processing, the ordered growth of Ge dots only needs a simple prepatterning of the substrate. In a self organized growth on a prepatterned substrate the Ge dots will grow in the etched seedholes, only. Onto these substrates a silicon capping layer is grown, which will be strained only on top of the Ge dots.

To utilize the strain it is indispensable to align the active area of the device on the Ge dot. In the European project D-DotFET the seedholes are defined by optical lithography, while for critical overlay steps, such as the source and drain extensions and the gate, e-beam lithography is used. To ensure an accurate overlay it is necessary to investigate the single components for their overlay accuracy and the accuracy of the interplay of the components. Furthermore it has to be examined, if the influence of the process will hamper the overlay accuracy.

Results for the overlay accuracy for the D-DotFET process show that the requirements can be fulfilled by using a proper marker layout and a process, which will conserve the markers.

HL 15.2 Mon 11:30 ER 164

SnO_2-nanostructures for gas sensing applications — •Alexandra Tischner[1], Anton Köck[1], Thomas Maier[1], Michael Kast[1], Christoph Stepper[1], Judith Januschewsky[2], Christian Edtmaier[2], Christian Gspan[3], and Gerald Kothleitner[3] — [1]Austrian Research Centers GmbH - ARC, Nano-Systemtechnologien, Wien, Österreich — [2]Institut für Chemische Technologien und Analytik, Nano-Werkstoffe, Technische Universität Wien, Österreich — [3]Zentrum für Elektronenmikroskopie, Graz, Österreich

Gas sensors based on nanocrystalline SnO_2 films and single-crystalline SnO_2-nanowires have been developed. The films with a thickness of 30-100 nm are fabricated by a spray pyrolysis process on SiO_2-coated Si-substrates and processed in arrays of parallel bars, which are connected on both ends by ohmic metal contacts. The operating mode is based on a change in the electrical conductance along the SnO_2-bars due to reducing or oxidizing gases. The sensors are operated at 200-400°C, show high sensitivity to humidity and are able to detect CO down to a concentration of 5 ppm. The SnO_2-nanowires are fabricated by tempering 150-300 nm thick SnO_2 films at temperatures of 800-1000°C. This process results in growth of SnO_2-nanowires with 30-400 nm diameter and length up to several 100 μm. TEM analysis proves the single crystallinity of the nanowires. The SnO_2-nanowires are deposited on SiO_2-coated Si-substrates and contacted by means of photolithography. Investigations of the sensor performance of nanowires in comparison to nanocrystalline SnO_2 films are in progress.

HL 15.3 Mon 11:45 ER 164

Si-based vertical MOSFETs for high temperature applications — •Peter Iskra, Thomas Zilbauer, Dorota Kulaga-Egger, Martin Schlosser, Torsten Sulima, and Iganz Eisele — Universität der Bundeswehr München, Werner-Heisenberg Weg 39, 85579 Neubiberg

The operation of a MOSFET at high temperatures is limited by the collapse of the pn-junctions due to the increase of intrinsic carriers. High doping concentrations may extend the temperature range, but the reduced space charge zone leads to Zener tunnelling. Isolating the channel by two intrinsic zones ($n^+ip^+in^+$-structure for n-channel MOSFET) decrease the tunnelling probability and furthermore allows the use of higher doping concentrations.

A commercial LPCVD-system was used for the deposition of $n^+ip^+in^+$-structures, characterized by SIMS. For IV-measurements the epitaxy stacks were structured using reactive ion etching, passivated and metalized. Leakage currents were compared to a standard $n^+p^+n^+$-structure at different temperatures. First attempts have been

made for an application of the $n^+ip^+in^+$ stack in vertical MOSFETs.

HL 15.4 Mon 12:00 ER 164

Carbon Nanotube Field-Effect Transistors Probed by — •Eduardo Lee, Kannan Balasubramanian, Marko Burghard, and Klaus Kern — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569, Stuttgart

Carbon nanotube field-effect transistors (CNFETs) have attracted substantial interest due to their potential use in (opto)-electronics. For instance, CNFETs have been shown to display photoconductivity, thus being interesting for light detecting devices. On the other hand, despite the rapid development on the understanding and performance of CNFETs, several issues are still to be investigated in more detail, such as the carbon nanotube (CNT)-metal interfaces, and the spatial origin of their photoconductive response. Scanning photocurrent microscopy (SPCM) has been shown to be a potentially powerful tool to characterize CNFETs. Strong photocurrent responses are typically observed at the contacts, resulting from the Schottky barriers. Moreover, the ability to spatially resolve the photocurrent responses, enables the investigation of CNT photoconductivity in more detail.

This contribution reports on SPCM characterization of field-effect transistors based on CNTs. Photocurrent images are obtained for zero and non-zero drain-source biases. It is demonstrated that the close relationship between the photocurrent response and the local electric field, enables the mapping of the electrostatic potential profile through SPCM characterization. Finally, it is shown that the photoconductive response does not occur homogeneously within the device.

HL 15.5 Mon 12:15 ER 164

Towards an electrically driven single photon source — •Christian Jendrysik, Roland Enzmann, Daniela Baierl, Christian Seidel, Andreas Heindl, Silvan Türkcan, Gerhard Böhm, Ralf Meyer, Jonathan Finley, and Markus-Christian Amann — Walter Schottky Institute, Am Coulombwall 3, D-85748 Garching, Germany

To realize applications like quantum cryptography electrically driven, efficient single photon sources are necessary. We present a concept of an electrically driven, quantum dots based single photon device, which is furthermore compatible with a high quality resonator like a photonic crystal and should therefore allow high extraction efficiencies.

The quantum dots are pumped optically via a light emitting diode (LED) which is monolithically integrated underneath the quantum dot layer. The wavelength of the photons emitted by the LED can be adjusted to resonant or non-resonant excitation of the quantum dots. For high efficiency it is necessary to shift the emission of the quantum dots into the mode of the photonic crystal. This can be done by a Schottky contact in reverse bias. Thus an electrical field at the location of the quantum dots can be generated which leads to a red shift of the emission because of the quantum confined stark effect. Hence the wavelength of the quantum dots can be modified independently of the pumping process. First measurements show the feasibility of our concept to realize a single photon device.

HL 15.6 Mon 12:30 ER 164

InGaN MQW laser diodes with cleaved facets on sapphire and bulk GaN substrates — •J. R. van Look[1], S. Einfeldt[2], V. Hoffmann[2], A. Knauer[2], 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

The development of AlInGaN based diode lasers has gained tremendous interest due to various applications ranging from optical data storage to laser displays. For reasons of cost and availability, nitride based laser diodes are commonly grown on c-plane sapphire substrates. However, the misalignment between the sapphire and GaN cleave planes typically leads to the formation of steps and terraces in the laser facets, resulting in a deterioration of the laser performance. In this talk we will present a novel method in order to reproducibly obtain high quality facets for lasers grown on (0001) sapphire substrates. Based on a laser scribing process we were able to fabricate gain-guided laser diodes with smooth facets which showed threshold current densities of 7.5 kA/cm^2 at an emission wavelength of 405 nm. Furthermore, we transferred this technique to lasers grown on bulk GaN substrates which reduced the threshold current density to 4.5 kA/cm^2. A comparison of the performance characteristics of these laser diodes including threshold current densities, emission spectra and differential quantum efficiency will be provided.

HL 15.7 Mon 12:45 ER 164

Electrical characterization of SONOS-structures for non-volatile memories — •Matthias Allardt[1], Jörg Weber[1], and Andreas Bemmann[2] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]X-FAB Dresden GmbH & Co. KG, 01109 Dresden, Germany

Silicon-oxide-nitride-oxide-silicon layers (SONOS) in the form of MOS-capacitors and MOS-transistors are investigated. The oxide/oxynitride films are deposited by chemical vapor deposition. Both the film thickness and the deposition parameters are varied. The devices are characterized by temperature- and time-dependent capacitance–voltage-measurements and current–voltage measurements. In particular, we have verified the memory effect of the structures. The data retention was studied to characterize the storage traps and to analyze the dominant discharge mechanism. The results show that the discharge depends almost logarithmically on time and is temperature-dependent. From our investigations it is evident that several mechanisms influence the discharge process. At present, only a qualitative characterization of the defects is possible.

HL 16: Quantum dots and wires: Optical properties I

Time: Monday 14:00–17:15 Location: ER 164

HL 16.1 Mon 14:00 ER 164

Optical properties of electrically pumped CdSe quantum dot structures — •Thomas Meeser, Joachim Kalden, Kathrin Sebald, Jürgen Gutowski, Arne Gust, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P. O. Box 330 440, 28359 Bremen, Germany

CdSe quantum dots (QDs) embedded into MgS barriers possess a high potential as active material for single photon emitters working at room temperature in the green spectral region because of the enhanced confinement of the carriers leading to an improved luminescence stability. We will present micro-electroluminescence (μ-EL) measurements on a resonant-cavity light emitting diode (RCLED) which was grown by molecular beam epitaxy containing an active region consisting of self-assembled CdSe QDs in a cavity and a distributed Bragg reflector. In this presentation we will focus on integrated μ-EL intensity measurements of the QD ensemble and single-QD emission lines in dependence on the applied voltage and sample temperature. The comparison of the results achieved for single QDs leads to an estimate of the sample temperature at the position of the active region during LED operation. In addition, we will compare these results to micro-photoluminescence measurements which were performed at the same sample position including the discussion of the change of PL characteristic by the variation of the external electric field.

HL 16.2 Mon 14:15 ER 164

Triggered polarization-entangled photon pairs from a single quantum dot up to 30 K — •Robert Hafenbrak[1], Sven M. Ulrich[1], Peter Michler[1], Lijuan Wang[2], Armando Rastelli[3], and Oliver G. Schmidt[3] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße1, 70569 Stuttgart — [3]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden

The radiative biexciton-exciton decay in (In,Ga)As semiconductor quantum dots has the potential of being a source of triggered polarization-entangled photon pairs. However, this entanglement is in general reduced by the anisotropy-induced exciton fine structure splitting. Here we present measurements (1) on improved quantum dot structures, providing both significantly reduced inhomogeneous

emission linewidths and near-zero fine structure splittings. A high-resolution detection technique is introduced which allows us to accurately determine the fine structure in the photoluminescence emission and therefore select appropriate quantum dots for quantum state tomography. We were able to verify the conditions of entangled or classically correlated photon pairs in full consistence with observed fine structure properties. Furthermore, we demonstrate reliable polarisation-entanglement for elevated temperatures up to 30 K. The fidelity of the maximally entangled state decreases only little from 72% at 4 K to 68% at 30 K.

(1) Hafenbrak et al., New J. Phys. 9 (2007) 315

HL 16.3 Mon 14:30 ER 164

Tailoring of mode-locking by shaping laser pulse sequencies — •Stefan Spatzek, Alex Greilich, Dmitri Yakovlev, and Manfred Bayer — Experimentelle Physik II, Technische Universität Dortmund, D-44221 Dortmund, Germany

Electron spins in ensembles of quantum dots (QDs) provide an attractive proposal to implement quantum information technologies in a solid-state environment. Unfortunately, inhomogeneities within an ensemble lead to the rapid loss of coherence among the phases of the spins.

We report about the mode-locking effect on InGaAs/GaAs QDs, dependent on the temporal pulsewidth at different magnetic fields in a range of 150 - 800 fs measured by time-resolved Faraday rotation. A periodic train of circularly polarized light pulses of mode-locked laser synchronizes the precession of the spins to the laser repetition rate, transferring the mode-locking into the spin system [1]. We have proved, that the mode-locking effect is more pronounced by longer excitation pulses, due to decreasing of the spectral width of the pulse. In the excited inhomogeneous QDs ensemble one observes the spin precessions on different frequencies. Therefore, with decreasing of the spectral pulsewidth one excites smaller distribution of the QDs, that lead to the longer dephasing of the QD ensamble.

[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).

HL 16.4 Mon 14:45 ER 164

Controlled Optical Charging of Single InGaAs Quantum Dots — •Dominik Heiss, Vase Jovanov, Max Bichler, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, Garching, Deutschland

We propose an all optical spin readout concept for individual electron spins in single self assembled quantum dots (QDs). By employing the spin-conditional absorption of a circularly polarized light pulse tuned to the X^{-1} absorption line, we propose to convert the spin information of the resident electron to charge information. Subsequent nonresonant photoluminescence (PL) then directly reveals the charge state of the quantum dot and, therefore, the spin orientation of the resident electron. We have applied time gated PL to confirm that efficient optical charging and non invasive measurement of the charge state can be performed in the same dot. The structures investigated are n-Schottky photodiodes with a dilute ensemble of $In_{0.5}Ga_{0.5}As$ QDs in the intrinsic region. A 20 nm $Al_{0.3}Ga_{0.7}As$ barrier below the dot layer inhibits electron tunnelling escape, whilst holes are efficiently removed when a high electric field ($|E| > 20$ kV/cm) exists in the intrinsic region. This leads to electron accumulation and X^{-n} transitions are prominent in the readout phase of the measurement and our results are in good agreement with a rate equation model of the optical charging process. In contrast, for $|E| < 20$ kV/cm the optical charging rate becomes very low ($\sim 390 s^{-1} W^{-1} cm^2$) demonstrating that the charge and spin state of the dot can be tested via PL over millisecond timescales, without altering it.

HL 16.5 Mon 15:00 ER 164

Hot trion and excited exciton states of single InGaAs/GaAs quantum dots — •Elisabeth Siebert, Till Warming, and Dieter Bimberg — TU Berlin, Institute of Solid State Physics, Sekr. EW 5-2, Hardenbergstr. 36, D-10623 Berlin, Germany

For a detailed understanding of the electronic structure of self-organized quantum dots (QDs) high-resolution measurements that reveal the spectrum of excited states are essential. Here, polarized photoluminescence excitation (PLE) spectra of the positive trion and the exciton of a number of MBE-grown single InGaAs/GaAs QDs were recorded and compared to results of 8-band k·p calculations.
The exciton and trion absorption spectra comprise two characteristic parts. ΔE=60 meV above the ground state energy exists a quasi continuous band of absorption features. The corresponding transitions involve hybrid states of QDs and wetting layer. In our study we concentrate on the regime below ΔE=60 meV where the PLE spectrum of the exciton consists of well separated sharp resonances, corresponding to absorptions into excited exciton states, and a broad resonance around 35 meV due to exciton-phonon coupling. Upon adding a positive charge carrier, the PLE spectrum has a more complex structure due to the singlet-triplet splitting of the hot trion states. The sharp resonances, of both trion and exciton show clear dependence on linearly or circularly polarized excitation and detection. Moreover the spectra of different dots, detected on the ground state energy of the same excitonic complex, reveal substantial similarities. This work is partly funded by SANDiE NoE, contr. no. NMP4-CT-2004-500101.

HL 16.6 Mon 15:15 ER 164

Excitonic dynamics in II-VI quantum rods — •Alexander W. Achtstein, Björn Möller, Andrew Ebbens, and Ulrike Woggon — Institute of Physics, Technical University of Dortmund, D-44221 Dortmund, Germany

Highly luminescent colloidal II-VI semiconductor nanorods of large aspect ratio and diameters within the semiconductors exciton Bohr radius are studied by spatially and time-resolved spectroscopy. The influence of rod thickness variation for constant rod aspect ratio is investigated with respect to excitonic confinement and exciton dynamics. High resolution PL measurements show the existence of an excitonic fine structure inside the rods. Possible reasons for its appearance will be discussed. Temperature dependent cw and time resolved PL measurements are conducted to study the influence of this 1D confinement on the electronic structure of these nanowires. Ultrafast dynamics shows, that deexcitation is mainly provided by two competing relaxation channels. The fast one in the 100ps regime can be attributed to nonradiative processes, whereas the slow one, with time constants of about 1ns, can be assigned to the radiative lifetime, which is much longer than the radiative lifetime for bulk II-VI materials.

15 min. break

HL 16.7 Mon 15:45 ER 164

Nonlinear Optical Microscopy of a Single Self-assembled InGaAs Quantum Dot — •Claudia Ruppert[1], Markus Wesseli[1], Emily C. Clark[2], Jonathan J. Finley[2], and Markus Betz[1] — [1]Physik-Department E11, TU München — [2]Walter Schottky Institut and Physik-Department E24, TU München

Semiconductor quantum dots (QDs) exhibit exciting prospects for solid state qubits. Here we present the first ultrafast all-optical scheme for manipulation and read-out of a single QD and, thereby, pave the way towards a variety of such quantum coherent studies [1].

A single InGaAs/GaAs QD is isolated by an aluminum shadow mask of 450 nm diameter. Optical excitation and read-out is achieved in a nondegenerate pump-probe scheme. Carriers are generated in the wetting layer beneath the QD with a 100 fs pump pulse and captured into the QD. The excitation induced transmission changes are analyzed over a broad range of probe wavelengths and various delay times. In particular, we identify signatures of the single exciton transition at $E_X = 1.374\ eV$ and transitions of several multi-exciton complexes. These bleaching signals are in the order of $\Delta T/T \sim 10^{-5}$ and reveal a picosecond dynamics likely related to intra-QD carrier relaxation.

In the next step, we will analyze QDs with excitonic transitions around 1.3 eV which are characterized by a larger confinement potential and better optical quality. To this end, we have developed a novel femtosecond Ti:Sapphire oscillator that, remarkably, provides ∼30 fs pulses tunable to wavelengths as long as 970 nm.

[1] M. Wesseli et al., Appl. Phys. Lett. **88**, 203110 (2006).

HL 16.8 Mon 16:00 ER 164

Optical properties of InGaN quantum dot stacks — •Joachim Kalden, Henning Lohmeyer, Kathrin Sebald, Thomas Meeser, Jürgen Gutowski, Christian Tessarek, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

In the blue to UV spectral region InGaN quantum dots (QDs) are an up-and-coming material system. Beside research concerning the fundamental properties of these QDs, it is necessary to increase the QD density for laser applications. Hence samples with multiple QD layers are characterized to investigate the influence of stacking on the optical

properties. Therefore, we compare micro-photoluminescence (μ-PL) measurements of single and stacked QD layers grown by metal-organic vapor phase epitaxy. The optical emission properties are discussed with respect to polarization and temperature, respectively. In contrast to the single QD layer, no sharp emission lines can be found for the unstructured stacked layers. Their ensemble PL band is easily traceable up to room temperature. To prove the QD origin of these samples mesa structures are prepared by focused-ion-beam etching. As expected, for decreasing mesa diameter the broad emission band of the QD ensemble splits up and individual sharp emission lines can be observed. Their characteristics are comparatively discussed with the results achieved from the single QD layer samples. Additionally, gain measurements on single QD layers and QD stacks will be discussed.

HL 16.9 Mon 16:15 ER 164

High-fidelity all-electrical preparation of spin-polarized electrons in single InAs quantum dots — •W. Löffler[1,3], J. Müller[1], H. Flügge[1], C. Mauser[1], S. Li[2,3], T. Passow[1,3], P. Asshoff[1,3], M. Hetterich[1,3], and H. Kalt[1,3] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]Institut für Hochfrequenztechnik und Quantenelektronik, Universität Karlsruhe (TH) — [3]DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe, Germany

Electrical spin-injection devices provide a unique way to prepare spin-polarized electrons in many separated semiconductor quantum-dots at the same time. Using a semimagnetic spin-polarizer like ZnMnSe, the electron spin polarization can easily be prepared to unity. We have shown that these electrons can be injected into InAs quantum dots preserving the polarization. Here, we present recent investigations to enhance the spin-polarization at low magnetic fields and to study the temporal dynamics in these devices. We implemented and optimized the growth of high-quality ZnMnSSe spin-aligner layers and established time-resolved electroluminescence measurements.

HL 16.10 Mon 16:30 ER 164

Optical emission from spin singlet and triplet few electron states of a self-assembled quantum dot molecule — •Emily C. Clark[1], Christoph Scheurer[2], Hubert Krenner[1], Max Bichler[1], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, Technical University of Munich, 85748 Garching, Germany — [2]Lehrstuhl für Theoretische Chemie, Technische Universität München, 85748 Garching, Germany

We report magneto-optical investigations of coupled exciton states in individual quantum dot molecules. The samples investigated consist of a single pair of vertically stacked, self assembled In0.5Ga0.5As dots, embedded into the intrinsic region of an n-type GaAs Schottky photodiode.[1] This structure allows us to tune the electric field along the growth axis, switch on an off coupling between the molecular states and controllably add electrons to the molecule. In the absence of a magnetic field a series of characteristic crossings and anti-crossings are observed in the emission spectrum, as neutral and charged exciton states in the dots couple and form molecular orbitals.[2] The magnetic field is shown to mix the s- and p-orbital states in each dot, giving rise to anti-crossings due to hybridization of the mixed s-p orbital states. From our measurements, we deduce the coupling strengths of the mixed states as a function of the magnetic field and extract information about the molecular electronic structure. Our experimental findings will be compared with calculations of the negatively charged exciton states subject to magnetic fields.[1] Krenner et. al Physical Review Letters, 94, 057402, 2005 [2]Krenner et. al Phys. Rev. Lett. 97, 076403, 2006

HL 16.11 Mon 16:45 ER 164

Carrier relaxation in quantum dots by means of time resolved transmission in two color pump probe experiments — •Hannes Kurtze[1], Robert Heinle[1], Manfred Bayer[1], Jan Seebeck[2], Frank Jahnke[2], Dirk Reuter[3], and Andreas Wiek[3] — [1]Experimentelle Physik Universität Dortmund, D-44221 Dortmund, Germany — [2]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen, Germany — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Systematic time-resolved pump-probe studies with independent variation of pump and probe energies have been performed on InAs/GaAs quantum dot samples covering a wide range of confinement parameters. From these studies a phonon bottleneck for carrier relaxation can be excluded for small delay times after pump excitation. The use of time resolved transmission instead of time resolved photoluminescence offers also the opportunity to observe optically inactive carrier populations and their dynamics. Typical results of such measurements will be given in this talk.

HL 16.12 Mon 17:00 ER 164

Electrical injection and optical probing of spins in a single quantum dot — •Tilmar Kümmell[1], Mohsen Ghali[1], Robert Arians[1], Jan Wenisch[2], Karl Brunner[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Experimentelle Physik III, Universität Würzburg, D-97074 Würzburg

In order to use the spin as an information carrier, mechanisms for injection, storage and readout of a single spin are required. We use InAs quantum dots, known for spin relaxation times up to th ms regime, in combination with a diluted magnetic semiconductor (ZnMnSe) that has been proven to be an efficient source of spin polarized carriers. P-i-n-structures allow us to realize both polarized single dot emitters and single spin storage devices.

In the single dot emitter, a spin polarized electron injected from the n-ZnMnSe spin aligner recombines in a single InAs quantum dot with a hole coming from p-GaAs. This results in a significantly polarized electroluminescence from a single quantum dot. Polarization degrees of more than 35% are reached at B=4T, showing an efficient spin injection into the single quantum dot. Similar p-i-n structures are used for electrical charging of a single dot with spin-polarized electrons. Optical probing of a charged single dot using micro-magnetoluminescence exhibits a characteristic polarization pattern of both trionic and excitonic recombination lines. We show that this pattern reflects the polarization of the initially injected electron and can therefore in principle be used for a readout process of a single spin.

HL 17: Poster I

Time: Monday 16:30–19:00 Location: Poster D

HL 17.1 Mon 16:30 Poster D

Infrared spectroscopy on the fullerene C_{70} under pressure — •Komalavalli Thirunavukkuarasu[1], Christine.A. Kuntscher[1], Ferenc Borondics[2], Gyöngyi Klupp[2], and Katalin Kamarás[2] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, P.O.Box 49, Budapest, Hungary H 1525

C_{70} is the most commonly occurring higher order fullerene next to C_{60}. Although several experimental investigations have been performed on this compound, the properties of C_{70} is not yet well understood. On cooling, C_{70} undergoes two orientational ordering transitions, one at 350 K and the other at 280 K which are accompanied by structural phase change [1]. The pressure-induced orientational ordering in C_{70} is expected around 1 GPa [2]. For a better understanding of the pressure-induced phenomena in C_{70} we carried out pressure-dependent transmittance measurements on pure C_{70} compound over a broad frequency range (400-22000 cm^{-1}) for pressures up to 10 GPa. The pressure-induced changes in the vibrational modes and the shift of the electronic absorption edge with increasing pressure are reported. *Supported by the DFG.*

[1] G. B. Vaughan et al., Chem. Phys. **178**, 599 (1993).
[2] H. Kawamura et al., J. Phys. Chem. Solids **54**, 1675 (1993).

HL 17.2 Mon 16:30 Poster D

Ionization potentials of the first members of the nanodiamond series — •Lasse Landt[1], Kathrin Klünder[1], Konstantin Lenzke[1], Trevor Willey[2], Tony van Buuren[2], Jeremy Dahl[3], Robert Carlson[3], Thomas Möller[1], and Christoph Bostedt[1] — [1]Technische Universität Berlin, Germany — [2]Lawrence Livermore National Laboratory, USA — [3]MolecularDiamond Technologies, USA

We experimentally determined the ionization potentials of small hydrogen-passivated nanodiamonds, so-called diamondoids. Diamondoids can be considered the smallest possible cage-like subunits that can be excised from diamond lattice closing the gap between large hydrocarbon molecules and nanodiamonds. Ranging in size from 0.5 to 1 nm, they can be perfectly size- and shape-selected. Ionization potentials were measured using total ion-yield spectroscopy. All data were taken from neutral, high purity samples in the gas phase yielding unprecedented comparability to theoretical predictions. The experimental ionization potentials for this new interesting class of nano-carbon materials is compared to theoretical predictions.

HL 17.3 Mon 16:30 Poster D

Fibre reinforced carbon aerogels for application as electrochemical double layer capacitors — •Henning Lorrmann[1], Volker Lorrmann[1], Ingo Riedel[1,2], Carsten Deibel[2], Gudrun Reichenauer[1], Matthias Wiener[1], and Vladimir Dyakonov[1,2] — [1]Bavarian Center for Applied Energy Research (ZAE Bayern), Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg, Germany — [2]Experimental Physics VI, Physical Institute, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg

Fibre-reinforced carbon aerogels have been prepared from resorcinol-formaldehyde (RF) for application as electrodes in electrochemical storage devices. Fibres allow ambient pressure drying without solvent exchange even for a molar ratio of resorcinol to catalyst as low as five. Accordingly, shrinkage of the precursor-aerogels during drying-process is not critical. Electrochemical properties have been investigated by means of impedance spectroscopy, cyclic voltammetry and galvanostatic charge/discharge cycles. Capacities of up to $200 F/g$ have been reached. The Ragone-plot, calculated from the impedance-data, exhibits high power densities even for high energy densities due to high specific capacitance (energy) as well as low internal resistance (power). N_2-sorption measurements reveal large micropore volumes. However, specific surface (area per mass) is relatively low compared to bulk aerogels, as fibers contain little surface. The particle size can be adjusted by variation of the resorcinol-to-catalyst-ratio, whereas the density mainly depends on the ratio of RF to the total mass.

HL 17.4 Mon 16:30 Poster D

Non-Oriented and Oriented Protein Immobilization on Diamond Surfaces — Simon Quartus Lud[1], •Philipp Sebastian Koch[1], Florian Spirkl[1], Rainer Jordan[2], Paola Bruno[3], Dieter M. Gruen[3], Jose A. Garrido[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Materials Science Department, Argonne National Laboratory, Argonne, Illinois 60439, USA — [3]Chemistry Department, Technische Universität München, Lichtenbergstr. 4, 85748, Garching, Germany

Interfacial molecular assemblies play an important role for applications in all fields of biosensor design. Due to its numerous remarkable material properties, like its extreme stability, large electrochemical window and good biocompatibility, diamond is a very attractive candidate for chemical and biochemical sensing. We discuss various methods for the immobilization of proteins on a diamond substrate. More specifically, we report on random and oriented modes of binding to ultrananocrystalline diamond (UNCD) surfaces. Diamond thin films are first modified by pure chemical grafting of benzene diazonium salts with functional headgroups. AFM, XPS, electrochemical CV, and NEXAFS spectroscopy have been used to verify the direct covalent attachment of the aromatic molecules. The results confirm the presence of a very stable, homogeneous, and dense monolayer for both headgroups.

HL 17.5 Mon 16:30 Poster D

Selective growth and treatment of carbon nanotubes on various substrates — •Philipp Zeigermann, Hans Kleemann, Manuela Janietz, Mathias Steglich, and Bernd Schröter — Universität Jena, Institut für Festkörperphysik, Max-Wien-Platz 1, 07743 Jena, Deutschland

A selective growth of carbon nanotubes with particular structural and electronic properties is a prerequisite to utilize them in electronic and sensor devices.

We grow single-wall nonotubes by chemical vapour deposition (CVD) using methane as precursor gas and metallic catalyst films on various substrates like silicon, fused silica and sapphire. Scanning electron microscopy, x-ray photoelectron and raman spectroscopy demonstrate the high purity of these nanotubes. A hydrogen partial pressure can favour the growth of semiconducting nanotubes. A selective effect of hydrogen and methane has also been found in plasma and thermal treatment of nanotubes. /1/ /2/.

We investigate these effects as well as the thermal treatment in vacuum and air to develope strategies to purify, select and functionalize nanotubes as well as to check their stability.

/1/G. Zhang, et al.: Selective Etching of Metallic Carbon Nanotubes by Gas-Phase Reaction Science 314 (2006) 974-977

/2/A. Hassanien, et al.: Selective etching of metallic singlewall carbon nanotubes with hydrogen plasma Nanotechnology 16 (2005) 278-281

HL 17.6 Mon 16:30 Poster D

Morphology of graphene layers deposited on various substrates — •Ulrich Stöberl, Jonathan Eroms, Ursula Wurstbauer, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

Following recent TEM studies on suspended graphene sheets, the ripple structure of graphene is believed to be an intrinsic property, influencing transport quantities, such as the minimum conductivity and the mobility of the carriers. Here, we investigate to what extent the roughness of the underlying substrate can modify the morphology of graphene layers. To this end, we have prepared single and few layer graphene samples using the mechanical exfoliation technique on standard, oxidized silicon wafers, and MBE grown GaAs and InGaAs wafers. The latter show a characteristic cross-hatched pattern with an rms roughness of about 5 nm, whereas the silicon wafers are smooth with a roughness below 1 nm. AFM investigations demonstrate that the surface of the graphene films is determined by the roughness of the underlying substrates. Furthermore this has important implications on the transport properties of the graphene film.

HL 17.7 Mon 16:30 Poster D

Untersuchung von Graphenschichten auf Siliziumkarbid mit Hilfe der Ramanspektroskopie — •Jonas Röhrl, Martin Hundhausen, Ralf Graupner, Konstantin Emtsev, Thomas Seyller und Lothar Ley — Technische Physik, Friedrich-Alexander Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Graphen, eine einzelne Graphitschicht, ist als 2-dimensionales elektronisches System von grundlegendem Interesse. Proben mit einer oder wenigen Graphenschichten werden gewöhnlich durch mechanische Exfolierung von Graphitkristallen (HOPG- highly oriented pyrolytic graphite) gewonnen. Im Unterschied dazu untersuchen wir hier Graphen, das sich auf SiC-(0001) Oberflächen als epitaktische Schicht beim Anlassen durch Verdampfen von Silizium bildet. Zur Charakterisierung von ein- bzw. mehrlagigen Graphenschichten eignen sich die G- und die 2D-Mode im Ramanspektrum. Wir zeigen, dass es systematische Unterschiede in den Ramanspektren von Monolage, Doppellage und mehreren Lagen gibt, die benutzt werden können, um die lokale Schichtdicke (Anzahl von Graphenlagen) mit optischen Methoden zu bestimmen. Für die Graphenmonolage finden wir im Vergleich zu freitragenden Graphenschichten eine deutliche Verschiebung der 2D- und G-Mode zu höheren Frequenzen. Da sich die erste Graphenlage im Kontakt mit dem SiC-Substrat befindet, führen wir diese Verhärtung der Phononen im Wesentlichen auf den Einfluss mechanischer Spannungen zurück, die während des Abkühlens aufgrund unterschiedlicher Ausdehnungskoeffizienten von SiC und Graphen entstehen. Wir diskutieren außerdem den Einfluss der Kohn-Anomalie.

HL 17.8 Mon 16:30 Poster D

Transport through multilayer graphene — •Thomas Lüdtke, Patrick Barthold, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover

We present transport measurements through thin films of graphite in dependence of backgate voltage and temperature.
The thin films of graphite are obtained by micromechanical cleavage of natural graphite similar to the technique described in Ref.[1]. An optical microscope is used to localize the graphite films that are deposited on a silicon substrate with 300nm SiO_2 layer. By using electron beam lithography we are able to contact the samples. Transport measurements were performed at temperatures between 1.4 K and 300 K. As we apply a backgate voltage we see a peak in the resistivity that we contribute to a field effect. In addition to transport measurements on flakes we present measurements on mesoscopically patterned devices.

[1] K. S. Novoselov et al., Proc. Natl. Acad. Sci. USA, vol. 102, p.10451 (2005)

HL 17.9 Mon 16:30 Poster D

Transport in antidot lattices in graphene layers — •Jonathan Eroms, Ulrich Stöberl, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We prepared antidot lattices in single and bilayer graphene sheets using electron beam lithography and reactive ion etching. The lattice period a was ranging between 140 nm and 200 nm. In single layer samples with a lattice period of 200 nm we find quantum Hall plateaus and Shubnikov-de Haas oscillations with the half-integer quantization that is commonly observed in single layer samples. We also find a pronounced weak localization peak in the longitudinal resistance. The mobility of the graphene flake was not sufficient to observe commensurability peaks of the antidot lattice. In samples with very narrow constrictions between the antidots, we observe a suppression of the conductance in a finite range of back gate voltage, *i.e.*, a gap develops.

HL 17.10 Mon 16:30 Poster D

THz detectors on the basis of HgTe-Quantum wells — •Fathi Gouider[1], Hartmut Buhman[2], Christoph Brüne[2], Günter Hein[3], and Georg Nachtwei[1] — [1]Institut of Applied Physics, Technical University of Braunschweig, Mendelssohnstr.2, D- 38106 Braunschweig — [2]Universität Würzburg EP III, Am Hubland, D-97074 Würzburg — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig,Germany

The investigations of the THz-photoresponse (PR) of devices with HgTe QWs embedded in CdHgTe barriers are aimed at obtaining photosignals at smaller magnetic fields. The QWs have a thicknes of d_{QW} =12nm, so that the material HgTe of the QW possesses a semimetallic band structure. We found an effective mass of about $m_c = 0.026m_0$ for our samples from cyclotron resonance measurements (transmission of THz waves, Voigt configuration, Ge detector). As this cyclotron mass is by about a factor 3 smaller than the one of electrons in GaAs, the same Landau level splitting as in GaAs is reached at about 1/3 of the magnetic field. In this presentation, we present measurements of the THz photoconductivity on quantum Hall systems. HgTe/HgCdTe (MCT) heterostructures with Corbino geometry are investigated. A recipe for the preparation of metallic Corbino contacts on MCT is shown. The system is excited by the radiation of a p-Ge laser (from1.7 to 2.5 THz) and the PR is measured versus the magnetic field B . Because of the lower effective mass in MCT, the cyclotron resonance(CR) in this system appears at a relatively low magnetic field $B \approx 2$ T.

HL 17.11 Mon 16:30 Poster D

Photovoltage Induced by Microwave Radiation on AlGaAs/GaAs Hall Bars — •Tobias Krohn, Nikolai Mecking, André Wirthmann, and Detlef Heitmann — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

We have investigated the photovoltage that was induced by irradiating microwaves on Hall bars containing a two dimensional electron system (2DES) in a AlGaAs/GaAs heterostructure. The dimensions of the Hall bars were in the 100 μm regime. The experiments were performed at fixed frequency in a sweep of a magnetic field B that was applied perpendicularly with respect to the 2DES. The temperature was 4.2 K.

Our set up allows us to investigate a wide frequency range from 9 GHz to 170 GHz. We observe a rich mode spectrum with modes exhibiting positive or negative B dispersions, which we can model, respectively, by confined magnetoplasmon and edge magnetoplasmon modes. Both types of modes are governed by characteristic lengths. We find that these lengths reflect the dimensions in the close vicinity of the contacts, indicating that they are the origin of the induced photovoltage.

We gratefully acknowledge support through SFB 508 and BMBF 01BM461.

HL 17.12 Mon 16:30 Poster D

FIR and MW Spectroscopy on Carbon-Doped Two-Dimensional Hole Systems — •Kevin Rachor[1], Thomas Raab[1], Carsten Graf von Westarp[1], Detlef Heitmann[1], Andrea Stemmann[1], Christian Heyn[1], Christian Gerl[2], Werner Wegscheider[2], Dirk Reuter[3], and Andreas Wieck[3] — [1]Institut für Angewandte Physik, Uni Hamburg, 20355 Hamburg — [2]Institut für Experimentelle und Angewandte Physik, Uni Regensburg, 93040 Regensburg — [3]Ruhr-Universität Bochum, 44801 Bochum

The recent development of Carbon-doped AlGaAs heterostructures on (100) substrates permits an experimental access to two-dimensional hole systems (2DHS) with high mobilities and no anisotropy [1]. Using a microwave generator and a Fourier transform spectrometer we perform both microwave and broadband far infrared transmission experiments on such samples covering a frequency range from 50 GHz to 20.000 GHz (1.67 cm^{-1} to 600 cm^{-1}). Cyclotron resonances measured in perpendicular magnetic fields up to 14 T at 1.6 K are presented here. The effective mass m* shows a strong magnetic field dependance revealing the highly non-parabolic band structure of hole systems. Surprisingly, m* depends strongly on the temperature, too. In a certain regime of the magnetic field an additional resonance, propably an intersubband resonance is detected which is possible due to a warping of the energy contour [2]. The authors are grateful to the DFG for support through SFB 508.

[1] A. D. Wieck et al. Appl. Phys. Lett. 85, 2277 (2004).
[2] E. Bangert et al. PRL 53, 493 (1984).

HL 17.13 Mon 16:30 Poster D

Towards growth on Si: Determining the offsets of Ga(N,As,P)/GaP MQW structures by optical spectroscopy — •Christian Karcher, Bernardette Kunert, Kerstin Volz, Wolfgang Stolz, and Wolfram Heimbrodt — Dept. Physics and Material Sciences Center, Philipps-University of Marburg, Germany

Realising a monolithic optoelectronic device on Si substrate such as an efficient direct laser material would open up completely new fields of applications. The indirect compound semiconductor GaP has a lattice constant almost equal to that of Si. The novel Ga(N,As,P) direct band-gap material can be grown pseudomorphically on GaP. We study these compressively strained Ga(N,As,P)/GaP MQWs by means of both temperature- and pressuredependent modulation- and photoluminescence-spectroscopy. By applying pressure upon the samples one is able to determine the offsets of the direct Ga(N,As,P)-bandgap with regard to the indirect bandgap of the GaP-barrier. We provide this insight by comparing the modulated reflectance to the photoluminescence of the sample. The obtained results yield additional knowledge about the band structure and in particular the offset of the quantum well, which is essential for achieving room-temperature lasing in the near future.

HL 17.14 Mon 16:30 Poster D

Influence of sulfur on the polarization degree in spin-injection light-emitting diodes with lattice-matched ZnMnSSe spin aligners — •Jens Müller, Wolfgang Löffler, Benedikt Westenfelder, Heinz Kalt, Dongzhi Hu, Daniel M. Schaadt, and Michael Hetterich — Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

We investigate the spin alignment of electrons in ZnMnSSe-based alloys and their subsequent injection into InGaAs quantum dots using spin-injection light-emitting diodes (spin-LEDs). Due to the antiferromagnetic coupling of neighbored Mn spins in ZnMn(S)Se one finds a maximum *effective* Mn concentration for $x_{\mathrm{Mn}} \sim 14\%$. However, the maximum giant Zeeman splitting occurs for $x_{\mathrm{Mn}} \sim 9\%$, apparently due to a strong increase of the effective temperature T_{eff} with manganese content. To further improve the achieved spin injection efficiency in spin-LEDs we grew ZnMnSSe aligner layers lattice-matched to GaAs. Because of poorer crystal quality in the resulting quaternary alloys, magneto-PL measurements show lower spin-polarization with increasing sulfur content. At the same time we found a dramatic increase in the intra-Mn photoluminescence at about 2.1 eV. This increase is thought to originate from localization effects of excitons that lead to Auger-like transitions within manganese atoms. The maximum circular polarization degree achieved in InGaAs quantum dot ensemble measurements of lattice-matched spin-LED structures was in the order of 70%.

HL 17.15 Mon 16:30 Poster D

High Resolution Measurement of the Thermal Expansion Coefficient of Semiconductor Multilayer Lateral Nanostructures — •Björn Brüser[1], Ullrich Pietsch[1], Souren Grigorian[1], Tobias Panzner[1], Jörg Grenzer[2], and Ute Zeimer[3] — [1]Festkörperphysik, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany — [2]Forschungszentrum Rossendorf e.V., P.O.Box 510119, D-013414 Dresden, Germany — [3]Ferdinand-Braun Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 24, D-12489 Berlin, Germany

We measured the thermal expansion coefficient of a vertically stacked multi-quantum-well structure buried under a thick GaAs top layer be-

fore and after lateral patterning of the GaAs top layer. After patterning the thermal expansion coefficient of the whole multi-quantum-well structure differs from that of the planar structure by about 20%. Based on calculations in terms of methods of finite elements the effect is explained by the influence of the strain field originating from the bottom edges of the etched nanostructure. Due to the long range nature of this strain field the strain release within the individual quantum wells changes as a function from the distance from the valley.

HL 17.16 Mon 16:30 Poster D

Crystallization of strongly correlated indirect excitons — •Patrick Ludwig[1,2], Alexej Filinov[1], Heinrich Stolz[2], and Michael Bonitz[1] — [1]CAU zu Kiel, ITAP, Leibnizstraße 15, D-24098 Kiel — [2]Universität Rostock, Institut für Physik, Universitätsplatz 3, D-18051 Rostock

We consider small ensembles of optically excited indirect excitons in a single quantum well. Using Path Integral Monte Carlo we compute from first principles the spatial separation of electrons and holes and the lateral quantum Stark confinement in the quantum well due to a strong electric field from a tip electrode [1]. Electrons and holes are shown to form permanent dipoles with a strong repulsion giving rise to interesting correlation and quantum effects [2,3]. By changing the field strength, tip to sample distance and excitation intensity (exciton number) and temperature we predict the parameter range where exciton crystallization is expected to be observable in experiments on ZnSe based quantum wells.

[1] P. Ludwig et al., phys. stat. sol. (b) 243, No. 10, 2363 (2006)
[2] A. Filinov et al., phys. stat. sol. (c) 3, No. 7, 2457 (2006)
[3] A. Filinov et al., J. Phys: Conf. Series 35, 197 (2006)

HL 17.17 Mon 16:30 Poster D

Epitaxially grown ZnO heterostructures for nanophotonic devices — •Marcel Ruth and Cedrik Meier — Department of Physics, Group NanoPhox, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg

Due to its unique properties such as the large direct bandgap of 3.37eV and its high exciton binding energy, zinc oxide (ZnO) is a highly promising semiconductor for optoelectronic devices even at room temperature. By adding cadmium (Cd) or magnesium (Mg) the bandgap can be tuned between 3.0eV and 4.0eV. Above that, it is simpler to form laterally patterned devices and structures based on ZnO than on gallium nitride (GaN), e.g., by chemical etching.
For the fabrication of high-quality ZnO-based heterostructures as required for nanophotonic applications, plasma-assisted molecular beam epitaxy (MBE) is a very suitable technique. Our samples are grown in a vertical MBE system (Riber Compact 12) with double zone effusion cells and a RF-plasma source for atomic oxygen.
We present the first results of the epitaxially grown ZnO, (Zn,Mg)O and (Zn,Cd)O layers on c-plane sapphire and ZnO. The samples are characterized by morphological methods *in-situ* by reflection high energy diffraction (RHEED) and *ex-situ* methods such as atomic force microscopy (AFM), scanning electron microscopy (SEM) and x-ray diffraction (XRD). Furthermore, photoluminescence (PL) spectroscopy is used to determine their usability for nanophotonic devices like photonic crystals and microdisks.

HL 17.18 Mon 16:30 Poster D

Antilocalisation in InGaAs/InAlAs inverted 2DEGs — •Ines Hense, Ursula Wurstbauer, Dieter Schuh, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, 93043 Regensburg, Germany

InGaAs is one of the most studied ternary alloy systems because of its important rule in the development of electronic and optoelectronic devices. Due to a huge lattice missmatch between GaAs and InAs of about 7 % it is necessary to grow a some hundred nanometers thick buffer layer with a stepwise increasing In-concentration. In this way one creates a virtual substrate lattice-matched to InGaAs.

We present at low temperature magnetotransport experiments on 2DEGs which reside in an InAs-channel which was modulation-doped from the bottom side. One first finding was an increased magnetoconductance at low magnetic fields caused by weak antilocalisation. Following next will be an enhanced nanostructuring, e.g. to get Aharanov-Bohm rings or gate-defined quantum dots.

HL 17.19 Mon 16:30 Poster D

Structural and optical properties of ZrO_2 and Al_2O_3 thin films and Bragg reflectors grown by pulsed laser deposition — •Jan Sellmann, Chris Sturm, Rüdiger Schmidt-Grund, Helena Hilmer, Holger Hochmuth, Christian Czekalla, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Our objective is to build a threshold-less laser based on the emission from a Bose-Einstein condensate of exciton-polaritons in a semiconductor microcavity-resonator. For this purpose, high reflective mirrors with smooth boundaries are necessary. The aspired resonator structure consists of a half-wavelength ZnO cavity embedded between two ZrO_2/Al_2O_3 Bragg reflectors.

We present high-reflective ZrO_2/Al_2O_3 Bragg reflectors grown by pulsed laser deposition on c-plane sapphire and silicon substrates. For ZrO_2/Al_2O_3 Bragg reflectors with a layer pair number of 12.5, reflectivity values of 99.8% at 3.3 eV and smooth surfaces have been reached. As preceding investigations, the optical and structural properties as the refractive indices, the crystal structure, and the surface properties of the used materials have been determined and optimised. It was found that these properties depend on the substrate and the position in the Bragg reflector layer stack.

The optical and structural properties of the single layers and Bragg reflectors have been gained from spectroscopic ellipsometry in the energy range (1.0-4.5) eV, X-ray diffraction measurements, atomic force microscopy, and transmission scanning electron microscopy.

HL 17.20 Mon 16:30 Poster D

Characterization of GaSb-based heterostructures by spectroscopic investigations — •Sebastian Imhof, Christina Bückers, Björn Metzger, Angela Thränhardt, Sangam Chatterjee, and Stephan W. Koch — Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps Universität Marburg, Renthof 5, 35032 Marburg

The material system (AlGaIn)(AsSb) is suitable for laser emission at 2μm or longer wavelength, which is interesting for various applications, e.g. material processing, gas detection, medical diagnostic and laser surgery. A wide range of material combinations is being considered for application [1-3], but there are still uncertainties with regards to their structural properties, such as band alignment, strain and general bandstructure parameters. In order to gain information on these structural properties, we investigate GaSb-based heterostructures by modulation spectroscopy using e.g. photomodulated reflection. The experimental data are compared to simulations based on a microscopic theory.

[1] M. Rattunde, J. Schmitz, G. Kaufel, M. Kelemen, J. Weber, J. Wagner, Appl. Phys. Lett. 88, 081115 (2006)
[2] C. L. Canedy, W. W. Bewley, J. R. Lindle, C. S. Kim, M. Kim, I. Vurgaftman, J. R. Meyer, J. Electron. Mater. 35, 453 (2006)
[3] E. A. Pease, L. R. Dawson, L. G. Vaughn, P. Rotella, and L. F. Lester J. Appl. Phys. 93, 3177 (2003)

HL 17.21 Mon 16:30 Poster D

Development of Photonic Sensors for Parallel Molecule Detection Based on Microresonators — •Mario Hauser, Christian Sailer, Cristian Gohn, Christian Schäfer, Wolfgang Löffler, and Heinz Kalt — Universität Karlsruhe (TH), Karlsruhe, Germany

We report on the development of versatile photonic sensors for label-free detection of proteins and DNA on the basis of semiconductor microdisks.

The detection principle bases on the shift of the frequency of optical whispering gallery modes (WGMs) and has been proven in the case of silica spheres [1]. Each resonator will be functionalized by fixing proteins to its perimeter which can selectivley bind to well defined partners as in the case for complementary DNA sequences or antigen/antibody combinations. The evanescent field of the WGM polarizes a molecule attached to the resonator which in return shifts the mode frequency.

For detection of the modal shift of WGMs an add/drop filter scheme with integrated waveguides passing a series of microdisks at a small distance is shown. Waveguides and microdisks can be etched simultaneously with standard semiconductor technologies from a single substrate to form an integrated device. We present first results of the fabrication and the characterization of the optical resonances.

[1] S. Arnold et. al., Shift of whispering-gallery modes in microspheres by protein adsorption, Optics Lett., vol. 28, 272 (2003)

HL 17.22 Mon 16:30 Poster D

Gain measurements of violet and blue InGaN lasers using the variable stripe length method — •J. Schlegel[1], J. R. van

Look[1], V. Hoffmann[2], A. Knauer[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

The development of group III-nitride based quantum wells (QWs) for blue and green laser diodes has attracted great interest in recent years. In order to realize these InGaN QW structures a significant increase of the indium content within the quantum well layer is required. However, the quantum efficiency and gain characteristics of these high indium containing QW structures is hindered by poor material quality, due to the formation of defects, compositional fluctuations and interface roughness. To optimize the growth of InGaN QWs optically pumped laser structures with varying indium content and emission wavelengths ranging between 400 and 460 nm have been characterized. These laser structures were grown by metalorganic vapor phase epitaxy (MOVPE) on (0001) sapphire substrates. The optical gain spectra were determined using the variable stripe length method (VSLM). Based on that information the layer quality and the homogeneity in the quantum well growth of different InGaN layer structures was compared. Furthermore the effect of the barrier design (i.e. GaN/InGaN as well as InGaN/InGaN) on the gain characteristics of these lasers will be investigated.

HL 17.23 Mon 16:30 Poster D

Investigations of the ability of photovoltaic solar power generators to receive RF radiation — •Markus Drapalik and Viktor Schlosser — Department of Electronic Properties of Materials, Faculty of Physics, University of Vienna, Austria

The installation of an electrical power generator of 1 MW_p operated by photovoltaic modules occupy an area of approximately 7000 m^2. Effective electrical shielding of receiving, reflecting, transmitting and emitting RF radiation of the components is very limited due to the necessity to capture as much incoming solar radiation as possible. Semiconducting pn-junctions which are the basic components of a photovoltaic power generator can act as simple RF receivers. Received electromagnetic radiation cause an increased level of electrical noise within the system which can affect the electronic components for power conditioning. Beside light intensity fluctuations RF radiation contributes to the generation and reemission of RF noise to the environment. Purpose of the present work is to investigate the ability of single solar cells and small solar modules to receive RF signals in the range of 10 Hz to 12 GHz. The amplitude modulated high frequency signal of a RF generator unit is coupled into an antenna which is placed close to the photovoltaic device. The solar power generator's output is connected in parallel to an elctrical load and to a highly sensitive two phase lock in amplifier which allows us to detect the phase resolved modulated response of multiple harmonics of the modulation frequency which is chosen in the range of 1 kHz. First results of the investigations will be presented and discussed.

HL 17.24 Mon 16:30 Poster D

Modellbasierte Optimierung von III-V Solarzellen — •Simon P. Philipps, Martin Hermle, Wolfgang Guter, Frank Dimroth und Andreas W. Bett — Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg

Solarzellen aus III-V Halbleitermaterialien ermöglichen hohe Wirkungsgrade, da mehrere Solarzellen mit verschiedenen Bandlücken übereinander gestapelt werden können. So kann das Sonnenspektrum effizienter genutzt werden. Die Realisierung von III-V Mehrfachsolarzellen ist aufgrund der komplexen Struktur sehr anspruchsvoll. Eine Tripelzelle beispielsweise umfasst mehr als zwanzig unterschiedliche Schichten, die sich in ihrem Verhalten gegenseitig beeinflussen und somit aufeinander abgestimmt werden müssen. Dementsprechend aufwändig ist die rein experimentelle Optimierung der Zellstrukturen. Eine effizientere Optimierung wird durch modellbasierte Analysen ermöglicht. Am Fraunhofer-Institut für Solare Energiesysteme wird dafür die Halbleitersimulationsumgebung PVObjects verwendet. Aufgrund der komplexen Schichtstrukturen werden zunächst die einzelnen Teilzellen, sowie die Tunneldioden einzeln modelliert und optimiert, um anschließend die gesamte Zellstruktur zu optimieren. In diesem Beitrag werden beispielhaft Ergebnisse von modellbasierten Optimierungen von III-V Einfachsolarzellen gezeigt, die zu einem tieferen Verständnis des Einflusses verschiedener Zellparameter auf den Wirkungsgrad geführt haben. Dies schafft eine wichtige Grundlage für die folgende Optimierung von Mehrfachsolarzellen.

HL 17.25 Mon 16:30 Poster D

Composition Dependence of Defects in CuIn1-xGaxSe2 Solar Cells — •Tobias Eisenbarth, Thomas Unold, Christian Kaufmann, Raquel Caballero, Daniel Abou-Ras, and Hans-Werner Schock — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany

Chalcopyrite solar cells based on CuIn1-xGaxSe2 absorber layers so far yield the highest thin film solar cell efficiencies, with the potential to surpass the 20% efficiency mark in the near future. There are still a number of fundamental questions about the relation between the composition and the structural and electronic properties of the absorber films, in particular the relationship between the structural and electronic defects and their effect on the device performance of the solar cells. To investigate this issue further a series of CuIn1-xGaxSe2 solar cells was prepared with $0 < x < 1$, covering the full range of gallium/indium ratios using our standard three-stage co-evaporation process. The cross-section of the solar cells has been investigated in a SEM system to reveal details about the structure. On the same cells, defect spectroscopy was performed using admittance spectroscopy and drive-level capacitance profiling, to obtain an estimate of the number of deep defects present in the devices. Additionally, photoluminescence spectroscopy was applied to obtain more information about the recombination properties of the series of devices.

HL 17.26 Mon 16:30 Poster D

Deep level transient spectroscopy measurements on CuInS2-thin film solar cells — •Stephanie Malek, Martin Knipper, and Jürgen Parisi — Carl-von-Ossietzky-Universität Oldenburg, Germany

During the last decade CuInS2 was investigated for its use as absorber in thin film solar cells. Now these cells are ready for volume production. The advantages against already used materials are e. g. high absorbing capacity and cost-efficient and sustainable production. Because of the great discrepancy between predicted degree of efficiency and the already reached degree more investigations are necessary. To get a better understanding of the electron transport and recombination in order to arise efficiency we characterize the solar cells by deep level transient spectroscopy (DLTS). This method gives information about crystal defects depending on their electric position. Transient capacity measurements in the range of 25 K and 350 K allow us to determine activation energy and concentration of electron traps.

HL 17.27 Mon 16:30 Poster D

Correlations of the structural and electrical characteristics of magnetron-sputtered ZnO:Al- and Molybdenum thin films — •Jennifer Heinemann[1], Ingo Riedel[1], Frank Hergert[2], and Jürgen Parisi[1] — [1]Energy- and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, Carl-von-Ossietzky-Strasse 9-11, D-26111 Oldenburg — [2]Johanna Solar Technology GmbH, Münstersche Straße 24, D-14772 Brandenburg an der Havel

This contribution reports on investigations of the n-ZnO:Al-front contact and Molybdenum-back electrode used in Cu(In,Ga)(S,Se)2 thin film solar cells. The transparent ZnO:Al-window contact (band gap: 3.3eV) and the Mo-electrode were both deposited by DC-Magnetron-Sputtering. By variation of the deposition parameters like Argon pressure, sputtering power, deposition rate and substrate temperature the properties of the films (e.g. grain size, textured growth, sheet conductivity) change. This requires to correlate the structural and morphological qualities with the electrical behavior. The aim of this work is to study the structural properties of the electrode materials as systematically varied by the applied process parameters and to establish their impact on the electrical film characteristics. The sheet resistance and the according conductivity of the differently prepared films were measured by four-probe current-voltage measurements. Structural and morphological properties were investigated by X-ray diffraction, force and scanning electron microscopy.

HL 17.28 Mon 16:30 Poster D

Modelling of spectral photoluminescence yields from $Cu(In_{1-x}Ga_x)Se_2$ thin film absorber — •Sebastian Knabe, Levent Gütay, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

Photoluminescence provides means to determine different physical semiconductor properties, such as spectral absorption, defect densities and their respective energy levels, and excess carrier densities

which might be expressed in terms of quasi-Fermi levels. For multilayer systems glass substrate/CIGSe-absorber/CdS-window layer we have calculated the luminescence photon flux propagating towards the detector with a 1D matrix transfer formalism. Light entrance side has been chosen through the CdS-window as well as through the glass substrate; the detector is located at the CdS-window side. For excess carrier depth profile forming the basis for the luminescence by radiative recombination we introduce a carrier generation profile dependent on absorption coefficient and photon energy, and calculate carrier densities with bulk life time/diffusion length LD, and surface recombination velocities at rear Sd and front side S0 and solve the continuity equation. We analyze the influence of LD, Sd, S0 on the spectral shape of the luminescence yield including interference effects and discuss the suitability for the extraction of the splitting of quasi-Fermi levels which in solar cell absorbers quantifies the quality of the photo excited state and limits the potential open circuit of finally processed diodes.

HL 17.29 Mon 16:30 Poster D

Local Fluctuations of Absorber Properties of $Cu(In,Ga)Se_2$ for "Real Life" Conditions by Sub-Micron Resolved PL — •Levent Gütay and Gottfried H. Bauer — Institute of Physics, University of Oldenburg, Germany

We analyze $Cu(In,Ga)Se_2$ absorber layers and solar cells in a confocal microscope setup by photoluminescence (PL) experiments. We present results on lateral inhomogeneities of the absorbers in terms of local fluctuations of the band gap and splitting of quasi-Fermi-levels which can be extracted from spectrally resolved PL (300K) scans across several tens of microns. Excitation fluxes amount to $10^2 - 10^5$ suns equivalent. We analyze the significance and the statistical distribution of the occurring fluctuations of splitting of quasi-Fermi-levels $(E_{Fn} - E_{Fp})$ which we plot in histograms, seemingly showing gaussian-like shapes. The width and shape of these distributions will be discussed, as they show substantial dependence on the excitation flux. We have extrapolated the features of the histograms from our excitation fluxes towards 1 sun equivalent in order to correct our data for absolute values $(E_{Fn} - E_{Fp})$ derived from calibrated luminescence analyses at 300 K and 1 sun equivalent on non-laterally resolved PL-studies, which provide access to the average on PL-yields $(\ln(\sum Y_{PL}))$ instead of the average of local $(E_{Fn} - E_{Fp})$ which writes $(\sum \ln(Y_{PL}))$. In our approach we strongly appeal for sufficient high spatial resolution of any experiment on polycrystalline solid matter.

HL 17.30 Mon 16:30 Poster D

Spatially resolved photoluminescence measurements on Cu(In,Ga)Se_2 absorbers and their analysis by Fourier transforms and Minkowski-operations — •Florian Heidemann, Levent Gütay, Matthias Langenmeyer, and Gottfried H. Bauer — Institute of Physics, University of Oldenburg, Germany

Thin film systems like Cu(In,Ga)Se_2 gain more and more importance in photovoltaics. Such multilayer structures however show significant structural and topological spatial variations which are obviously introduced by polycristallinity. With the help of spatially resolved photoluminescence measurements these variations, which are accompanied by spatial fluctuations in optoelectronic properties such as recombination rates and minority life times, can be measured. For the visualisation and quantification of measurements from Cu(In,Ga)Se_2 multilayer structures 2D Fourier transforms and erosion/dilatation Minkowski-operations (opening functions) are applied. These methods provide an insight in size and shape of the spatial patterns as well as into frequencies of occurrence and distribution of characteristic features. Moreover, the comparison of patterns recorded at different local positions for feature extraction with methods mentioned above allow for the proof whether data sets are statistically representative, say, scan areas are sufficiently large.

HL 17.31 Mon 16:30 Poster D

Co-Sputtering of (Zn,Mg)O buffer layers on CIGSSe thin film solar cells — •Felix Erfurth[1], Benjamin Hussmann[1], Thomas Niesen[2], Jörg Palm[2], Alexander Grimm[3], Achim Schöll[1], and Eberhard Umbach[1] — [1]Universität Würzburg, Experimentelle Physik II — [2]Avancis GmbH, München — [3]Hahn-Meitner-Institut, Berlin

To better meet the environmental requirements of thin film solar cells based on Cu(In,Ga)(S,Se)$_2$ (CIGSSe), the substitution of the CdS buffer layer by using a dry physical deposition method is of great interest. (Zn,Mg)O buffer layers deposited by rf-magnetron sputtering can result in efficiencies comparable with CdS containing solar cells. The properties of these layers depend on a multitude of parameters like sputter power, sputter pressure, and layer thickness, which therefore affect the characteristics of the entire solar cell. Of prime interest is the impact of the Mg/Zn-ratio, which in principle allows to tailor the optical band gap of the buffer layer. We are able to vary the Zn/Mg-ratio by controlling the sputter power of two separated ZnO and MgO sputter targets. By varying one specific parameter while leaving all others constant we have optimised the sputter deposition in order to achieve high efficiency solar cells. We present the influence of various parameters on cell properties like efficiency, filling factor, open circuit voltage, and short circuit current. In-situ X-Ray Photoelectron Spectroscopy measurements have been performed to investigate the direct impact of the sputter parameters on the chemical and stoichiometric properties of the buffer layer and of the absorber-buffer interface.

HL 17.32 Mon 16:30 Poster D

Correlation of grain structure and electrical properties of Cu(In,Ga)Se$_2$ thin-film solar cells — •Melanie Nichterwitz, Daniel Abou-Ras, Jürgen Bundesmann, Roland Scheer, and Hans-Werner Schock — Hahn-Meitner-Institut Berlin, Germany

Electron back scatter diffraction (EBSD) and electron beam-induced current (EBIC) in a scanning electron microscope are powerful tools to investigate the structural and electrical properties of polished cross sections of Cu(In,Ga)Se$_2$ thin-film solar cells. Electron beam induced current measurements allow for the analysis of the charge carrier transport with a high spatial resolution and the extraction of the minority charge carrier diffusion length. In combination with EBSD, it was possible to gain information about the influence of grain boundaries on the current collection of Cu(In,Ga)Se$_2$ thin-film solar cells. At several positions, reduced EBIC signals correlate with the positions of grain boundaries, as located by means of EBSD. These grain boundaries are identified as regions of enhanced recombination. Solar cells with various chemical compositions of the Cu(In,Ga)Se$_2$ absorbers were studied.

HL 17.33 Mon 16:30 Poster D

Lateral Inhomogeneities in $CuInS_2$-Thin Film Absorbers by Confocal Optical and Spectroscopic Analyses With μm-Lateral Resolution — •Martin Suhlmann[1], Sebastian Meier[1], Levent Gütay[1], Alexander Meeder[2], Rudolf Brüggemann[1], and Gottfried H. Bauer[1] — [1]Institute of Physics, Carl von Ossietzky University Oldenburg, F.R.Germany — [2]Sulfurcell Solartechnik G.m.b.H., Berlin

$CuInS_2$-absorbers from runs for thin film pv-module production have been analyzed by confocal spectrally resolved photoluminescence (PL) and focused spectral white light transmission. We observe in 300K-experiments substantial lateral variations in PL-yield, spectral shapes, and white light spectral transmission, potentially originating from the grainy structure, which we interpret in terms of lateral variations in element composition, defect densities and according lateral fluctuations of the splitting of quasi-Fermi levels $(E_{Fn} - E_{Fp})$. In histograms we show the distribution of fluctuations of $(E_{Fn} - E_{Fp})$ and extract half widths and higher order momenta. The comparison with CIS-absorbers of lab cells prepared under differing conditions and with data from selenide chalcopyrites, such as $Cu(In,Ga)Se_2$ show weaker fluctuation of the latter ones.

HL 17.34 Mon 16:30 Poster D

InGaAsP/InGaAs tandem solar cells for higher conversion efficiencies in multi-junction solar cells — •Ulf Seidel, Erol Sagol, Nadine Szabó, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany

III-V multi-junction solar cells are currently the most efficient photovoltaic devices. The present world record multi-junction solar cells (eta > 40%) contain three absorber layers: Ge, GaInAs and InGaP. Our idea is to replace the bottom Ge subcell by a more efficient InGaAsP/InGaAs tandem solar cell with low band gaps. The preparation of materials and solar cells with higher band gaps (> 1.4 eV) on the lattice constant of GaAs is already well-established, in contrast to tandem solar cells with lower band gap materials grown on InP. However, low band gaps, in particular an 1 eV absorber, are desired to raise the theoretical efficiency limit of multi junction solar cells. Here, InGaAsP/InGaAs tandem solar cells with low band gaps (1.03 eV, 0.73 eV) were grown monolithically and lattice-matched on InP(100). The serial connection of the two subcells was realized by a tunnel diode, including n-doped InGaAs and p-doped GaAsSb layers. In-house measured conversion efficiencies were much higher than the efficiency that

was achieved with a single-junction Germanium subcell. The combination of the GaAs/InGaP tandem with higher band gaps and our low band gap tandem prepared on different substrates with different lattice constants can now be realized by mechanical stacking and also via splitting of the solar spectrum.

HL 17.35 Mon 16:30 Poster D

Properties of the crystal lattice and electronic structure of metastable III(N,V) semiconductors — •Martin Güngerich[1], Gerhard Weiser[1], Wolfram Heimbrodt[1], Oleg Rubel[1], Peter J. Klar[2], Paul Harmer[3], Mark P. Jackson[3], and Matthew P. Halsall[3] — [1]Fachbereich Physik und WZMW, Philipps-Universität, 35032 Marburg, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, 35392 Gießen, Germany — [3]Department of Electronic and Electrical Engineering, University of Manchester, Manchester M60 1QD, United Kingdom

The incorporation of nitrogen on group-V lattice sites in III-V semiconductors like GaP, GaAs and GaSb leads to substantial changes of the vibrational spectrum and the electronic structure compared to the host crystals. Our work gives an overview of the interesting physical properties of such metastable compounds with N concentrations up to a few percent. We show that local vibrational modes (LVMs) of the N atoms are a common feature in these alloys. The pressure-dependent frequency shifts of the LVMs are used to investigate the micro-mechanical properties of the N-Ga bonds. It is shown that the electronic structure in both Ga(N,P) and Ga(N,As) is governed by an interplay between the spatial distribution of the N impurities themselves and the coupling of their localized states to the host conduction bands. Correlations between different local N environments and the respective changes of the global electronic structure are studied on hydrogenated ternary Ga(N,As)/Ga(N,P) as well as on quaternary (Al,Ga)(N,As) crystals which exhibit disorder on the nearest-neighbour shells of the N atoms.

HL 17.36 Mon 16:30 Poster D

Homo- and heteroepitaxial growth behavior of upright InAs nanowires on InAs and GaAs substrates — •Jens Bauer[1], Volker Gottschalch[1], Hendrik Paetzelt[1], Gerald Wagner[2], and Ulrich Pietsch[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannesallee 29, D-04103 Leipzig — [2]Institut für Kristallographie und Mineralogie, Universität Leipzig, Linnestr. 5, D-04103 Leipzig — [3]Festkörperphysik, Universität Siegen, D-57068 Siegen

Semiconductor nanowires (NW) acquire recently attraction because of promising new application fields in electronics and optoelectronic. We applied the vapor-liquid-solid mechanism with gold seeds in combination with low-pressure metal-organic vapor phase epitaxy (LP-MOVPE) to achieve replicable InAs NW growth with high growth rates. Since the initial alloying of the gold seeds with the substrate material plays a deciding role for the inceptive NW growth, InAs free standing nanowires were grown on GaAs(111)B substrate as well as on InAs/GaAs(111)B quasi-substrate. The influence of the MOVPE parameters will be discussed with respect to NW morphology and real-structure. A special focus will be set on the heteroepitaxial InAs NW growth on GaAs substrates. Gracing-incidence x-ray studies and transmission electron microscopy investigations revealed the existence of a thin $Ga_xIn_{1-x}As$ graduated alloy layer with embedded crystalline gold alloy particles at the NW substrate interface. The effect of droplet composition on the VLS growth will be presented in a thermodynamic model.

HL 17.37 Mon 16:30 Poster D

Selective-area growth of III-V nanowires — •Hendrik Paetzelt[1], Volker Gottschalch[1], Jens Bauer[1], and Gerald Wagner[2] — [1]Institut für Anorganische Chemie, Universität Leipzig — [2]Institut für Mineralogie, Kristallographie und Materialwissenschaft, Universität Leipzig

We present a catalyst-free approach for the growth of III-V semiconductor nanowires which is of interest to build ordered arrays of nanowires without the vapor-liquid-solid mechanism. The nanowires were grown from circular openings of a SiN_x mask on GaAs (111)B substrate using the selective-area metal-organic vapor phase epitaxy. The opening were defined by electron-beam lithography and wet chemical etching of the SiN_x-layer which was deposited using plasma enhanced chemical vapor deposition. We investigated the growth conditions (III/V-ratio, temperature, pressure, mask-openings, ...) for GaAs-, InAs- and InGaAs-nanowires. At optimized conditions extremely uniform arrays of semiconductor nanowires with diameters down to 50 nm were realized. The nanowires with a growth direction in [111]B direction showed a hexagonal cross-section and (110) facet sidewalls. The nanowires were characterized with cathodo-luminesenz and transmission electron microscopy.

HL 17.38 Mon 16:30 Poster D

Switching the Charge of a Single Mn-Dopant in InAs with the STM in Experiment and Model — •Felix Marczinowski, Focko Meier, Jens Wiebe, and Roland Wiesendanger — Institut für Angewande Physik, Universität Hamburg

We performed low-temperature scanning tunneling microscopy and -spectroscopy on Mn-doped InAs. We looked at (110) surfaces prepared by in-situ cleavage of InAs samples with Mn doping densities of $1*10^{17}cm^{-3}$ and $1*10^{19}cm^{-3}$. We find rings of increased differential conductance surrounding each Mn dopant with bias-voltage dependent diameter. When the ring crosses the acceptor, the well known anisotropic shape of the bound-hole wave function [1] appears in topographs. We take the rings as evidence for a charge-change of the acceptors caused by the tip-induced potential. A very simple Tersoff-Hamann based model, integrating the voltage dependent tip-induced quantum dot and the decharging, was used to accurately reproduce our observations. Our understanding allows interpreting the observed ring shapes as equipotential lines of the tip-induced quantum dot and the ring intensity as a direct measure for the screened Coulomb potential of the charged acceptor.

[1] Marczinowski, F.; Wiebe, J.; Tang, J.-M.; Flatté, M. E.; Meier, F.; Morgenstern, M. & Wiesendanger, R. ,Phys. Rev. Lett. 99, 157202 (2007)

HL 17.39 Mon 16:30 Poster D

Photoluminescence and ultrafast spectroscopy on diffusion barriers between GaAs quantum wells and GaMnAs layer — •R. Schulz, A. Wagner, T. Korn, U. Wurstbauer, D. Schuh, W. Wegscheider, and C. Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

GaMnAs is a highly interesting material system for future spintronic devices. We present a study of nonmagnetic GaAs quantum wells (QW) embedded in AlGaAs barriers, close to a ferromagnetic GaMnAs layer. The samples were grown on semi-insulating GaAs(001) and contain two QWs, where one QW is close (between 3 and 10 nm) to the GaMnAs layer and the other one is farther away (120 nm), and serves as a reference. We studied the influence of different types and widths of the barrier material (AlGaAs layer and a short-period AlAs/GaAs superlattice) as well as post-growth annealing. The photoluminescence (PL) of the upper quantum wells shows a significant broadening and quenching depending on barrier width. Additionally, time-resolved Faraday rotation (TRFR) reveals that the spin lifetime in the upper QW is up to 50 times longer than that in the lower QW. We attribute these observations to backdiffusion of Mn into the QW during and after growth. Both, the PL and the TRFR, are highly sensitive to small quantities (below 0.05 %) of Mn and allow us to study the efficiency of barrier layers in suppressing Mn diffusion.
We acknowledge support by the DFG via project SCHU1171/1 and SFB 689 TP B4.

HL 17.40 Mon 16:30 Poster D

Test and characterisation of a self-built III-V molecular beam epitaxy system — •Kirill Trunov, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum

A self-built three-chamber III-V molecular beam epitaxy (MBE) system with some non-conventional, low-cost technical and software solutions, such as ball bearing free cell- and window-shutter mechanisms is discussed. The first Si-doped $Al_{1-x}Ga_xAs$/GaAs(100) heterostructures grown by this MBE system exhibit a Hall mobility exceeding 2.0×10^6 cm^2/Vs at 4.2 K after illumination with the corresponding carrier density of about 5.0×10^{11} cm^{-2}. As further example for the performance of the system, first results for the growth of GaAs on Ge(100) substrate are discussed. Financial support from DFG GRK384 is gratefully acknowledged.

HL 17.41 Mon 16:30 Poster D

High mobility GaN based 2DEG heterostructures by MBE — •D. Broxtermann, M. Sivis, A. Bedoya Pinto, J. Malindretos, and A. Rizzi — IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August Universität Göttingen, D-

37077 Göttingen, Germany

In order to realize spin electronic devices using GaN diluted magnetic semiconductors as spin injectors or detectors, well-matched GaN-based semiconductor heterostructures for spin control are required. The $Al_xGa_{1-x}N/In_yGa_{1-y}N$ heterostrucutures for $x, y = 0...0.2$ are considered here. In our work we first optimize the MBE process of AlGaN/GaN heterostructures on MOCVD GaN templates. Thereby the GaN flux as well as the pretreatment of the substrates have been found to be crucial for good crystal quality. To obtain state of the art high mobility structures, we vary the AlGaN barrier width, the GaN cap layer thickness as well as the Al composition. The electrical properties are analyzed by magneto transport experiments and corresponding calculations of a self-consisting Schrödinger-Poisson solver.

HL 17.42 Mon 16:30 Poster D

Manganese implanted GaAs films — •Danilo Bürger[1], Heidemarie Schmidt[1], Qingyu Xu[1], Andreas Kolitsch[1], Stephan Winnerl[1], Harald Schneider[1], Shengqiang Zhou[1], Kay Potzger[1], Manfred Helm[1], Gisela Biehne[2], and Volker Gottschalch[3] — [1]Forschungszentrum Dresden-Rossendorf e.V., Institut für Ionenstrahlphysik und Materialforschung — [2]Universität Leipzig, Institut für Experimentelle Physik II — [3]Universität Leipzig, Arbeitskreis Halbleiterchemie

Electron spin preservation has been proven in unmagnetic GaAs over several μm by time-resolved luminescence measurements [1]. The synthesis of Mn-alloyed GaAs has introduced a controllable spin degree of freedom in the GaAs device technology. Approx. 1 μm thick n-type (Si) and p-type (Zn) GaAs films have been grown on highly conducting n- and p-GaAs substrates by metalorganic chemical vapour deposition. For magnetotransport measurements reference samples have been grown on insulating substrates. Mn^+ ion beam implantation with 300/150 keV at 200°C yielded a boxlike Mn-implantation profile of the 250 nm thick GaAs surface layer with a nominal implantation dose dependent Mn content of 1 and 6 at%. Rapid thermal annealing has been performed at 650°C for 10 s. Magnetic properties have been investigated by means of SQUID-magnetometry. The relation between concentration of free charge carriers, defect formation and magnetoresistance effects in manganese implanted GaAs will be discussed with respect to theoretically predicted double-exchange mechanisms.
[1] D. Hägele et al., Appl. Phys. Lett. 73, 1580 (1998)

HL 17.43 Mon 16:30 Poster D

Post growth annealing behaviour and carrier concentration of $Ga_{1-x}Mn_xAs$ grown on (001), (311) and (110) GaAs substrates — •Michael Hirmer, Ursula Wustbauer, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

We present a detailed study of post-growth annealing experiments of thin $Ga_{1-x}Mn_xAs$ films grown by low temperature molecular beam epitaxy. The films were grown on (001), (311) and (110) semi-insulating GaAs substrates with layer thickness ranging from 5 to 300nm. Since the ferromagnetism of this Zener-like diluted magnetic semiconductor is hole-mediated, the ferromagnetic transition temperature T_C can be increased corresponding to $T_C \propto x_{eff} p^{1/3}$ (x_{eff}: effective Mn concentration, p: carrier density) by post growth annealing. This reduces the Mn-interstitial lattice defects, which act as double donors and couple antiferromagnetically with substitutional Mn, thereby suppressing the ferromagnetism. As a result, we have increased T_C by annealing at about 200°C in air to 167K. To improve the process, we monitored the resistance in situ and identified negative annealing-effects, which were more distinctive with higher As:Ga ratio during growth. The out-diffusion of Mn_I is strongly dependent on growth direction, annealing temperature and the passivation process on the surface. To estimate the Mn_I content and get the enhancement of carrier concentration (p), we calculated p from high magnetic field Hall measurements before and after annealing. The changes in the measurements suggest that the anomalous Hall-effect is not only caused by scattering processes.

HL 17.44 Mon 16:30 Poster D

Growth of InN and InGaN/InN heterostructures for electronic device applications — •Joerg Hisek[1], Heiko Bremers[2], Uwe Rossow[2], Jochen Aderhold[3], Juergen Graul[1], and Andreas Hangleiter[2] — [1]LFI, Leibniz Universitaet Hannover, Schneiderberg 32, 30167 Hannover — [2]IAP, TU Braunschweig, Mendelsohnstr. 2, 38106 Braunschweig — [3]Fraunhofer Wilhelm-Klauditz-Institut, Bienroder Weg 54E, 38108 Braunschweig

As a low-bandgap material, InN has a rather low electron effective mass and may therefore be expected to exhibit quite large electron mobility, making it potentially useful as a channel material for HEMTs or bipolar devices. Due to the difficulties in epitaxial growth of InN and the strong surface electron accumulation, carrier densities found InN layers are still quite large. We have grown InN as well as InGaN/InN heterostructures using RF-MOMBE. On c-plane sapphire 500-1000 nm thick InN layers were grown at about 500° C. InGaN/InN structures were realized by adding a thin InGaN cap layer with up to 10% Ga. By AFM we find a well developed step structure with indications for step bunching with step heights of twice the c-lattice constant. HRXRD show good quality InN with rocking widths as low as 400 arcsec for (0002) and (10-15) reflections. Inclusions of metallic Indium are below 0.2%. Hall-effect data result in electron densities in the high 1018 cm-3 and electron mobility up to 800 cm2/Vs. Preliminary measurements on InGaN/InN structures indicate somewhat higher electron densities at similar mobility. Further investigations are underway to reveal a possible 2D behaviour at the InGaN/InN interface.

HL 17.45 Mon 16:30 Poster D

Influences of growth conditions on surface properties of MBE grown InN films — •Anja Eisenhardt, 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

We present a study of the InN surface properties investigated in a UHV system (base pressure $< 2\times10^{-10}$ mbar) consisting of a surface analytics chamber directly connected to a molecular beam epitaxy (MBE) chamber. Thin InN films were grown on $GaN/Al_2O_3(0001)$ as well as on GaN/SiC(0001) templates by plasma assisted MBE. The growth was monitored using reflection high energy electron diffraction (RHEED). The dependence of the surface properties (e.g. morphology, stoichiometry and surface electronic structure) on growth conditions was studied using atomic force microscopy as well as X-ray and ultraviolet photoelectron spectroscopy. For stoichiometric and nitrogen rich conditions, the InN grows in the Stranski-Krastanov mode and 3D transmission spots are observed in the RHEED pattern, while a streaky RHEED pattern induced by residual indium on the surface is found for In rich conditions. Depending on In-flux and template 2×2, 2×1, $\sqrt{3}\times\sqrt{3}$ surface reconstructions were observed. Differences in the core level as well as valence band spectra will be presented and discussed. For nitrogen rich conditions, insertion of excess nitrogen takes place, whereas a shift of all occupied states by 0.3 eV towards E_F was observed after indium rich growth.

HL 17.46 Mon 16:30 Poster D

Temperature and doping dependent photon-recycling in GaInP-GaInAs double heterostructures — •Raymond Hoheisel, Wolfgang Guter, Simon Philipps, Frank Dimroth, and Andreas Bett — Fraunhofer Institut für Solare Energiesysteme, Heidenhofstrasse 2, 79110 Freiburg

The effect of photon recycling in GaInP-GaInAs heterostructures as a function of doping concentration, GaInAs layer thickness, temperature and total excitation intensity is presented. The radiative recombination process is investigated by an activated germanium substrate on which the GaInP-GaInAs heterostructures are grown. The photon recycling signal is measured by the Ge photodiode via spectral response from the upper layers. The experimental data show that the internal quantum efficiency of radiative recombination increases significantly with decreasing temperature. The influence of temperature dependent nonradiative recombination centers affecting the Shockley-Read-Hall (SRH) lifetime and the photon recycling signal is discussed.

HL 17.47 Mon 16:30 Poster D

Minimierung von seriellen Widerstandsverlusten in Solarzellen mit Hilfe von SPICE-Netzwerksimulation — •Marc Steiner, Simon Philipps, Martin Hermle, Frank Dimroth und Andreas Bett — Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg, Deutschland

Der photovoltaisch generierte Strom einer Solarzelle wird über eine kammartige Struktur metallischer Finger eingesammelt. Der Wirkungsgrad von Solarzellen hängt unter konzentriertem Sonnenlicht wesentlich von der Geometrie dieser Kontakte auf der Vorderseite der Solarzelle ab. Bei einer Konzentration von 500 Sonnen entstehen Stromdichten von etwa 15A/cm2. Deshalb ist es wichtig die Geometrie und Verteilung der Metallfinger in Bezug auf die ohmschen Widerstandsver-

luste zu optimieren ohne dabei zuviel aktive Fläche abzuschatten. Die Solarzelle wurde mit Hilfe des Zweidiodenmodells und einer Netzwerksimulation der SPICE-Familie zur digitalen Berechnung elektrischer Schaltkreise modelliert. Die Simulation wurde anhand gemessener Materialparameter (Dunkelströme, spez. Widerstände) parametrisiert und die Ergebnisse wurden mit Messdaten von speziell hierfür hergestellten Testzellen validiert. Der Verlauf der wichtigsten Solarzellenkenngrößen wie Wirkungsgrad und Füllfaktor gegenüber der Konzentration wurde durch das Modell gut wiedergegeben. Physikalische Effekte wie der nicht passivierte Solarzellenrand wurden durch zusätzliche Randdioden reproduziert, um auch die optimale Solarzellengröße ermitteln zu können. Die Methodik der Netzwerksimulation, sowie ein Vergleich von experimentellen und gerechneten Daten, werden vorgestellt.

HL 17.48 Mon 16:30 Poster D

Doping Concentration Measurement by Spatially Resolved Spin Noise Spectroscopy — •Michael Römer, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University of Hannover, Appelstr. 2, 30167 Hannover, Germany

We introduce spin noise spectroscopy as an optical method to spatially resolve the impurity concentration in n-doped, direct gap semiconductors [1, 2]. The technique is contact free and allows for a lateral resolution of about one micrometer and a depth resolution better than 50 micrometers.

We demonstrate the depth resolution in a proof of concept experiment using a 700 μm n-doped GaAs stack with two different doping concentrations. The spin noise spectrum is measured by below band-gap Faraday-rotation at low temperatures with a high frequency spectrum analysis technique. Additionally, measurements at higher temperatures and further optimizations of the detection setup will be discussed.

[1] M. Oestreich, M. Römer, R. Haug, and D. Hägele, "Spin Noise Spectroscopy in GaAs", Phys. Rev. Lett. **95**, 216603 (2005). [2] M. Römer, J. Hübner and M. Oestreich "Spin Noise Spectroscopy in Semiconductors", Rev. Sci. Instrum. **78**, 103903 (2007).

HL 17.49 Mon 16:30 Poster D

Optical investigation of doped and undoped AlN layers — •Günther M. Prinz[1], Ingo Tischer[1], Martin Schirra[1], Martin Feneberg[1], Sarad B. Thapa[2], Ferdinand Scholz[2], Yoshitaka Taniyasu[3], Makoto Kasu[3], Rolf Sauer[1], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, D-89069 Ulm — [3]NTT Basic Research Laboritories, NTT Corporation, 3-1 Morinosato-Wakamiya, Atsugi, 243-0198, Japan

Aluminum nitride (AlN) represents the upper end of the technologically interesting ternary alloy system AlGaN with an ultra-wide direct band gap of approximately 6.1 eV at liquid helium temperature. Here doped and undoped AlN layers on sapphire and SiC were investigated by means of cathodoluminescence and Raman spectroscopy. All layers show intense near-band edge luminescence at approx. 6eV. This luminescence shifts down as a function of the Si doping concentration but is independent for growth on the two different substrates or for different growth temperatures. Concomitantly, the E_2^{high}-Raman mode shifts to lower wave numbers, indicating tensile strain in the doped AlN layers. Correlating these results quantitatively we show that the near-band edge luminescence shift is exclusively due to tensile strain and is not a result of a reduced band gap through high doping concentrations as suggested in literature.

HL 17.50 Mon 16:30 Poster D

High temperature electron spin relaxation in bulk GaAs — •Stefan Oertel, Jens Hübner, and Michael Oestreich — Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, 30167 Hannover

The electron spin relaxation in weakly n-doped bulk GaAs in the temperature range from 300K to 450K is determined by time and polarization resolved photoluminiscence spectroscopy with a synchroscan streakcamera. The spin relaxation is dominated by the D'yakonov-Perel' relaxation mechanism in this temperature regime, leading to spin relaxation times between 60 and 10 ps. The influence of faster electron momentum scattering becomes explicitly apparent by examining the dependency of the spin relaxation time on the excitation density. The density dependency is studied by directly mapping the spatial density profile of the photoluminiscence on the streakcamera.

HL 17.51 Mon 16:30 Poster D

Optical gain in Ga(NAsP) quantum wells using the variable stripe-length method — •Daniel Franzbach, Christoph Lange, Michael Schwalm, Sangam Chatterjee, Bernadette Kunert, Kerstin Volz, Wolfgang Stolz, and Wolfgang Rühle — Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg

A series of Ga(NAsP) quantum well samples grown by MOVPE on a GaP substrate with varying concentrations of N and As is measured using the variable stripe-length method.

A Nd:YAG laser is used for excitation. The beam is widened to 4cm, clipped to a rectangular shape and focussed onto the sample. A cylindrical lens allows for exciting a stripe-shaped region, whose length is controlled with two slit apertures. Amplified spontaneous emission is collected from the facet of the sample. By varying the length of the stripe, the gain can be determined.

Both the absorptive regime and spectral regions with optical gain are covered. Different excitation conditions are studied, and gain up to 20/cm is observed. The dependence of the gain maximum on the material composition is determined.

HL 17.52 Mon 16:30 Poster D

Temporal evolution of gain and carrier dynamics of (GaIn)As/(GaIn)(NAs) heterostructures — •Niko Köster[1], Christoph Lange[1], Sangam Chatterjee[1], Angela Thränhardt[1], Bernadette Kunert[1], Kerstin Volz[1], Wolfgang Stolz[1], Stephan Koch[1], Wolfgang Rühle[1], Galina Khitrova[2], Hyatt Gibbs[2], and Lutz Geelhaar[3] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg — [2]College of Optical Sciences, The University of Arizona, 1630 E University Blvd, Tucson, Arizona 85721 USA — [3]Infineon Technologies, München, Germany

We present gain measurements of III-V semiconductor samples, both highly temporarily and spectrally resolved. The pump-probe Ti:Sapphire amplifier-driven setup features high excitation densities, a temporal resolution of below 200fs and a white-light supercontinuum probe. The latter, in combination with a spectrometer with a (GaIn)As photo-diode array, allows for the spectral resolution within one experimental run. The experimental spectra are compared with calculations based on a microscopic theory, which requires no free fit parameters. The good agreement underlines the predictive capability of the theory. Gain up to gL = 0.002 for (GaIn)As and gL = 0.003 for (GaIn)(NAs) per quantum well is observed, as well as numerous effects related to carrier dynamics such as feeding and hot carrier relaxation.

HL 17.53 Mon 16:30 Poster D

Einfluss der Schichtdicke von GaMnAs auf die Curietemperatur und die Magnetotransporteigenschaften — •Matthias Schmidt, Florian Adler, Andrea Stemmann, Christian Heyn und Wolfgang Hansen — für Angewandte Physik und Zentrum für Mikrostruktuforschung, Hamburg, Deutschland

Wir untersuchen die Curietemperatur und Transporteigenschaften von GaMnAs-Schichten. Spezielles Augenmerk liegt hier auf dem Einfluss der Schichtdicke, welche über zwei Methoden variiert wird. Erstens wurden Schichten unterschiedlicher Dicke mittels Molekularstrahlepitaxie gewachsen. Da die Wachstumsbedingungen einen starken Einfluss auf die Probeneigenschaften bezüglich Transport und Curietemperatur haben, sind alle Proben unter gleichen Wachstumsbedingungen entstanden. Die zweite Methode zur Variation der Schichtdicke besteht im nachträglichen Dünnen durch Ätzen. Dazu wird mit Hilfe einer Ätzlösung aus Wasser, Phosphorsäure und Wasserstoffperoxyd bei der Probe mit der dicksten GaMnAs-Schicht die Schichtdicke reduziert. Wir finden unterschiedliches Verhalten von GaMnAs-Proben vergleichbarer Schichtdicken, die entweder MBE gewachsen oder nachträglich verdünnt wurden.

HL 18: Invited Talk Buhmann

Time: Tuesday 9:30–10:15 Location: ER 270

Invited Talk HL 18.1 Tue 9:30 ER 270
Quantum Spin Hall Insulator State in HgTe Quantum Wells — •Hartmut Buhmann[1], Markus König[1], Steffen Wiedmann[1], Christoph Brüne[1], Andreas Roth[1], Laurens W. Molenkamp[1], Xiao-Liang Qi[2], and Shou-Cheng Zhang[2] — [1]Physikalisches Institut, EP3, Universität Würzburg, Würzburg, Germany — [2]Department of Physics, Standford University, Standford CA, USA

Recent theory predicted that the quantum spin Hall effect, a fundamentally new quantum state of matter that exists at zero external magnetic field, may be realized in HgTe/(Hg,Cd)Te quantum wells [1]. We fabricated such sample structures with low density and high mobility in which we could tune, through an external gate voltage, the carrier conduction from n-type to p-type, passing through an insulating regime. For thin 'normal' quantum wells (well width $d < 6.3$ nm), the insulating regime showed the conventional behavior of vanishingly small conductance at low temperature. However, for thicker 'inverted' quantum wells ($d > 6.3$ nm), the nominally insulating regime showed a plateau of residual conductance close to $2e^2/h$ [2]. Further investigations confirmed that these observations provide experimental evidence of the quantum spin Hall effect.

[1] B.A. Bernevig, T.L. Hughes, S.-C. Zhang, Science **314**, 1757 (2006).

[2] M. König, S. Wiedmann, C. Brüne, A. Roth, H. Buhmann, L.W. Molenkamp, X.L. Qi, and S.C. Zhang, Science **318**, 766 (2007).

HL 19: Symposium Spin Effects in Semiconductors of Reduced Dimensionality

Time: Tuesday 10:30–13:00 Location: ER 270

Invited Talk HL 19.1 Tue 10:30 ER 270
Novel devices using local control of magnetic anisotropies in (Ga,Mn)As. — •Charles Gould, Jan Wenisch, Silvia Hümpfner, Katrin Pappert, Manuel Schmidt, Christian Kumpf, Karl Brunner, Georg Schmidt, and Laurens W. Molenkamp — Physikalisches Institut, Universitat Wuerzburg, Am Hubland, D-97074 Wuerzburg, Germany

(Ga,Mn)As has long been the prototypical ferromagnetic semiconductor for investigations into spintronics devices, in large part because of its rich magnetic anisotropies. Until recently, all devices simply inherited their magnetic anisotropy from the bulk parent layer from which they were formed. To produce more sophisticated devices, a method of local anisotropy control of device elements is needed. Moreover, using shape anisotropy, which is effective in metals, will not work because of the relatively low magnetization and the strong crystalline anisotropies in magnetic semiconductors.

In this talk, I will present our discovery of a novel method for local anisotropy control. The method is based on using nano-lithography to pattern the (Ga,Mn)As in such a way as to cause anisotropic strain relaxation. The strong spin-orbit coupling in the material, which links the magnetic properties to the crystal structure, then leads to a new anisotropy term which can be engineered to completely control the local anisotropy of device elements.

To demonstrate the usefulness of this method, I will present a nonvolatile memory element consisting of two nanobars, orthogonal to each other, and each with a uniaxial anisotropy along its primary axis.

Invited Talk HL 19.2 Tue 11:00 ER 270
Local spin manipulation in a semiconductor by nanostructured ferromagnets — Patric Hohage, Simon Halm, Jörg Nannen, and •Gerd Bacher — Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Duisburg, Germany

The ability to locally define and manipulate carrier spin states in a semiconductor is one key issue in spintronics. We use fringe fields provided by tiny ferromagnets with well-defined magnetization to obtain local spin control in an underlying semiconductor.

In a first series of experiments, the fringe field of microstructured Fe/Tb multilayer ferromagnets with out-of-plane magnetization was used to imprint a remanent magnetization into the magnetic ion system of a magnetic semiconductor. This results in a locally varying carrier spin polarization of up to 25 % at zero external fields. We show that the ferromagnetic state can be switched by an intense laser pulse and probe the magneto-optical response of the semiconductor. In a second series of experiments fringe fields stemming from ferromagnets with in-plane magnetization are used to locally modify the coherent spin dynamics of both, electrons and magnetic ions. We demonstrate the ability of a complete reversal of the spin orientation within the spin coherence time of magnetic ions in CdMnZnSe quantum wells with respect to a reference measurement and discuss the potential of locally manipulating coherent spin states in GaAs up to room temperature.

*work done in collaboration with Y. Fan, J. Puls, F. Henneberger (HU Berlin), E. Schuster, W. Keune (U Duisburg-Essen), D. Reuter, A. Wieck, S. Fischer, U. Kunze (U Bochum)

Invited Talk HL 19.3 Tue 11:30 ER 270
Nonequilibrium nuclear-electron spin dynamics in semiconductor quantum dots — •Fritz Henneberger and Ilya Akimov — Humboldt-University Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany

Optical spin pumping and the hyperfine dynamics is investigated in the situation where the spin of a localized electron interacts only with a few hundred nuclear moments in the surrounding lattice. Both pumping and read-out of the spin state is accomplished via the trion feature. The formation of a dynamical nuclear polarization as well as its subsequent decay by the dipole-dipole interaction is directly resolved in time. Because not limited by intrinsic nonlinearities, polarization degrees as large as 50 % are achieved, even at elevated temperatures. The data signify a nonequilibrium mode of nuclear polarization, distinctly different from the standard spin temperature cooling concept.

Invited Talk HL 19.4 Tue 12:00 ER 270
Electrical spin injection into single InGaAs quantum dots — •Michael Hetterich[1], Wolfgang Löffler[1], Thorsten Passow[1], Dimitri Litvinov[2], Dagmar Gerthsen[2], and Heinz Kalt[1] — [1]Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), D-76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), D-76128 Karlsruhe, Germany

In the context of a potential future quantum information processing we investigate the simultaneous initialization of electronic spin states in InGaAs quantum dot (QD) ensembles via electrical injection from diluted magnetic ZnMn(S)Se spin aligners. Metallic nano-apertures on top of our spin-injection light-emitting diodes enable us to individually address and optically read-out spin states in *single* QDs. A reproducible spin polarization degree close to 100% is observed for a subset of the QD ensemble although injection takes place into the upper Zeeman level of the dots, thus confirming the robustness of spin states in the latter. However, the ensemble-*averaged* polarization degree shows a strong drop with increasing QD emission wavelength. Our measurements suggest that spin relaxation processes outside the QDs as well as the energetic position of the electron Fermi level play a crucial role in the explanation of this effect (e.g. formation of a 2D electron gas at the III–V/II–VI interface). A further contribution is defect-related spin scattering at the interface. Improved structures with optimized Fermi level position and lattice-matched ZnMnSSe spin aligners are currently under development.

Invited Talk HL 19.5 Tue 12:30 ER 270
Transport in 2DEGs and Graphene: Electron Spin vs. Sublattice Spin — •Maxim Trushin and John Schliemann — Institute for Theoretical Physics University of Regensburg D-93040 Regensburg

Firstly, we present a model study of a curved two-dimensional electron gas (2DEG) [1] with Rashba spin-orbit (SO) interactions where for a certain relation between the SO coupling strength and curvature radius the tangential component of the electron spin becomes a conserved quantity for any spin-independent scattering potential [2]. This

striking feature is exhibited by rolled-up 2DEGs and is not shared by their usual planar counterparts with Rashba SO interaction. Secondly, we focus on current-induced spin accumulation in a planar 2DEG with SO coupling of both the Rashba and the Dresselhaus type. This phenomenon sometimes also referred to as the kinetic magnetoelectric or inverse spin-galvanic effect [3] and shows for the system under study significant anisotropies. To investigate the spin responce to an in-plane electric field we rely on the exact analytical solution of the Boltzmann equation for electron spin and momentum [4]. The approach developed here is also applicable to the description of carrier transport in graphene [5] where low energy excitations have, with respect to the sublattice degree of freedom, a similar chiral structure as the usual 2DEG with Rashba SO interaction. [1] S.Mendach et al. Physica E v23, 274 (2004) [2] M.Trushin and J.Schliemann New J. Phys. v9, 346 (2007) [3] S.D.Ganichev et al. J. Magn. Magn. Mater. v300, 127 (2006) [4] M.Trushin and J.Schliemann Phys. Rev. B v75, 155323 (2007) [5] M.Trushin and J.Schliemann Phys. Rev. Lett. v99, 216602 (2007)

HL 20: Invited Talk Worschech

Time: Tuesday 14:15–15:00 Location: ER 270

Invited Talk HL 20.1 Tue 14:15 ER 270
Y-branched nanojunctions as nanoelectronic logic elements, memory devices and sensors — •Lukas Worschech, David Hartmann, Christian Müller, and Alfred Forchel — Technische Physik, Am Hubland, Universität Würzburg, 97074 Würzburg

In the ballistic nonlinear transport regime, nanoelectronic devices show several electric properties very different from those of diffusive conductors. In branched nanojunctions self-switching, tuneable bistability, rectification and deviations from the Onsager-Casimir symmetry relations can occur, whenever the device dimensions are smaller than the screening length and the mean free path of electrons. We have fabricated Y-branch switches with lengths of a few tens of nanometers by electron beam lithography and etching techniques in GaAs/AlGaAs heterostructures. Exploiting nonlinear ballistic transport in Y-branched nanojunctions compact logic gates, memory devices and noise enhanced sensors were realized. In branched nanojunctions subthermal switching and detection of signals hidden in noise are reported.

HL 21: Symposium Semiconductor Nanowires

Time: Tuesday 15:15–17:45 Location: ER 270

Invited Talk HL 21.1 Tue 15:15 ER 270
Electron Transport in InAs Nanowire Quantum Dots — •Andreas Fuhrer[1,2], Carina Fasth[1], and Lars Samuelson[1] — [1]The Nanometer Structure Consortium, Lund Universtity, Box 118, S-221 00 Lund, Sweden — [2]School of Physics, University of New South Wales, Sydney, New South Wales 2052, Australia

We investigate electron transport in single [1,2] and double quantum dots [3-5] defined in catalytically grown InAs nanowires containing down to a single electron. We determine g-factor [1] and strength of the spin-orbit interaction [2] directly from excited state measurements in these few electron quantum dots. Using local gates to deplete homogeneous InAs nanowires offers a high degree of tunability for defining double quantum dots [2]. Here we show that such systems are ideally suited to manipulate single spins and charges for electron pumping [4], charge read-out [5] and spin manipulation applications.

[1] M. T. Björk, A. Fuhrer, et al. Phys. Rev. B 72, 201307 (2005)
[2] C. Fasth, A. Fuhrer, et al. Phys. Rev. Lett. 98, 266801 (2007)
[3] C. Fasth, A. Fuhrer, et al. Nano Letters 5, 1487 (2005)
[4] A. Fuhrer, C. Fasth, et al. Appl. Phys. Lett. 91, 052109 (2007)
[5] D. Wallin, A. Fuhrer, et al. Appl. Phys. Lett. 90, 172112 (2007)

Invited Talk HL 21.2 Tue 15:45 ER 270
Electronic properties of gate defined and etched quantum dots in InAs nanowires — •Ivan Shorubalko[1], Andreas Pfund[1], Simon Gustavsson[1], Renaud Leturcq[1], Silke Schön[2], and Klaus Ensslin[1] — [1]Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland — [2]FIRST lab, ETH Zurich, 8093 Zurich, Switzerland

Two different methods to fabricate few-electron quantum dots (QDs) in InAs nanowires (NWs) and a highly sensitive charge detector are demonstrated. In the first method QDs are defined electrostatically by top finger-gates. This simple technique produces high quality and fully tunable QDs containing a small number of electrons. For particular spin configurations in the double dot, we observe that the current can be suppressed due to the Pauli exclusion principle. We use this Pauli blockade spectroscopy to investigate spin relaxation mechanisms, as well as mixing of spin states. In the second method we use a single local-wet-etching step to fabricate a QD in a NW and a quantum point contact (QPC) in an underlying two-dimensional electron gas. The self-aligned QPC is used as a local gate for the QD and as a charge read-out at the same time. Charge stability diagrams measured by transport through the quantum dot and charge detection merge perfectly. Experiments on counting of single electrons tunneling through the QD showed a signal to noise ratio of more than 80 (at 20kHz bandwidth). We demonstrate a measurement of the electrical current by counting electrons passing through the QD. We also show that the device works as a single photon detector in the meV range.

Invited Talk HL 21.3 Tue 16:15 ER 270
prismatic quantum heterostructures on MBE grown GaAs nanowires — •Anna Fontcuberta i Morral — Walter Schottky Institut, TU Muenchen, Garching, Germany

Semiconductor nanowires are believed to play a decisive role in the electronic and optoelectronic devices of the XXI century. Their synthesis is a rapidly expanding field, due to the expectations that nanoscale objects and their associated phenomena have to offer to basic and applied science. Here we report on a new method for the growth of GaAs nanowires and related prismatic quantum heterostructures using Molecular Beam Epitaxy (MBE), by avoiding the use of gold as seed for the nanowires. The use of Molecular Beam Epitaxy presents an additional interest, as this technique allows us to produce ultra-pure nanowires and quantum heterostructures on the nanowire facets with very high crystalline quality and atomically sharp interfaces. This new versatility of MBE in the growth of nanostructures opens great possibilities for the generation of novel devices with additional optical and electronic functionalities, as it has been previously shown in planar structures.

Invited Talk HL 21.4 Tue 16:45 ER 270
From ordered arrays of nanowires to controlled solid state reactions — •Margit Zacharias — Faculty of Appl. Science (IMTEK), Albert Ludwigs University Freiburg, Georges-Koehler-Allee 103, 79110 Freiburg — formerly at: MPI of Microstructure Physics, Weinberg 2, 06120 Halle

There has been increasing interest in intentional synthesis of nanowires and nanotubes based on a large variety of materials. A deeper understanding and a sufficient control of growth are in the center of current research interest. Strategies for position-controlled and nanopatterned growth of nanowire arrays will be demonstrated by selected examples based on ZnO nanowires as well as discussed in terms of larger scale realization and future prospects.[1] The physical properties of single ZnO nanowires will be presented on selected examples.

Recently, we demonstrated one-dimensional free-standing spinel nanotubes which were transformed from nanowires via the Kirkendall effect in solid-state reaction.[2] We expect that the nanoscale Kirkendall effect should provide a general fabrication route to hollow nanostructures, including high aspect ratio nanotubes.[3] Such ordered arrays of spinel nanotubes may possess similar application potentials as

carbon nanotubes.

[1] H.J. Fan, P. Werner, M. Zacharias, Small 2 (2006) 700.

[2] H.J. Fan, M. Knez, R. Scholz, E. Pippel, K. Nielsch, D. Hesse, M. Zacharias, U. Gösele, Nature Materials 5 (2006) 627.

[3] H.J. Fan, U. Gösele, M. Zacharias, Small 3 (2007) 1660.

Invited Talk HL 21.5 Tue 17:15 ER 270

Top-Down and Bottom-Up: Nanophotonics with ZnO and Silica Nanowires — •Tobias Voss — University of Bremen, Bremen, Germany — Harvard University, Cambridge MA, USA

We used tapered silica fibers and silica nanowires fabricated in a top-down process to inject laser light into sub-wavelength ZnO nanowires obtained in a bottom-down approach. This technique allowed us to study the waveguiding properties of individual ZnO nanowires. We found that high-order waveguide modes, which carry a significant fraction of the energy at the wire surface or even outside the wire in the form of evanescent fields, were frequently excited. Finite difference time domain numerical simulations confirmed the experimental observations and provided quantitative estimates for the coupling efficiency.

We also studied femtosecond-pulse excitation of individual ZnO nanowires with 800-nm photons from a femtosecond oscillator (60 fs; 11 MHz; 80 nJ). The large ZnO bandgap of 3.37 eV at room temperature requires multi-photon processes for the excitation of electron-hole pairs in the nanowires. We observed second-harmonic generation and the excitation of blue and green photoluminescence. Part of the light emitted from the nanowire couples into its waveguide mode and is emitted from the far end of the nanowire. By comparing the spectra at the excitation spot and at the far end of the nanowire, we were able to measure the transmission losses of the non-linearly excited ZnO nanowire. We observed a significant local heating of the nanowire at the excitation spot and analyzed the temperature distribution in the nanowire with finite-element simulations.

HL 22: Hybrid systems

Time: Tuesday 9:30–11:00 Location: EW 201

HL 22.1 Tue 9:30 EW 201

Coherent exciton - surface plasmon polariton interaction in hybrid metal semiconductor nanostructures — •Parinda Vasa[1,2], Robert Pomraenke[1], Stephan Schwieger[2], Yuri Mazur[3], Vasyl Kunets[3], Erich Runge[2], Gregory Salamo[3], and Christoph Lienau[1] — [1]Insitut für Physik, Carl von Ossietzky Universität Oldenburg, 26129 Oldenburg, Germany — [2]Technische Universität Ilmenau, Theoretische Physik I, Postfach 100565, 98684 Ilmenau, Germany — [3]Department of Physics, University of Arkansas, Fayetteville, Arkansas 72701, USA.

We report the first measurement of a coherent coupling between Surface Plasmon Polaritons (SPPs) excited on a metal grating and excitons in a GaAs/AlGaAs Quantum Well (QW). The hybrid metal-semiconductor nanostructure is fabricated by molecular beam epitaxy followed by electron beam lithography. The structure is designed to maximize the radiative interaction between the two excitations which is probed by low-temperature, angle-resolved, far-field reflectivity measurements. As a result of the coupling, a significant shift of $\sim$ 7meV and an increase in broadening by $\sim$ 4meV of the QW exciton resonance are observed. The coupling strengths are calculated based on a phenomenological, coupled oscillator model and are found to be as large as 50meV. Such a strong interaction can significantly enhance the luminescence yield of a semiconductor.

HL 22.2 Tue 9:45 EW 201

Electromagnetic Interaction between a Quantum Dot and Metallic Structures in the Optical Sub-wavelength Regime — •Matthias Reichelt[1,2], Colm Dineen[2], Armis R. Zakharian[2], Jerome V. Moloney[2], and Stephan W. Koch[3] — [1]Department Physik, Fakultät für Naturwissenschaften,Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Department of Mathematics, University of Arizona, Tucson AZ 85721, USA — [3]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg, Germany

Recently the investigation of sub-wavelength metallic structures has been of great interest since surface plasmonic effects generate large confined electric fields [1]. In this work we study a combined system of a quadrupole-like bowtie and a quantum dot and present a numerical approach for calculating the electromagnetic field and the microscopic material equations simultaneously [2]. As application we compute the electromagnetic force [3] on the quantum dot under different excitation conditions. We show that it is possible to confine the dot laterally in the bowtie gap region (<100nm).

[1] P.J. Schuck *et al.*, Phys. Rev. Lett. **94**, 017402 (2005)

[2] M. Reichelt, C. Dineen, S.W. Koch, and J.V. Moloney, submitted

[3] P. Meystre, *Atom Optics*, Springer (2001)

HL 22.3 Tue 10:00 EW 201

Photoresponse of Hybrids made of Carbon Nanotubes and CdTe Nanocrystals — •Bernd Zebli[1], Hugo A. Vieyra[1], Itai Carmeli[2], Achim Hartschuh[3], Jörg P. Kotthaus[1], and Alexander W. Holleitner[4] — [1]Department für Physik and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München, Geschwister-Scholl-Platz 1, 80539 Munich, Germany — [2]Department of Chemistry and Biochemistry, Tel-Aviv University, Tel-Aviv 69978, Israel — [3]Department für Chemie, Physikalische Chemie, Butenandtstr. 5-13 E, 81377 Munich, Germany — [4]Walter-Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

We observe that the photoresponse of single-walled carbon nanotubes can be adjusted by the absorption characteristics of colloidal CdTe nanocrystals, which are bound to the side-walls of the carbon nanotubes via molecular recognition. To this end, the hybrid systems are characterized using charge transport measurements under resonant optical excitation of the carbon nanotubes and nanocrystals, respectively. We investigate the photoresponse of both ensembles of hybrid systems and single carbon-nanotube-nanocrystal-hybrids. The data suggest a bolometrically induced increase of the current in the carbon nanotubes, which is due to photon absorption in the nanocrystals.

We acknowledge financial support by the SFB 486 TPA1 of the Deutsche Forschungsgemeinschaft, the Center for NanoScience (CeNS), and the Nanosystems Initiative (NIM) in Munich.

HL 22.4 Tue 10:15 EW 201

Comparison of Charge Transport in organic P3HT and inorganic Al-doped zinc oxide nanoparticles — •Maria Hammer[1], Daniel Rauh[2], Ingo Riedel[2], 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]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg, Germany

The preparation of electronic devices from solution receives a lot of attention nowadays due to the low cost potential. One approach is an organic–inorganic hybrid system for applications in solar cells. For a deeper understanding of these material combinations, we examine the charge transport in the organic semiconductor poly(3-hexylthiophene) and the inorganic Al-doped zinc oxide nanoparticles, respectively. We present the charge carrier mobility in dependence of the charge carrier densities and temperature measured on field effect devices. Contact effects due to the workfunction of the injecting electrodes are taken into account. We survey the properties of the transport in these disordered systems, organic and inorganic, in the high carrier concentration regime. Those will be discussed with respect to the underlying transport models.

HL 22.5 Tue 10:30 EW 201

Light-Induced Charge Transfer in Hybrid Composites of Silicon Nanocrystals and Organic Semiconductors — •Roland Dietmüller[1], Sabrina Niesar[1], Robert Lechner[1], André R. Stegner[1], Rui N. Pereira[1], Martin S. Brandt[1], Martin Trocha[2], Hartmut Wiggers[3], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Evonik Degussa GmbH, Paul-Baumann-Str.1, 45772 Marl, Germany — [3]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany

Organic semiconductors have received a lot of attention for novel, low

cost electronic applications. Silicon or SiGe nanocrystals could be incorporated in such organic devices to tailor their physical properties. For example, hybrid organic/inorganic solar cells could benefit from the solution processing of the organic and inorganic components and from the broad absorption range of the non-toxic silicon.

We have investigated the charge transfer between Silicon nanocrystals (Si-nc) and organic semiconductors via light-induced electron spin resonance (LESR). Composites of Si-nc with the π-conjugated polymer poly(3-hexylthiophene-2,5-diyl) (P3HT) and with the fullerene derivate [6,6]-phenyl C-61-butyric acid methyl ester (PCBM) have been probed with LESR. The LESR measurements show that a light-induced charge transfer between Si-nc and P3HT takes place, which results in a positive polaron on the P3HT. PCBM, in contrast, acts in composites with Si-nc as an electron acceptor and after illumination a long-living radical anion of PCBM can be detected.

HL 22.6 Tue 10:45 EW 201

Real space imaging of the Fe/GaAs(110) interface with Cross-Sectional Scanning Tunneling Microscopy — •Lars Winking, Martin Wenderoth, Jan Homoth, Swante Sievers, and Rainer G. Ulbrich — IV. Phys. Inst., Georg-August-Universität Göttingen

The unique nearly lattice-matched system Fe on GaAs is a promising candidate for future spintronics applications. Spin-injection has already been demonstrated by several groups even though the obtained efficiencies are still limited [1,2]. It is assumed that this shortcoming is due to imperfections at the Fe/GaAs heterointerface, however up to now is not clear weather defects at the interface that lead to very leaky Schottky diodes [2], or the formation of a nonmagnetic interface compound are responsible [1]. In this contribution we present the first real space investigation of the Fe/GaAs(110) interface with Scanning Tunneling Microscopy across the cleaved interface. This new approach enables us to explore the structural as well as the electronic properties of the Fe/GaAs(110) interface with atomic resolution [3]. We can directly link the atomic structure of the heterointerface to spatially varying electronic properties like the local potential Φ in the GaAs space charge layer and the variation of the Schottky barrier height along the interface. This work was supported by the DFG-SFB 602 TP A7

[1] K. H. Ploog, JAP, 91, pp. 7256 (2002) [2] A. Hirohata et al., PRB 66, 035330 (2002) [3] T.C.G. Reusch et al., PRL 93, 206801(2004)

HL 23: Quantum dots and wires: Transport properties I

Time: Tuesday 11:00–13:00 Location: EW 201

HL 23.1 Tue 11:00 EW 201

Determining doping concentration and mobility in GaN nanowires by opto-electrical characterization — •Thomas Richter, Michel Marso, Ralph Meijers, Raffaella Calarco, Detlev Grützmacher und Hans Lüth — Instiute of Bio- and Nanosystems (IBN1) and Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich, D-52425 Jülich, Germany

Nanostructures such as semiconductor nanowires have an increasing interest as possible candidates for novel beyond-CMOS nanodevice concepts. This is strongly motivated by their already proven high versatility and practical applications. Nevertheless of these promising achievements, there are still great challenges concerning fundamental questions of physics in those nanoscaling devices. Properties like the doping and resulting electrical transport are an important field of research. We report the growth of GaN nanowires by plasma-assisted molecular beam epitaxy on Si (111) substrate. These nanowires vary in density and diameter from 20 to 300 nm. For the electrical characterisation the nanowires GaN have then been transferred to a Si (100) substrate covered with a layer of SiO2. Single nanowire devices have been fabricated by e-beam patterning technique. The electrical transport properties of the resulting metal-semiconductor-metal nanostructures are analyzed by means of current voltage measurements. The transport in nanowires is extremely sensitive to the wire diameter due to the size dependent recombination barrier. This effect is used to determine doping level and mobility of the nanowires and to confirm our previously developed surface recombination model for GaN nanowires.

HL 23.2 Tue 11:15 EW 201

Controlling electrons in InAs-nanowire quantum dots — •Marc Scheffler[1], Stevan Nadj-Perge[1], Leo P. Kouwenhoven[1], Magnus T. Borgström[2], Rienk Algra[2], and Erik P.A.M. Bakkers[2] — [1]Kavli Institute of Nanoscience Delft, Delft, The Netherlands — [2]Philips Research Laboratories, Eindhoven, The Netherlands

Quantum dots are an established technique to trap and control electrons in a solid; in particular towards the long-term perspective of quantum computation. Here we show how tunable quantum dots can be created in InAs nanowires by local gating, with the final goal of spin manipulation. While we can observe the influence of the electron spin already in a single quantum dot, the case of a double quantum dot is even more interesting: adjusting the coupling between the two dots, we present the different stability diagrams from independent to strongly coupled dots. In the interacting regime the electron spin plays an important role that can govern the transport through the double dot and thus allows for direct observation of the spin state in the dot.

HL 23.3 Tue 11:30 EW 201

Room temperature memory operation of an in-plane quantum-wire transistor with embedded quantum dots — •Christian R. Müller, Lukas Worschech, Jan Heinrich, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Memory operation of an in-plane gated quantum-wire transistor with embedded quantum dots is demonstrated at room temperature. The quantum-wire transistor is realized by electron beam lithography and wet chemical etching on the basis of a GaAs/AlGaAs heterostructure with self-assembled InAs quantum dots. Room temperature memory operation of the quantum dots was observed, when they were positioned approximately in the center of a Si-doped AlGaAs spacer, where the conduction band shows a minimum. The charge state of the quantum dots is read out by transport measurements with the threshold voltage of the quantum wire reflecting the charge state. The memory operation is due to a pronounced charging and discharging of the quantum dots which is achieved by sweeping up and down the gate voltage at the electrically isolated side gates. In such quantum-wires, threshold hysteresis of a few 100 mV is observed at room temperature.

HL 23.4 Tue 11:45 EW 201

Electrochemical p-doping modification of carbon nanotubes with Prussian Blue — •Alicia Forment-Aliaga[1], Ralf Thomas Weitz[1], Marko Burghard[1], and Klaus Kern[1,2] — [1]Max-Planck Institute for Solid State Research, Stuttgart, Germany — [2]Institut de Physique des Nanostructures, EPFL, Lausanne, Switzerland

Electrochemical modification is an effective method to tune the properties of carbon nanotubes. In this communication, we report on the modification of individual carbon nanotubes (SWCNTs) by electrodeposition of the molecular magnet Prussian Blue (PB) FeIII4[FeII(CN)6]3*nH2O (n=14-16). While previous studies have primarily addressed the electrocatalytic properties of PB-modified bulk nanotube electrodes,1 the motivation behind the present work is to investigate the influence of inorganic coatings on the charge transport characteristics of individual SWCNTs. The formation of PB under the applied electrochemical conditions has been proven by various characterization techniques. In contrast to metallic SWCNTs whose electrical conductivity remained largely unaffected, semiconducting tubes exhibited a strongly altered behavior after PB deposition. Specifically, in the latter case, the conductance vs. gate voltage curves were substantially shifted toward more positive gate voltages, indicative of enhanced p-type doping of the tubes. Temperature-dependent measurements revealed that the threshold voltage decreases significantly upon cooling, which is attributed to freezing out of the hole transfer from PB to the underlying nanotubes. 1 J. Li et al. Adv. Funct. Mater. 2007, 17, 1574

HL 23.5 Tue 12:00 EW 201

Determination of the specific resistance of individual free-standing ZnO nanowires with the low energy electron point source microscope — •Dirk Henning Weber[1], André Beyer[1], Berthold Völkel[1], Eva Schlenker[2], Andrey Bakin[2], Andreas

Waag[2], and Armin Gölzhäuser[1] — [1]Physik supramolekularer Systeme, Universität Bielefeld — [2]Institut für Halbleitertechnik, Technische Universität Braunschweig

A low energy electron point source (LEEPS) microscope is used to determine the electrical conductivity of individual freestanding ZnO nanowires in UHV. The nanowires were contacted with a manipulation tip and I-V curves were taken at different wire lengths. From those, the specific resistance was calculated and separated from the contact resistance. By comparing the specific resistances of ZnO nanowires with diameters between 1100 and 48 nm, a large surface contribution for the thin nanowires was found. A geometric model for separation between surface and bulk contributions is given. The results of electrical transport measurements on vapor phase grown ZnO nanowires will be discussed, as well as the size dependence of the wire resistance.

HL 23.6 Tue 12:15 EW 201

Carbon nanotube nano-electromechanics — •Andreas K. Hüttel, Benoit Witkamp, Menno Poot, Samir Etaki, and Herre van der Zant — Molecular Electronics and Devices, Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA Delft, The Netherlands

Single wall carbon nanotubes (SW-CNTs) excel in many ways as a nano-electromechanical system. With their high Young's modulus, extreme flexibility, smoothness on a molecular level, small cross-section and low mass, they promise possibilities of observing the quantization of mechanical motion. In addition, their electronic structure is well-characterized, enabling the identification of mechanical effects.

We present low-temperature transport measurements targetting both the longitudinal (stretching) and the transversal (bending) vibration mode of suspended SW-CNTs. Data on low-bias current suppression in short (100nm) CNT quantum dots points towards "phonon" or "distortion" blockade mechanisms. In addition, indications of mechanical modes in higher-order tunneling are shown. Different sample geometries and fabrication techniques are discussed.

HL 23.7 Tue 12:30 EW 201

Franz-Keldysh effect in GaN nanowires — •Raffaella Calarco[1], Toma Stoica[1], Ralph Meijers[1], Thomas Richter[1], Anna Cavallini[2], Laura Polenta[2], Marco Rossi[2], and Hans Lüth[1] — [1]Institute of Bio- and Nanosystems (IBN1) and cni - Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, 52425 Jülich, Germany — [2]Phys.Department and CNISM, University of Bologna, Viale Berti Pichat 6/2, 40127 Bologna, Italy

In recent years III-nitride based nanowires have attracted a lot of interest because of their potential applications for nanoelectronic devices [1]. Due to the large surface-to-volume ratio of the wires, the optoelectronic properties as well as growth processes are essentially dependent on the wire diameter. We have studied GaN NWs obtained by catalyst-free radio frequency PAMBE on Si(111) in N-rich conditions [2-4]. Surface Photovoltage Spectroscopy and Spectral Photoconductivity (SPC) measurements have been carried out to analyze the near band-edge absorption in GaN nanowires [5]. A strong diameter dependence of the band absorption tail was found by SPC measurements. The band-edge tailoring and its wire-diameter dependence can be explained by the Franz-Keldysh effect induced by the electric field at the wire surface. The experimental values of the absorption tail are well in agreement with the results obtained by simulating the electric field in a cylindrical model. [1] Y. Huang etal. Science 294, 9, 1313 (2001). [2] R. Calarco et al.Nano Letters 5, 981 (2005). [3] A. Cavallini et al. Nano Letters, 6(7), 1548 (2006). [4] R. Meijers et al. J.Cryst. Growth, 289, 381 (2006) [5] A. Cavallini et al. Nano Letters, 7, 2166 (2007).

HL 23.8 Tue 12:45 EW 201

Local Density of States in Mesoscopic Samples from Scanning Gate Microscopy — •Marco G. Pala[1], Benoit Hackens[2], Frederico Martins[3], Hermann Sellier[3], Vincent Bayot[2], Serge Huant[3], and Thierry Ouisse[3] — [1]IMEP-LAHC-MINATEC, CNRS, INPG and UJF, BP 257, 38016 Grenoble, France — [2]CERMIN, DICE Lab, UCL, B-1348 Louvain-la-Neuve, Belgium — [3]Institut Néel, CNRS, and UJF, BP 166, 38042 Grenoble, France

We study the relationship between the local density of states (LDOS) and the conductance variation ΔG in scanning-gate-microscopy experiments on mesoscopic structures [1]. This is a weakly invasive technique, applicable to nanostructures patterned in subsurface two-dimensional (2D) electron gases. The probe is used as a scatterer which locally modifies the electron flow properties, and generates 2D conductance maps as a function of the tip position.

We present an analytical model showing the correspondence between the conductance shift ΔG and the LDOS in the single-channel transmission regime. We analyze the physical conditions for the validity of this relationship both for one-dimensional and two-dimensional systems when several channels contribute to the transport [2]. We focus on realistic Aharonov-Bohm rings including a random distribution of impurities and analyze the LDOS-ΔG correspondence by means of exact numerical simulations, when localized states or semi-classical orbits characterize the wavefunction of the system.

[1] F. Martins et al., Phys. Rev. Lett. **99**, 136807 (2007)
[2] M.G. Pala et al., To be published.

HL 24: Photonic crystals II

Time: Tuesday 9:30–13:15 Location: EW 202

HL 24.1 Tue 9:30 EW 202

Direction selective filter using 3D photonic structures for ultralight trapping in solar cells — •Johannes Üpping, Andreas Bielawny, Paul T. Miclea, and Ralf Wehrspohn — Institut für Physik, Universität Halle-Wittenberg, Halle, Germany

We suggest a model to implement three dimensional photonic structures with direction-selective properties to be incorporated in solar cells. Our devices enhance the pathway of incident light within the solar cell in the spectral region of low absorption by restricting the reemission angle of the solar cell, this kind of light trapping we call ultra light trapping. Numerical studies of 3D photonic structures have been carried out with different numerical methods in order to find convenient structures. By matching photonic stop gaps of our device to the electronic bandgap of the cells semiconductor material, and with the orientation of the stop gaps high-symmetry axes around, but not in the direction of normal incidence, we inhibit the propagation of light selectively in angle and spectral distribution. At normal incidence, high transmission is provided because of another high symmetry axis of the photonic crystal. The result is a decrease in the allowed angle of reemission for the solar cell. A direction selective transmission calculation and corresponding microwave measurements show the ability of an inverted opal structure for ultra light trapping.

HL 24.2 Tue 9:45 EW 202

Coupled Bragg Pillar Cavities with Localized and Delocalized Mode Structure — •Matthias Karl[1], Shunfeng Li[1], Erich Müller[2], Dagmar Gerthsen[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), 76128 Karlsruhe

In the context of a further application in quantum information processing we are investigating the optical coupling of spatially separated quantum dots (QDs) via optical microcavity modes. For this purpose we study pillar cavities with top and bottom GaAs/AlAs Bragg mirrors. InAs QDs are embedded in the middle of the lambda-thick cavity emitting at around 950 nm. Out of this molecular-beam epitaxially grown layer structure single and connected pillars are milled by means of a focused-ion beam. A micro-photoluminescence set-up with an additional spatial resolution allows to measure the intensity distribution for different modes. Depending geometrically on the diameters of the pillars and the coupling bridge between two of them it is possible to design connected pillars with the coexistence of localized and delocalized cavity modes. The design of such cavity structures is devised using a step-index fiber simulation based on the finite-element method. Experimental results confirm these predicted cavity mode structures.

HL 24.3 Tue 10:00 EW 202

Local Infiltration of Individual Pores with Optical Non-

linear Polymers in Macroporous Silicon Photonic Crystals — •Peter Nolte[1], Daniel Pergande[1], Stefan S. Schweizer[1], Ralf B. Wehrspohn[1], Markus Geuss[2], and Martin Steinhart[2] — [1]Institut für Physik, Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Photonic crystals (PhC) are a promising concept for new optical components. Passive devices in PhC, e.g. complex waveguides, are widely known, but for most applications active devices are required. One possible way to realize such devices is the functioning of 2D-PhC. This can be done by combining 2D-PhC with optical nonlinear (nlo) polymers. We present an experimental technique for the infiltration of individual pores which allows the realization of a broad spectrum of different designs. For the infiltration experiments we use 2D-PhC templates made of marcroporous silicon. After electrochemical deposition of a gold layer we use a focused ion beam machine and a mature infiltration technique for the infiltration of individual pores.

HL 24.4 Tue 10:15 EW 202

Simulation of Optical Nanostructures via a Fourier Modal Method — •Sabine Essig[1,2,3] and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe — [3]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe

We present simulation results for three-dimensional periodic nanostructures via the Fourier Modal Method in combination with the Scattering-matrix approach. This method provides us with the possibility to investigate the optical properties of photonic crystals in an easy way. By carefully applying Fast Fourier Factorization rules also metallic nanostructures such as photonic metamaterials can be simulated.

In our simulations we pay particular attention to chiral metamaterials. We show calculations of transmittance and reflectance spectra as well as electric and magnetic field distributions inside these structures.

HL 24.5 Tue 10:30 EW 202

Silicon on insulator photonic crystal nanostructures for label free optical biosensing — •Thomas Zabel, Dominic F. Dorfner, Uli Rant, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, TU Muenchen, Am Coulombwall 3, 85748 Garching

Silicon based photonic crystal (PC) nanostructures are of widespread interest for realizing optical waveguides, low-loss bends and nanoscale cavities. The mode frequencies of such cavities is highly sensitive to their local dielectric environment, making them interesting for sensitive label free optical bio-sensing. We have designed and realized 2D PC nanocavity sensors based on the biocompatible SOI material system by defining a triangular lattice of air-holes in a 300nm thick freestanding Si membrane. The 400nm lattice pitch results in a 2D PBG extending from $\sim 1.4 - 1.6\mu m$. A W1 waveguide is used to guide light into the structures and evanescently couple to point defect nanocavities defined in their immediate vicinity. Light from a tunable laser source allows measurements of cavity Q-factors and resonant frequencies by detecting radiation from the surface. Operating such structures in air and a micro-fluidic cell allow us to measure the cut-off wavelength of the PC waveguide and the cavity modes as a function of the local dielectric environment. We have optimized the cavity design and achieved Q-factors up to ~ 46000 in air and observed mode shifts up to $\Delta\lambda = 50nm$ upon immersing in various solvents. These structures allow local refractive index changes of $\Delta n/n < 0.001$ to be detected. Perspectives for sensing non-specifically adsorbed proteins such as BSA will be discussed. Supported financially by the Nanosystems Initiative Munich

HL 24.6 Tue 10:45 EW 202

Time-Domain Simulations for Metallic Nano-Structures — A Krylov-Subspace Approach Beyond the Limitations of FDTD — •Michael König[1,3], Jens Niegemann[1,2,3], Lasha Tkeshelashvili[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

Numerical simulations of metallic nano–structures are crucial for the efficient design of plasmonic devices. Conventional time–domain solvers such as FDTD introduce large numerical errors especially at metallic surfaces. Our approach combines a discontinuous Galerkin method on an adaptive mesh for the spatial discretisation with a Krylov-subspace technique for the time-stepping procedure. Thus, the higher-order accuracy in both time and space is supported by unconditional stability. As illustrative examples, we compare numerical results obtained with our method against analytical reference solutions and results from FDTD calculations.

HL 24.7 Tue 11:00 EW 202

Transmission Line Studies of Planar Optical Metamaterials — •Liwei Fu, Heinz Schweizer, Hongcang Guo, Na Liu, and Harald Giessen — 4. Physikalisches Institut, Universität Stuttgart, Germany

A number of recent studies have shown that optical metamaterials can be envisioned as nanocircuits in which local optical electric and magnetic fields are tailored and manipulated in the subwavelength domain [1, 2, 3, 4]. By properly arranging arrays of basic nano-scale circuit elements, stacked nano-transmission line metamaterials can be obtained to support forward or backward electromagnetic waves [2]. In this report we demonstrate transmission line circuit models for several planar optical metamaterials, which are synthesized based on retrieved nonlocal effective material parameters. Through these models, physical insight into the difference among several metamaterials can be obtained. We show further numerically that a negative index at optical frequencies with a high figure of merit (larger than 3.0 around 600 nm) can be obtained in an optimized meander structure. Most importantly, these circuit models provide the possible building blocks for 3D metamaterials.

[1] L. Fu, H. Schweizer, H. Guo, N. Liu, and H. Giessen, Appl. Phys. B 86, 425 (2007).

[2] N. Engheta, Science 317, 1698 (2007).

[3] H. Schweizer, L. Fu, H. Gräbeldinger, H. Guo, N. Liu, S. Kaiser, and H. Giessen, Phys. Stat. Sol. (b) 244, 1243 (2007).

[4] H. Schweizer, L. Fu, H. Gräbeldinger, H. Guo, N. Liu, S. Kaiser, and H. Giessen, Phys. Stat. Sol. (a) 204, 3886 (2007).

15 min. break

HL 24.8 Tue 11:30 EW 202

Bistable lasing and ultrafast mode switching in photonic crystal microcavities — •Sergei V. Zhukovsky[1], Dmitry N. Chigrin[1], Andrei V. Lavrinenko[2], and Johann Kroha[1] — [1]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [2]COM-DTU, Department of Communications, Optics, and Materials, NanoDTU, TU Denmark, Bld. 345V, 2800 Kgs.Lyngby, Denmark

We show analytically and numerically that a system based on coupled microcavities can exhibit bistable lasing. Bistability occurs when microcavity modes have similar intensity distributions within the gain region. Both incoherent (hole-burning) and coherent (population-pulsation) mode interaction processes contribute to the development of bistability. Unlike the modes of most ring-laser or polarization-bistable set-ups, the modes of coupled microcavities can still have different frequencies. The phase structure of the modes remains distinct, which makes them addressable for selective lasing using a pulsed injection signal with matching symmetry [1]. We demonstrate numerically that a switching of the laser wavelength by about 20 nm at the time scale of 10 ps is possible for twin coupled defects in a 2D photonic crystal lattice [1], by far exceeding the performance of a conventional (e.g., electrooptical or micromechanical) tuning of a microcavity. The results obtained can be used in the design of integrated optical components such as multiple-wavelength microlaser sources or optical memory cells (see [2]) with nearly monochromatic control signals.

[1] S. V. Zhukovsky et al, Phys. Rev. Lett. **99**, 073902 (2007).

[2] M. Hill et al, Nature **432**, 206 (2004).

HL 24.9 Tue 11:45 EW 202

Complex Liquid Crystal Director Fields Appearing in Photonic Crystals — Heinrich Matthias and •Heinz-Siegfried Kitzerow — Faculty of Science, University of Paderborn, Warburger Str. 100, 33098 Paderborn, Germany

It is well known that liquid crystals can be utilized to control the optical properties of photonic crystals. The frequencies of stop band edges and the resonance frequencies of microcavities embedded in photonic crystals can be tuned by changing the temperature or applying external fields [1]. However, the complex geometry of the cavities and the anchoring of the liquid crystal orientation at interfaces cause complicated director fields [2,3] rather than an ideal, uniform alignment of the liquid crystal molecules. In addition, chirality can induce a

twisted director field thereby adding an additional spatial periodicity (given by the helix pitch) to the structure. In this contribution, we describe different director fields that have been observed in the pores of photonic crystals by means of fluorescence confocal polarization microscopy. The stability conditions of topologically different director configurations are discussed.

[1] H.-S. Kitzerow, A. Lorenz, and H. Matthias: phys. stat. sol. (a) 204, 3754 (2007). [2] H. Matthias, T. Röder, S. Matthias, R. B. Wehrspohn, S. Picken and H.-S. Kitzerow: Appl. Phys. Lett. 87, 241105 (2005). [3] H. Matthias, S. L. Schweizer, R. B. Wehrspohn, and H.-S. Kitzerow: J. Opt. A: Pure Appl. Opt. 9, 389 (2007).

HL 24.10 Tue 12:00 EW 202

GaAs Micropyramids as Optical Resonators — •Torsten Beck, Matthias Karl, Frank M. Weber, Jaime Lupaca-Schomber, Shunfeng Li, Dongzhi Hu, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Universität Karlsruhe (TH) and Center for Functional Nanostructures (CFN), 76128 Karlsruhe, Germany

We fabricate and study GaAs micropyramids for future applications in quantum optics. Such pyramids are promising since high quality factors and small mode volumes should be feasible. The pyramidal shape is achieved by a combination of molecular-beam epitaxy, electron-beam lithography and a wet-chemical etching process. In contrast to self-assembled growth the chemical etching method allows control of the exact geometry of the pyramids especially the angle of the facets. To obtain a high optical confinement the pyramids are placed on a GaAs/AlAs distributed Bragg reflector (DBR). Besides the emission of the embedded InAs quantum dots the micro-photoluminescence spectra of the pyramidal structures show peaks of cavity modes. We investigate the mode arrangement depending on geometry. For comparison we simulate the modes with a finite-difference time-domain method. For an improvement of the optical confinement we deposite metallic films and overgrow the pyramids with DBRs. Furthermore, coupled resonator structures are fabricated.

HL 24.11 Tue 12:15 EW 202

Ethanol gas sensor based on Silicon Photonic Crystal — •Stefan L. Schweizer[1], Jürgen Wöllenstein[2], Armin Lambrecht[2], and Ralf B. Wehrspohn[1] — [1]Institut für Physik, Universität Halle-Wittenberg, 06099 Halle — [2]Fraunhofer Institut Physikalische Messtechnik, Heidenhofstr. 8, 79110 Freiburg

Gas sensors based on optical absorption are advantegous because of their sensitivity, selectivity and dynamic range. We use a 2D Photonic Crystal (PhC) based on silicon for qualitative and quantitative gas analysis of ethanol. The bandstructure of PhCs offers intriguing possibilities for the manipulation of electromagnetic waves. Taking advantage of the low group velocity and certain mode distributions for some k-points in the bandstructure of a PhC should enable the realization of very compact sensor devices for mobile applications.

We prepared sensing elements based on macroporous silicon PhCs consisting of up to 1000 of pore rows and measured the transmission with and without gas through the porous sensing element. We observed an enhancement in sensitivity of about 3 to 4 compared to a gas cell without a PhC. For further increase of the enhancement factor we optimized the photoelectrochemical etch process and switched to neutron transmutated doped silicon. Simulations predict an enhancement factor of about 30 which would allow a reduction of the setup by this factor - without loss of performance!

HL 24.12 Tue 12:30 EW 202

Simulation of Modified Radiation Dynamics using Higher-Order Methods — •Jens Niegemann[1,2,3], Lasha Tkeshlashvili[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

Since the original proposal of photonic crystals, the modification of radiation dynamics was considered a feature of fundamental interest. Here, we use higher-order time-domain calculations of the coupled Maxwell-Bloch-equations in order to investigate the influence of photonic crystals on the decay of initially excited 2-level atoms. In particular, we investigate the effects of finite sample sizes as well as the influence of non-radiative transitions and dephasing. All calculations are performed through a discontinuous Galerkin finite element technique. This method allows to accuratly model complex geometries while it still maintains flexibility and reasonable performance. Thus, it is very well suited to study a large variety of experimentally relevant systems.

HL 24.13 Tue 12:45 EW 202

Analysis of metallic nanometer meander structures — •Heinz Schweizer — University Stuttgart, 4. Phys. Inst. Pfaffenwaldring 57, 70569 Stuttgart

Metallic meander structures can be regarded as basic building blocks for optical metamaterials as they show capacitive series impedance over a large bandwidth [1]. This impedance leads to a negative permeability in a homogeneous metamaterial. Meander structures are also advantageous as their impedance stays mostly isotropic with respect to the angle of incidence. We analyze the electromagnetic response on the basis of group theory and find the coupling regimes for E- and B- fields that are justified by angle-dependent optical measurements on single metamaterial layers. From optical transmission spectra we find under 20°rotation of the incident k-vector around the H-field direction only little change of the transmission spectra. The capacitive impedance spans a spectral region from 550 nm up to 665 nm. Interpreting the single layer as a thin sheet homogeneous material the impedance value corresponds to a maximum permeability value of - 4.5 at 650 nm.

[1] H. Schweizer et al., phys. stat. sol. (a) 204, 3886 (2007).

HL 24.14 Tue 13:00 EW 202

Three-dimensional photonic metamaterials at optical frequencies — •Na Liu[1], Hongcang Guo[1], Liwei Fu[1], Stefan Kaiser[2], Heinz Schweizer[1], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, 70569 Stuttgart, Germany — [2]1st Physics Institute, University of Stuttgart, 70569 Stuttgart, Germany

We present a general method to manufacture three-dimensional optical metamaterials [1] using a layer-by-layer technique. Specifically, we introduce a fabrication process involving planarization, lateral alignment, and stacking [2]. We experimentally demonstrate three-dimensional split-ring resonator metamaterials as well as fish-net metamaterials. We investigate the interaction between adjacent stacked layers using the method of plasmon hybridization [2,3] and analyze the optical properties of stacked metamaterials with respect to an increasing number of layers. Our method should pave the way towards bulk metamaterials and give new design rules for a broadband response.

[1] C. M. Soukoulis, S. Linden, and M. Wegener, Science 315, 47 (2007).

[2] N. Liu, H. C. Guo, L. W. Fu, S. Kaiser, H. Schweizer, and H. Giessen, Nat. Mater. (2007), in press.

[3] N. Liu, H. C. Guo, L. W. Fu, S. Kaiser, H. Schweizer, and H. Giessen, Adv. Mat. 19, 3628 (2007).

HL 25: Spin controlled transport I

Time: Tuesday 14:15–15:30 Location: EW 202

HL 25.1 Tue 14:15 EW 202

Origins of the anisotropic magnetoresistance in GaMnAs — •Karel Vyborny[1] and Tomas Jungwirth[1,2] — [1]Institute of physics, Academy of Sciences of the Czech Republic, Cukrovarnicka 10, Praha 6, CZ–16253, Czech Republic — [2]School of Physics and Astronomy, University of Nottingham,* Nottingham NG7 2RD, United Kingdom

The bandstructure of the magnetic semiconductor GaMnAs within the mean-field kinetic-exchange model is sufficiently simple so as to allow to open the blackbox of numerical simulations of the conductivity tensor. The full (six-band, non-spherical) model can be cut down to an analytically tractable one while the numerical results of the AMR (relative difference of resistance under two orientations of magnetisation) do not change qualitatively.

Our calculations are based on the Boltzmann semiclassical formula for conductivity. Results suggest that the scattering on Mn impurities

is responsible for the sign and order of magnitude of the AMR which is dominantly of the non-crystalline type in GaMnAs.

HL 25.2 Tue 14:30 EW 202

Magneto-photogalvanic effect in (110) GaAs semiconductor quantum wells — •Peter Olbrich[1], Vasily V. Bel'kov[1,2], Dieter Schuh[1], Werner Wegscheider[1], Wilhelm Prettl[1], and Sergey D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, 93040, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We report on the observation of a magneto-photogalvanic effect (MPGE) [1] in (110)-grown GaAs semiconductor quantum wells. The MPGE so far has been demonstrated only in (001)-grown GaAs, InAs, SiGe and GaN quantum wells where its microscopic origin is the zero-bias spin separation [2]. The latter is caused by spin-dependent scattering of electrons due to a linear-in-k terms in the scattering matrix elements. Here we provide experimental and theoretical analysis of the MPGE current in (110)-grown GaAs showing that it is driven by asymmetric processes in excitation and relaxation of a Drude-like heated electron gas and reflects the contribution of structure inversion asymmetry. The results agree with the phenomenological description based on the symmetry. We demonstrate that the MPGE due to an in-plane magnetic field is only observed for asymmetric structures and vanishes if QWs are symmetric. Therefore it is an ideal tool to probe the symmetry of (110)-grown quantum wells, which is of importance to achieve long spin relaxation times.

[1] V.V. Bel'kov *et al.*, *J. Phys.: Cond. Mat.* **17**, 3405 (2005).
[2] S.D. Ganichev *et al.*, *Nature Physics* (London) **2**, 609 (2006).

HL 25.3 Tue 14:45 EW 202

Strain-dependent magnetic anisotropy in GaMnAs on InGaAs templates — •Joachim Däubler, Michael Glunk, Stephan Schwaiger, Lukas Dreher, Wladimir Schoch, Rolf Sauer, and Wolfgang Limmer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

We have systematically studied the influence of strain on the magnetic anisotropy of GaMnAs by means of HRXRD reciprocal space mapping and angle-dependent magnetotransport. For this purpose, a series of GaMnAs layers with Mn contents of ∼5% was grown by low-temperature MBE on relaxed InGaAs/GaAs templates with different In concentrations, enabling us to vary the strain in the GaMnAs layers continuously from tensile to compressive, including the unstrained state. Considering both, as-grown and annealed samples, the anisotropy parameter describing the uniaxial out-of-plane magnetic anisotropy has been found to vary linearly with hole density and strain. As a consequence, the out-of-plane direction gradually undergoes a transition from a magnetic hard axis to a magnetic easy axis from compressive to tensile strain. The experimental results are quantitatively compared with theoretical calculations based on the Zener mean-field model proposed by T. Dietl et al. [Phys. Rev. B 64, 195205 (2001)].

HL 25.4 Tue 15:00 EW 202

Magneto-gyrotropic photogalvanic effects due to inter-subband absorption in quantum wells — •Helgi Diehl[1], Vadim Shalygin[2], Sergey Danilov[1], Sergey Tarasenko[3], Vasily Bel'kov[3], Dieter Schuh[1], Werner Wegscheider[1], Wilhelm Prettl[1], and Sergey Ganichev[1] — [1]Terahertz Center, University of Regensburg, 93040 Regensburg, Germany — [2]St. Petersburg State Polytechnical University, 195251 St. Petersburg, Russia — [3]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We report on the observation of the magneto-gyrotropic photogalvanic effect [1] due to inter-subband transitions in (001)-oriented GaAs quantum wells. This effect is related to the gyrotropic properties of the structures. It is shown that inter-subband absorption of linearly polarized radiation may lead to spin-related as well as spin-independent photocurrents if an external magnetic field is applied in the plane of the quantum well. The experimental results are analyzed in terms of the phenomenological theory and microscopic models based on either asymmetric optical excitation or asymmetric relaxation of carriers in **k**-space. We observed resonant photocurrents not only at oblique incidence of radiation but also at normal incidence demonstrating that conventionally applied selection rules for the inter-subband optical transitions are not rigorous.

[1] S.D. Ganichev and W. Prettl, *Intense Terahertz Excitation of Semiconductors*, (Oxford University Press, 2006).

HL 25.5 Tue 15:15 EW 202

Micro coils for spin manipulation in semiconductors — •Chen Yuansen[1], Simon Halm[1], Tilmar Kümmell[1], Gerd Bacher[1], Tomasz Wojtowicz[2], Grzegorz Karczewski[2], and Wiater Maciej[2] — [1]Werkstoffe der Elektrotechnik,Universtät Duisburg-Essen, BismarckStr.81,47057,Duisburg,Germany — [2]Institute of Physics, Polish Academy of Science, Al.Lotnikow 32/46 02-668 Warsasw, Poland

In the research field of spintronics, local spin manipulation in semiconductors is one of the main goals. We used micro-structured aluminum coils to generate a switchable magnetic field in a CdMnTe/CdMgTe diluted magnetic semiconductor (DMS) quantum well (QW). As the effective g factor in a DMS QW is large (˜200 at 4K), carrier spin states can efficiently be manipulated even with low magnetic fields. Inside the coil area a magnetic field of several 10mT is obtained which allows to partly align the Mn2+ ions spins, and, via the sp-d exchange interaction, to polarize the spins of optically generated excitons. We investigated the spin polarization inside the micro coils by means of micro-photoluminescence spectroscopy. Without the need of an external magnetic field, we observed a spin polarization of up to +/-1.5% at 4K by introducing a positive or negative current, respectively. By applying current pulses, the spin polarization could be switched and measured with 100 ns time resolution. The current induced spin polarization is observed up to 40K. It was found that heat produced by the current disorders the Mn2+ spins and thus competes with the ordering achieved by the current-induced magnetic field.

HL 26: III-V semiconductors I

Time: Tuesday 15:45–18:15 Location: EW 202

HL 26.1 Tue 15:45 EW 202

Current-regulated giant anisotropic magnetoresistance in ultra thin (Ga,Mn)As — •Rashid Gareev[1], Markus Schlapps[1], Janusz Sadowski[2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Universitätstrasse 31, 93040 Regensburg, Germany — [2]MAX-Lab, Lund University, 22100 Lund, Sweden

We describe the way to regulate giant anisotropic magnetoresistance (GAMR) in ultra thin (Ga,Mn)As by changing the amplitude of alternating current across a Hall bar. The GAMR effect is observed in the planar geometry of current below the metal-insulator transition (MIT) at T<10K in 5 nm-thick Ga0.95Mn0.05As films after annealing in optimized conditions. The GAMR manifests itself in magnetization-dependent high- and low-resistance states along different crystallographic directions. From the angular dependences of GAMR in magnetic fields of different orientation we show that in high resistive state holes are strongly localized. We demonstrate that in the localized regime a decrease of the current amplitude is accompanied by an enhancement of the GAMR. The longitudinal resistance(corresponds to the sheet resistance) change between non-equivalent easy axes exceeds ˜100% at a current amplitude I=0.2nA. The dependence of the GAMR on the current strength we ascribe to suppression of e-e interactions and hole delocalization by electric field.

HL 26.2 Tue 16:00 EW 202

Magnetic properties of GaMnN/AlGaN Heterostructures — •D. Mai, A. Bedoya Pinto, D. Ruttke, J. Malindretos, A. Rizzi, H. Schuhmann, and M. Seibt — IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

GaMnN is a prototype GaN-based dilute magnetic semiconductor. In the past we have carefully studied the growth process and epitaxial GaMnN layers with diluted concentration of Mn up to some percent

have been grown. They reproducibly show a room temperature magnetization, however with a weak saturation $M_S = 0.03$ emu cm^{-3} and a small coercive field of 250 Oe. With the aim of investigating the effect of the Fermi level position relative to the Mn induced impurity band deep in the energy gap, AlGaN/GaMnN/AlGaN heterostructures have been grown. In fact due to the polarization charges at the interfaces a strong band bending is expected in the structure, which might change the Mn charge state in certain regions of the GaMnN layer. Magnetization measurements by SQUID show ferromagnetic behaviour at room temperature with saturation magnetization by a factor 40 higher than in the samples described above. Diverse heterostructure configurations have been characterized concerning the magnetic and electric properties and the results are discussed with reference to the assumed double-exchange mechanism for the magnetic coupling.

HL 26.3 Tue 16:15 EW 202

Electronic properties of ferromagnetic (Ga,Mn)As from a tight-binding model — •Marko Turek, Jens Siewert, and Jaroslav Fabian — Universität Regensburg

We present the results of several numerical investigations of bulk (Ga,Mn)As based on a tight-binding approach. In particular we study the density of states, the absorption rate and the inverse participation ratio as a function of the concentration of substitutional Mn-disorder. We find that the impurity band merges with the valence band for Mn concentrations larger than ˜1%. The Fermi-level lies within this impurity band. The impurity states show a significantly increased inverse participation ratio which reflects their localized character. This work is supported by the SFB 689.

HL 26.4 Tue 16:30 EW 202

Magnetic circular dichroism of Cr and Gd doped GaN — •David Wenzel[1,4], Klaus Schmalbuch[1,4], Bernd Beschoten[1,4], Gernot Güntherodt[1,4], Nicoleta Kaluza[2,4], Yong Suk Cho[2,4], Hilde Hardtdegen[2,4], Thomas Schäpers[2,4], Martin Röver[3,4], Jörg Malindretos[3,4], and Angela Rizzi[3,4] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Institut für Bio- und Nanosysteme IBN-1 Forschungszentrum Jülich, 52425 Jülich — [3]IV. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [4]Virtuelles Institut für Spinelektronik (VISel), Aachen-Jülich-Göttingen

We have investigated magnetic properties of Cr and Gd doped GaN epilayers grown by MOVPE and MBE, respectively. Ferromagnetism is observed in 0.1% Cr-doped samples with Curie temperatures exceeding 600 K.

Magnetic circular dichroism (MCD) has been studied in order to probe the involved magnetic states and to reveal the nature of the magnetic exchange interaction.

The Cr doped samples show large MCD at the band edge, which is typical for diluted magnetic semiconductors. In addition, there is a large MCD between 1.9 eV and 2.3 eV.

Similar spectral features are observed in Gd doped samples with doping concentrations up to 0.1% suggesting that the MCD is not directly linked to the magnetic dopants.

Work supported by HGF and by DFG through SPP 1133

HL 26.5 Tue 16:45 EW 202

Mn modulation-doped two-dimensional hole systems — •Ursula Wurstbauer, Matthias Habl, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

In order to study the interplay of localized magnetic ions with low-dimensional charge carrier systems, we have fabricated Mn modulation-doped two-dimensional hole gases in the InGaAs/InAs material system and report on magnetotransport measurements herein. For preparation of such systems, we grow shallow single InAs quantum well (QW) structures on a strain relaxed buffer on GaAs substrates by molecular beam epitaxy. Our investigations are focused on the dependence on the doping density and the symmetry of the QW structures. Magnetotransport measurements at low temperatures exhibit pronounced SdH-oscillations in the longitudinal resistance and well developed Hall-plateaus in the Hall-resistance. Furthermore, the temperature dependent sheet resistivity increases dramatically at lower temperatures, indicating a strongly localized system for both, the inverted and double sided doped QW structures. These structures show in the mK region below a critical magnetic field insulating and hysteretic behaviour. Additional jumps in the resistance can be observed, indicating ferromagnetic interaction between the holes in the two-dimensional hole system and the magnetic moments of the Mn^{2+} ions.

HL 26.6 Tue 17:00 EW 202

Current pulse induced coherence of spin packets injected across a Fe/GaAs interface — •C. Schwark[1,5], J. Moritz[1,5], L. Schreiber[1,5], B. Beschoten[1,5], G. Güntherodt[1,5], M. Lepsa[2,5], C. Adelmann[3], C. Palmstrøm[3], and P. Crowell[4] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich — [3]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN, USA — [4]School of Physics and Astronomy, University of Minnesota, Minneapolis, MN, USA — [5]Virtuelles Institut für Spinelektronik (VISel), Aachen-Jülich-Göttingen

Efficient electrical spin injection from a ferromagnet into a semiconductor has been demonstrated for various material systems by steady-state experiments. We introduce a novel time-resolved technique based on electrical pumping and optical probing. As a pump we apply ultrafast current pulses ($\geq$ 200ps) to electrically inject spin packets from an iron layer through a reverse biased Schottky barrier into a 5 μm thick n-GaAs layer, which exhibits spin dephasing times exceeding 50 ns at 20 K. Probing the electrically injected spin packets by time-resolved Faraday rotation using a pulsed probe laser beam, we observe up to 10 lamor precessions and resonant spin amplification [1] in a transverse magnetic field. This evidences that the current pulses trigger the phase coherence of the electrically injected spin packets.

Work supported by BMBF, DFG, and HGF.

[1] J. M. Kikkawa et al., Phys. Rev. Lett. 80 (1998)

HL 26.7 Tue 17:15 EW 202

Observation of dynamic nuclear polarization in GaAs(001) quantum wells close to a GaMnAs layer — •R. Schulz, A. Wagner, T. Korn, U. Wurstbauer, D. Schuh, W. Wegscheider, and C. Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

GaMnAs is a highly interesting material system for future spintronic devices, where both, spin and charge of carriers are manipulated. Here, we present a study of nonmagnetic GaAs quantum wells (QW) embedded in AlGaAs barriers close to a ferromagnetic GaMnAs layer. The samples contain two QWs, where one QW (12nm width) is close to the GaMnAs layer, separated by a thin AlGaAs layer and a short-period superlattice AlAs/GaAs. The second QW (10 nm width) is farther away (120 nm) and serves as a reference.

Time-resolved Faraday rotation experiments reveal a significantly increased spin lifetime in the upper QW (12 nm) of about 3 ns compared to the lower QW (10 nm) of about 130 ps. This long spin lifetime causes a dynamic nuclear polarization via the hyperfine interaction and thus an effective magnetic field. By tilting the sample with respect to the pump beam, this effective magnetic field has an in-plane component, which may add to or subtract from an external in-plane magnetic field, changing the Larmor precession frequency of the electron spins depending on the sign of the magnetic field, the intensity and helicity of the circularly-polarized pump beam.

We acknowledge support by the DFG via project SCHU1171/1 and SFB 689 TP B4.

HL 26.8 Tue 17:30 EW 202

Intersubband Spin Relaxation Mechanism in n-doped [110] GaAs Quantum Wells — •Lena Schmid[1], Shijian Chen[1], Stefanie Döhrmann[1], Stefan Oertel[1], Dieter Schuh[2], Werner Wegscheider[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]Institute of Experimental and Applied Physics, University of Regensburg, Universitätsstraße 31, 93040 Regensburg, Germany

The intersubband spin relaxation mechanism most likely represents the major spin dephasing channel in room temperature applications based upon heterostructures in (110) oriented GaAs for spins oriented along the growth direction.[1] The electron spin relaxation time τ_s in n-doped (110) GaAs/AlGaAs quantum wells is investigated by time- and polarisation-resolved photoluminescence measurements in dependence on the subband energy splitting and subband occupancy. The influence by the subband energy splitting on τ_s is deduced from well width dependent measurements, whereas different occupancies are adjusted by different sample temperatures. The n-doping suppresses the spin dephasing influence of holes created by the optical excitation. The (110) structure suppresses the Dyakonov-Perel relaxation mech-

anism for spins pointing in growth direction. Therefore the resulting spin relaxation times are long even at room temperature and the intersubband spin relaxation mechanism becomes the dominating spin relaxation mechanism.
[1] S. Döhrmann et al., Phys. Rev. Lett. **93**, 147405 (2004))

HL 26.9 Tue 17:45 EW 202

Current-induced spin polarization (CISP) in InGaAs monitored by Faraday-microscopy — •A. Müller[1,3], S. Glatthaar[1,3], S. Goebbels[1,3], K. Schmalbuch[1,3], B. Beschoten[1,3], G. Güntherodt[1,3], M. Hagedorn[2,3], and T. Schäpers[2,3] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich — [3]Virtuelles Institut für Spinelektronik (VISel), Aachen-Jülich-Göttingen

Most prominent methods to create spin-polarised carriers in semiconductors include optical orientation and electrical spin injection from a ferromagnetic electrode. A novel electrical method to create spin-polarised carriers without electric or magnetic fields has recently been demonstrated by Kato et al. [1]. The so-called Current-Induced-Spin-Polarisation (CISP) as observed in InGaAs is related to internal electric fields as a result of crystal strain in the material. We investigate the steady state spin polarisation in 160 μm wide Si-doped InGaAs channels grown on GaAs, with a cw laser using a high resolution Faraday microscope in Voigt geometry. Hanle images of the CISP are systematically acquired as a function of voltage, magnetic field, and temperature. Information on the spin dephasing times and the spatial homogeneity of the CISP is extracted from these measurements. Surprisingly, we observe symmetric Hanle curves in contrast to results by Kato et al. [1], demonstrating that the spins are oriented in the out-of-plane direction.
[1] Y. K. Kato et al., PRL 93, 176601 (2004)
Work supported by DFG through SPP 1285 and by HGF

HL 26.10 Tue 18:00 EW 202

Interactions of space-charge waves with magnetic fields in the semiconductor InP:Fe — •Burkhard Hilling[1], Michaela Lemmer[1], Micro Imlau[1], Manfred Wöhlecke[1], Valerij Bryksin[2], and Mikhail Petrov[2] — [1]Department of Physics, University of Osnabrück — [2]Ioffe Physico-Technical Institute, St. Peterburg, Russia

We report on the interaction of space-charge waves (SCW) with magnetic fields in semi-insulating InP:Fe single crystals. SCW are eigenmodes of spatial-temporal oscillations of a space-charge density. The optical excitation of SCW is performed with an oscillating interference pattern at a wavelength of $\lambda = 514$ nm and externally applied static electric fields of several kV/cm. The interference pattern is generated with a two beam interferometer, where one of the beams is phase-modulated using an electro-optic modulator. An influence of the magnetic field of up to $B = 0.86$ T on the amplitude of the SCW is observed. This influence reveals a quadratic behavior and depends strongly on the orientation of the magnetic field. The observed dependences give strong evidence for a dominant contribution of the magnetoresistance to this effect. The dependence of the variations of the amplitude on the wavevector of the SCW implies that measurements with SCW inside a magnetic field can be more precise than ordinary techniques to determine the magnitude of the magnetoresistance. Furthermore, advantages of this technique for material analysis are discussed. Financial support from the Deutsche Forschungsgemeinschaft (GRK 695) is gratefully acknowledged.

HL 27: Photonic crystals III

Time: Tuesday 16:00–19:00 Location: EW 203

HL 27.1 Tue 16:00 EW 203

Cherenkov radiation in photonic crystals — •Christian Kremers, Dmitry N. Chigrin, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

We have considered modifications of Cherenkov radiation mediated by a periodic dielectric function of a general three-dimensional photonic crystal [1]. Analytical solutions for electric and magnetic fields far from the trajectory of the moving charged particle have been derived as a Bloch mode expansion within the stationary phase approximation [2]. An asymptotic analysis of the Cherenkov far-field allows to generalize the Huygens principle, which provides a simple and intuitive picture of the spatial distribution of radiated field due to charged particle moving in a periodic medium. Consistent semi-analytical expressions have been obtained for the spatial and spectral distribution of the radiated power. We have also applied this method to the analysis of Cherenkov radiation in a two-dimensional photonic crystal. The spatial and spectral distribution of radiated power for different velocities of the charged particle have been substantiated by numerically rigorous finite-difference time-domain calculations.
[1] C. Luo, M. Ibanescu, S. G. Johnson, J. D. Joannopoulos, Science **299**, 368 (2003).
[2] D. N. Chigrin, Phys. Rev. E **70**, 056611 (2004).

HL 27.2 Tue 16:15 EW 203

Defocused Imaging of Single Emitters in Photonic Crystals — •Rebecca Wagner, Frank Cichos, and Sven Zimmermann — Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

Photonic crystals are materials with a periodically varying dielectric constant. By multiple scattering of light on this spatially modulated refractive index a photonic band structure and photonic band gaps are introduced. Because of the spatial variation of the refractive index the optical density of states inside a photonic crystal is a local property too. Thus a local probe for the study of local optical properties is needed. So far this has only been achieved for 2D photonic structures by means of near field scanning microscopy. We introduce a new technique that uses single emitters inside 3D photonic crystals as probes for its local optical properties. Besides the spectral redistribution of their emission which can be observed in an altered emission spectrum there occurs also an angular redistribution. This anisotropic emission of the embedded emitters can be imaged by defocused fluorescence microscopy since it modifies their defocused imaging patterns. This is shown with extensive calculations and experimental studies. A fitting procedure is introduced to extract the angular dependence of the photonic stop band from the experimental results.

HL 27.3 Tue 16:30 EW 203

Efficiency optimization for constructing maximally localized Wannier functions — •Tobias Stollenwerk, Dmitry N. Chigrin, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

The Wannier function approach is well suited for the description of photonic crystal based structures. The efficiency of this approach crucially depends on the degree of localization of the Wannier functions in real space. Due to the phase indeterminacy of the Bloch functions the problem of obtaining maximally localized Wannier functions is reduced to the problem of finding an optimal set of phases and is an optimization problem in parameter space of large dimensionality. In that respect, questions like, definition of the locality criterion or the choice of the optimization method, are of great importance.

We have systematically analyzed maximally localized Wannier functions of two-dimensional square and triangular lattice photonic crystals for both fundamental polarizations. Two definitions of the locality criterion have been introduced, namely the integrated modulus in the first unit cell and the second moment of the Wannier function. We have used the standard conjugate gradient optimization scheme as well as a genetic algorithm based stochastic algorithm to solve the optimization problem. We report on "pros-and-cons"of the different locality criteria and optimization methods applied to the problem of constructing maximally localized Wannier functions in photonic crystals.

HL 27.4 Tue 16:45 EW 203

Retrieving angle dependent effective parameters of metamaterials — •Christoph Menzel[1], Thomas Paul[1], Carsten Rockstuhl[1], Thomas Pertsch[2], and Falk Lederer[1] — [1]Institut für Festkörpertheorie- und optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland — [2]Institut für angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

The retrieval of effective parameters of metamaterials (MM) can be made with various approaches. The most common employs the reflected and transmitted amplitude at a finite MM slab. Inverting the analytical expression for reflection and transmission at a slab composed of a homogenous isotropic media having an arbitrary permittivity and permeability, allows to solve for them. This technique, and all the other approaches, are employed up to now only for normal incidence; providing only insufficient insights into the MM properties. For example, applying MMs as a perfect lens requires them to have an angle independent effective permittivity and permeability of both being -1, which has yet to be elucidated. In this contribution we outline how to extend this algorithm to predict the effective properties as a function of the angle of incidence and the polarization. The necessary requirements and the assumptions on the media's properties are outlined. The algorithm is applied exemplarily to determine the angle dependent properties of a fishnet structure. The properties are investigated as a function of the number of layers the MM is made of.

HL 27.5 Tue 17:00 EW 203

The Goos-Hänchen and Imbert-Fedorov shift at metamaterial interfaces — •Thomas Paul, Christoph Menzel, Carsten Rockstuhl, and Falk Lederer — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

Illuminating an interface separating two half-spaces with a finite beam at an incident angle larger than the critical angle of total internal reflection causes the reflected beam to be translated in space when compared to the incident one. A longitudinal displacement is usually called the Goos-Hänchen shift, a transversal the Imbert-Fedorov shift. Here we will reveal the peculiarities that occur if the reflecting media is not a natural homogenous but an artificial nanostructured media. We investigate at first photonic crystals (PCs). We show that beam shifts observable at such media are deducible from the dispersion relation of the Bloch modes in the infinite PC. As the second part, we will investigate beam shifts at the interfaces of metamaterials (MM), where a simultaneous strong dispersion in the permittivity and permeability can occur in finite spectral domains. Independent of the particular media we investigate at first the necessary symmetry conditions of the beam that have to be met in order to observe any of the shifts or both simultaneously. We present rigorous calculations which are compared to predictions achieved from classical models, namely the Artmann- or the Renard model. We outline configurations which allow observing giant shifts in both geometries, where emphasis is put on a giant Imbert-Fedorov shift.

15 min. break

HL 27.6 Tue 17:30 EW 203

Anderson localization and correlation length in random lasers — •Regine Frank, Andreas Lubatsch, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We present a systematical theory for the interplay of strong localization effects and absorbtion or gain of classical waves in 3-dimensional, disordered dielectrics, which is based on a selfconsistent resummation of self-interference (Cooperon) contributions. In the presence of absorption or gain, Anderson localized modes do not exist in a strict sense. However, in the case of linear gain (i.e. exponential intensity growth), causality in connection with the Cooperon pole structure predicts the appearance of a new *finite* length scale, which we interpret as the coherence length ξ of a random laser mode. A characteristic dependence of ξ on the gain intensity is found, consistent with experiments. In addition, we solve the fully time dependent problem of the laser rate equations of a 4-level laser (i.e. non-linear gain), coupled to the random gain medium, where the transport of light in the random medium is treated by the self-consistent Cooperon resummation. The results are compared with our semianalytic calculations for the case of linear gain.

HL 27.7 Tue 17:45 EW 203

Lasing and selected physical Properties of Photonic Composites obtained by doping of Liquid Crytsals with Nanomaterials — •Wolfgang Haase and Fedor Podgornov — Eduard-Zintl-Institute for Inorganic and Physical Chemistry, Darmstadt University of Technology, Petersenst. 20, D 64287 Darmstadt

We will report on some physical properties obtained by doping of Liquid Crystals (LC)/Ferroelectric Liquid Crystals (FLC) with different Nanomaterials as are Single Walled Carbon Nanotubes (SWCNT), Titaniumdioxide, Bariumtitanate. Tunable Lasing on cholesteric-nematic Nanocomposites could be obtained. Several electrooptical properties as are switching time, spontaneous polarization will be reported. The dielectric spectra of FLC/SWCNT show remarkable reduction of the absorption intensity, this has been interpreted as due to trapping of ions/charges on the interface FLC/SWCNT.

HL 27.8 Tue 18:00 EW 203

Polaritonic band gaps in gold films covered with high-refractive index gratings — •Alexander Sprafke, Karl Weis, and Gero von Plessen — I. Institute of Physics (1A), RWTH Aachen University, 52056 Aachen, Germany

In structured noble-metal films, surface-plasmon polaritons (SPPs) can be excited optically. SPPs consist of electromagnetic surface waves accompanied by longitudinal electron-density waves. Polaritonic crystals made from planar metal films covered with dielectric gratings have been shown to exhibit band gaps in the plasmon-polariton dispersions. Here, we investigate the polaritonic band gaps of gold films coated with high-refractive index ($n > 2$) gratings. The dependence of the band-gap width on the refractive index and filling factor of the gratings is studied experimentally and theoretically. In particular, the ultimate limits on the band-gap width achievable in these structures are discussed.

HL 27.9 Tue 18:15 EW 203

Theory of light localization in absorbing, disordered photonic crystals — •Andreas Lubatsch, Regine Frank, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We discuss light propagation in three dimensional photonic crystals exhibiting both, disorder in the scattering strength and absorption effects. To calculate transport quantities such as the diffusion coefficient, we use a systematical, semi-analytical theory based on a self-consistent Cooperon resummation of scalar waves. The presented theory takes into account the bandstructure of the photonic crystal as well as the non-conserving properties of the medium. The non-critical quantities, representing the effective medium, are self-consistentently calculated in the coherent potential approximation (CPA).

HL 27.10 Tue 18:30 EW 203

Electromagnetic Green's dyadic: finite difference time domain formulation — •Dmitry Chigrin — Physikalisches Institut, Universitaet Bonn, Nussallee 12, D-53115 Bonn, Germany

The electromagnetic Green's function (dyadic) is a central object in many topics of theoretical and computational electrodynamics. The knowledge of the Green's function for a given medium provides directly information about, e.g., the radiation dynamics of excited atoms in this medium or scattering processes on the medium inhomogeneities. In the same time, the finite-difference time-domain method (FDTD) is known to be very powerful and popular numerical tool of computational electrodynamics. Being simple in implementation and numerically rigorous in nature this method suits very well for large scale electrodynamics problems. In this presentation, an extension of the FDTD method for direct calculation of the electromagnetic Green's function will be discussed. An appropriate choice of initial and boundary conditions will be considered. An application of the method to the study of the radiation dynamics of two-level atom in a finite two-dimensional photonic crystal will be presented.

HL 27.11 Tue 18:45 EW 203

On the dispersion relation of light in metamaterials — •Carsten Rockstuhl[1], Christoph Menzel[1], Thomas Paul[1], Thomas Pertsch[2], and Falk Lederer[1] — [1]Institut für Festkörpertheorie- und optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland — [2]Institut für angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

The characterization of metamaterials (MM) is usually restricted to the determination of the effective parameters of a thin film at normal incidence. However, such information is of limited use as firstly, the parameters deduced from a thin film might differ from the bulk and secondly, the effective properties as encountered by a plane wave that propagates at an angle deviating from a crystallographic axis are not elucidated. Here will give an answer on how to obtain information on these properties. At the heart we will analyse the dispersion relation of Bloch periodic eigenmodes in MMs and describe how to deduce an

effective refractive index. This index will be compared with an index as retrieved from the reflected and transmitted amplitude of a plane wave at a finite MM slab. The analysis is done as a function of the frequency, the angle of incidence, and the polarization. Although both indices are in excellent agreement, we will argue that such an index ceases to have a meaning as a material but has to be understood as a wave parameter only. Such an index is only of use to describe the light propagation through the MM in a simplified manner. We will quantify properties in MMs such as anisotropy, and spatial and temporal dispersion.

HL 28: Transport properties

Time: Tuesday 9:30–12:00 Location: ER 164

HL 28.1 Tue 9:30 ER 164

Influence of electronic correlations on the frequency-dependent hopping transport in Si:P — •Elvira Ritz and Martin Dressel — 1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550, Stuttgart

At low energy scales charge transport in the insulating Si:P is by activated hopping between the localized donor electron states. Theoretical models for a disordered system with electron-electron interaction are appropriate to interpret the electric conductivity spectra [2]. With a novel and advanced method [3,4] we have measured the complex broadband microwave conductivity of Si:P from 0.1 to 5 GHz in a broad range of phosphorus concentration from 0.56 to 0.95 relative to the critical value $n_c = 3.5 \times 10^{18}$ cm^{-3} corresponding to the metal-insulator transition driven by doping. At T=1.1 K the samples show a super-linear frequency dependence of the conductivity indicating the influence of the Coulomb gap. At higher doping $n \to n_c$, an abrupt drop in the conductivity power law $\sigma_1(\omega) \sim \omega^\alpha$ is observed. The dielectric function ε_1 increases upon doping following a power law in $(1 - n/n_c)$. Dynamic response at elevated temperatures is also discussed.

[1] E. Ritz and M. Dressel, arXiv:0711.1256, in print

[2] B. I. Shklovskii and A. L. Efros, Zh. Eksp. Teor. Fiz. **81**, 406 (1981) [Sov. Phys. JETP **54**, 218 (1981)]

[3] M. Scheffler and M. Dressel, Rev. Sci. Instrum. **76**, 074702 (2005)

[4] E. Ritz and M. Dressel, to be published

HL 28.2 Tue 9:45 ER 164

Ballistic rectification in density-modulated 2D-systems — •Arkadius Ganczarczyk, Christian Notthoff, Bastian Marquardt, and Axel Lorke — Experimental Physics, Universität Duisburg-Essen and CeNIDE, Lotharstraße 1, 47057 Duisburg, Germany

We examine carriers in a 2-dimensional electron gas, which move ballistically along a boundary between two areas with different carrier densities. A voltage in the direction of the density-gradient (perpendicular to the applied current) is observed. The polarity of the transverse voltage depends on the direction of the density gradient and corresponds to a net current, which flows from the higher carrier density area to the lower density area. The direction of the transverse voltage is independent of the current polarity, which demonstrates rectification in the device. We also show that the transverse voltage depends on the relative variation of the carrier densities and the carrier mobility and has a parabolic dependence on the applied longitudinal bias. A theoretical model was developed for ballistic transport in density-modulated 2D-system, which includes the electric field needed to drive the applied current. This model is able to reproduce all major aspects of the experimental measurements. For small longitudinal currents experimental and simulated results agree well. However, the transverse voltage depends linearly on the longitudinal current whereas the experiment shows a parabolic dependence. This indicates that the presence of the transverse voltage cannot be fully described with a simple ballistic model.

HL 28.3 Tue 10:00 ER 164

Electron transmission through magnetic barriers displaced in B-space — Stefan Hugger, •Mihai Cerchez, Hengyi Xu, and Thomas Heinzel — Heinrich-Heine Universität, 40225 Düsseldorf

An inhomogeneous magnetic barrier was created in a Hall bar defined in a GaAs-AlGaAs two-dimensional electron gas, by the stray field present under the edge of a dysprosium magnetic film evaporated on top of the structure [1]. Tilting the sample by small angles around the position in which the field is parallel to the Hall bar in the current direction, one superimposes the perpendicular homogenous component of the applied field, and so shifts the magnetic barrier in B-space, while the magnetic barrier height remains constant to a good approximation. While the magnetic barrier is closed, we show that this experiment changes the balance between different mechanisms of transmission across the magnetic barrier, namely edge orbits, snake orbits and scattering. This produces a minimum in the resistance variation with the perpendicular homogenous field component, position of which depends on the height of the magnetic barrier [2]. The process is simulated with a Landauer-Büttiker model [3] with experimentally determined parameters. The simulations produce excellent agreement to the experiment.

[1] M. Cerchez et al, Phys. Rev. B 75, 035341 (2007)

[2] S. Hugger et al, arXiv:0708.2032, (2007)

[3] M. Büttiker, Phys. Rev. Lett. 57, 1761 (1986)

HL 28.4 Tue 10:15 ER 164

The minimum conductivity of graphene within quasiclassical approach — •Maxim Trushin and John Schliemann — Institut für Theoretische Physik Universität Regensburg D-93040 Regensburg

We investigate the minimum conductivity of graphene within a quasiclassical approach taking into account electron-hole coherence effects (or Zitterbewegung contributions) which stem from the chiral nature of low energy excitations. Relying on an analytical solution of the kinetic equation we study the carrier scattering on both short and long range scatterers. At the end we found a way how to distinguish between samples with the domination of short and long range scatterers from the minimum conductivity measurements. The model proposed qualitatively explains recent experiments with chemical doping of graphene [1]. Our findings concerning the short range scatterers can be found in Ref.[2].

[1] J. H. Chen, C. Jang, M. S. Fuhrer, E. D. Williams, M. Ishigami arXiv:0708.2408

[2] M. Trushin and J. Schliemann arXiv:0706.1888

HL 28.5 Tue 10:30 ER 164

Ab-initio modelling of thermodynamics and kinetics of point defects in indium oxide — •Péter Ágoston[1], Paul Erhart[2], Andreas Klein[1], and Karsten Albe[1] — [1]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt — [2]Lawrence Livermore National Lab, California, USA

The electrical and optical properties of indium oxide films strongly vary with the processing parameters. Especially the oxygen partial pressure and temperature determine properties like electrical conductivity, composition and transparency. Since this material owes its remarkable properties like the intrinsic n-type conductivity to its defect chemistry, it is important to understand both, the equilibrium defect thermodynamics and kinetics of the intrinsic point defects. In this contribution we present a defect model based on DFT total energy calculations using the GGA+U method. Further, the nudged elastic band method is employed in order to obtain a set of migration barriers for each defect species. Due to the complicated crystal structure of indium oxide a Kinetic Monte-Carlo algorithm was implemented, which allows to determine diffusion coefficients. The bulk tracer diffusion constant is predicted as a function of oxygen partial pressure, Fermi level and temperature for the pure material.

HL 28.6 Tue 10:45 ER 164

Flexural phonons in free-standing graphene — •Eros Mariani and Felix von Oppen — Fachbereich Physik, Freie Universitaet Berlin, Arnimallee 14, D-14195 Berlin (Germany)

Rotation and reflection symmetries impose that out-of-plane (flexural) phonons of free-standing graphene membranes have a quadratic dispersion at long wavelength and can be excited by charge carriers in pairs only. As a result, we find that flexural phonons dominate

the phonon contribution to the resistivity ρ below a crossover temperature T_x where we obtain an anomalous temperature dependence $\rho \propto T^{5/2} \ln T$. The logarithmic factor arises from renormalizations of the flexural phonon dispersion due to coupling between bending and stretching degrees of freedom of the membrane.

HL 28.7 Tue 11:00 ER 164

electronic transport in graphene nanoribbons calculated with recursive green's functions — •Hengyi Xu[1], Igor Zozoulenko[2], and Thomas Heinzel[1] — [1]Heinrich-Heine Universität, Düsseldorf, Germany — [2]Department of Science and Technology, Linköping University, Sweden

Graphene demonstrates some unique electronic properties. We have developed the recursive Green's function technique within the tight-binding model for the mesoscopic graphene which provides a simple and elegant way of accounting for the effects of the contacts. The nanoribbon and the contacts are assumed to be made of graphene and are modeled by appropriate on-site and hopping parameters. Based on this technique, we study the electronic states and transport properties of the narrow graphene ribbons with zigzag and armchair edges. The energy spectra with zigzag and armchair edges are similar to those of the armchair and zigzag carbon nanotubes. Using the Landauer formula approach, the mode-dependent conductance through the electrostatic potential barriers in the graphene ribbons is investigated. We found that the quantized conductance as a function of Fermi energy exhibits the coherent oscillations in the zigzag edge graphene. Also, conductance dips are present which are absent in the armchair edge graphene. In addition, electronic transport in the presence of disorder is studied.

HL 28.8 Tue 11:15 ER 164

Electrical transport properties of GaGdN epitaxial layers — •Amilcar Bedoya Pinto, Martin Roever, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August Universität Göttingen, D-37077 Göttingen, Germany

In the last years, the rare-earth element Gd has gained great attention as a magnetic dopant in the wide-gap semiconductor GaN, due to the unexpected high magnetic moment per Gd-atom induced in the host matrix at very low Gd-concentrations. In the DMS theory, ferromagnetic coupling is often linked to electrical transport. However, less is known about the electrical transport properties in Gd-doped GaN. For this purpose, GaGdN layers (d=500nm) have been grown by MBE on semi-insulating 6H(0001) SiC substrates. We find that Gd-doping increases the resistivity up to four orders of magnitude compared to unintentionally doped GaN, showing a temperature dependence ($T^{-1/2}$) in the low temperature-range (<60K), which is characteristic of hopping conductivity in an impurity band of localized states in the gap. In order to find out whether this impurity band is created by the spin-splitted f-states of Gd or rather by structural defects, samples with different Gd concentrations are studied. In addition, transport properties of silicon co-doped samples might clarify whether carriers play a role in mediating the observed ferromagnetism in this material system.

HL 28.9 Tue 11:30 ER 164

Real-space-real-time description of quantum transport in finite systems — •Esa Rasanen, Heiko Appel, Alberto Castro, and E.K.U. Gross — Freie Universitat Berlin, Germany

We have applied time-dependent density-functional theory (TDDFT) to investigate the electron flow through various two-dimensional (2D) structures. The finite 2D computing region is divided into (i) the time-independent quantum-dot reservoir initially filled with electrons and (ii) a time-dependent channel which contains a device potential (scattering center) of a desired shape at the center. First, the static Kohn-Sham equation is solved for the electrons in the reservoir. Thereafter, the ground-state Kohn-Sham wave functions are used as initial states and are propagated on the potential landscape smoothly connected to the reservoir, so that the electrons can enter the channel freely at times $t > 0$. The charge flow through the channel and device region is driven solely by the wave-packet dispersion and electron-electron repulsion. There is no external bias. We monitor the current density at different points in space until the unrealistic back-scattering effects due to the finite simulation area distort the description of a real infinite system. In several test cases, however, our approach leads to excellent agreement with the nonequilibrium Green's function method. Until now, we have applied our TDDFT approach in the level of adiabatic local-density approximation to simulate charge transport through quantum rings and quantum-point contacts in static, uniform magnetic fields.

HL 28.10 Tue 11:45 ER 164

Adaptive Finite Element Simulations of Ballistic Semiconductor Devices — •Stephan Kramer[1], Oliver Bendix[2], Kai Bröking[2], Ragnar Fleischmann[2], and Theo Geisel[2] — [1]Institut für Theoretische Physik, 37077 Göttingen — [2]Max-Planck-Institut für Dynamik und Selbstorganisation, 37073 Göttingen

Simulating the quantum mechanics of a ballistic semiconductor device requires the treatment of a stationary Schrödinger equation in a complex geometry with a great variety of boundary conditions. The presence of strong magnetic fields induce steep gradients on the wave function which impose high demands on the numerical methods.

We have implemented a finite-element simulation based on deal.II [1] equipped with several adaption schemes for the triangulation of the domain of the physical problem. This allows for resolving the details of the wave function on different length scales in different parts of the geometry. Especially in the area of the contacts of the device, where we have to calculate the wave function with great accuracy, we can locally employ a high grid resolution, whereas in other regions the mesh is kept coarse. This decreases the computational effort, only making it possible to run simulations for a sufficiently large number of magnetic fields to reproduce experimental results.

We use the computation of the transmission properties of a magnetic focussing device [2] from the scattering matrix as an example to demonstrate the benefits of a locally adaptive simulation code.

[1] www.dealii.org
[2] Nature Physics 3, 464 - 468 (2007)

HL 29: New materials

Time: Tuesday 12:00–13:15 Location: ER 164

HL 29.1 Tue 12:00 ER 164

Heusler compounds as thermoelectric materials — •Joachim Barth[1], Benjamin Balke[1], Fred Casper[1], Gerhard H. Fecher[1], Juergen Winterlik[1], Claudia Felser[1], Rosa Roberts[2], Andre Shkabko[2], and Anke Weidenkaff[2] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Empa - Materials Science and Technology, Ueberlandstrasse 129, CH-8600 Duebendorf

Thermoelectric materials have gathered a lot of interest in the recent years. They can be either used in power generating devices or in heating and cooling systems. Several materials show interesting properties; among them are the Heusler and Half-Heusler compounds. These materialclasses are of special interest because they are very diverse and can be easily tuned to the needs of applications. To illustrate the diversity and tunability of these materials several compounds and the creating process are presented.

The process of finding promising materials includes three steps. At first we use band structure calculations to identify promising compounds. In the second step we synthesize them by arcmelting, which is followed by annealing. During the final step we characterize them by measuring XRD, electrical and thermal conductivity and Seebeckcoefficient. The quality of the compounds as thermoelectric materials is determined by the Power Factor and the Figure of merit.

HL 29.2 Tue 12:15 ER 164

Orientational ordering and intermolecular interactions in the rotor-stator compounds $C_{60}{\cdot}C_8H_8$ and $C_{70}{\cdot}C_8H_8$ under pressure — •Komalavalli Thirunavukkuarasu[1], Chirstine A. Kuntscher[1], Gyula Bényei[2], István Jalsovszky[2], Gyöngyi Klupp[3], Katalin Kamarás[3], Éva Kováts[3], and Sándor Pekker[3] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Department of Organic Chemistry, Eötvös Loránd University, P.O.Box 32, Budapest, Hungary H 1518 — [3]Research Insti-

tute for Solid State Physics and Optics, Hungarian Academy of Sciences,P.O.Box 49, Budapest, Hungary H 1525

The fullerene-cubane molecular crystals $C_{60}{\cdot}C_8H_8$ and $C_{70}{\cdot}C_8H_8$ are the first members of the rotor-stator crystal family [1]. Static C_8H_8 molecules occupy the octahedral voids of the fullerene fcc structure and act as bearings for the rotating fullerene molecules. On cooling, $C_{60}{\cdot}C_8H_8$ undergoes a phase transition at 140 K due to orientational ordering of the C_{60} molecules, while $C_{70}{\cdot}C_8H_8$ undergoes transitions at around 390 K and 150 K. A first pressure-dependent transmittance study revealed an orientational ordering transition in $C_{60}{\cdot}C_8H_8$ induced at 0.8 GPa [2]. We have extended our spectroscopic studies to a broad frequency range for both $C_{60}{\cdot}C_8H_8$ and $C_{70}{\cdot}C_8H_8$ to monitor the vibrational properties and the absorption edge as a function of pressure. The nature of the observed anomalies and the electronic properties under pressure will be discussed. *Supported by the DFG.* [1] S. Pekker et al., Nature Materials **4**, 764 (2005). [2] C. A. Kuntscher et al., Phys. Stat. Sol. (b) **243**, 2981 (2006).

HL 29.3 Tue 12:30 ER 164

Numerical simulation of a fractal meta structure in the microwave regime — •Ernst Lenz, Benjamin Meier, and Heino Henke — TU Berlin, Fachgebiet Theoretische Elektrotechnik EN-2, Einsteinufer 17, 10587 Berlin, Germany

Metamaterials are artificial structures with novel and promising properties [1,2,3,4]. To reduce the unwanted scattering and diffraction effects of incoming electromagnetic waves it is necessary to achieve a higher degree of homogenization [1]. Therefore usually the unit cell size d is varied, while the wavelength λ remains constant.

We present simulation results of a fractal meta structure where we have replaced the well known split ring resonator (SRR) [2,3] by two concentric Koch snowflakes [5]. In that way a remarkable reduction of the resonance frequency could be achieved as compared to the SRR structure of the same spatial extent. Furthermore this results in a higher degree of homogenization of the introduced meta structure. Additionally we show that left-handed behavior is supported by simulation results as well as obtained by experimental data.

[1] V. G. Veselago, Sov. Phys. Usp. **10**, 509 (1968). [2] J. B. Pendry et al., IEEE-TMTT **47**, 2075 (1999). [3] D. R. Smith et al., PRL **84**, 4184 (2000). [4] N. Engheta et al., IEEE-TMTT **53**, 1535 (2005). [5] K. J. Falconer, *Fraktale Geometrie*, Spektrum, Berlin (1990).

HL 29.4 Tue 12:45 ER 164

Beaded carbon nanofilament via chemical vapor deposition — •Li Song[1], Alexander W. Holleitner[2], Huihong Qian[3], Achim Hartschuh[3], Eva M. Weig[1], and Jörg P. Kotthaus[1] — [1]CeNS und Fakultät für Physik, Ludwig-Maximilians-Universität, 80539 München — [2]Walter Schottky Institut, Technische Universität München, 85748 München — [3]Department für Chemie, Physikalische Chemie, Butenandtstr. 5-13, 81377 München

Due to their low density and extraordinary mechanical properties, carbon filaments and fibers have large commercial applications as reinforcements in composite materials. In order to transfer the maximum load onto the filaments, the interfacial strength between the host matrices and the filaments should be as high as possible. The interfacial strength mostly depends on the surfaces and shapes of the reinforcing filaments. Here, we present a chemical vapor deposition method to synthesize carbon nanofilaments with carbon beads on their surface. The stems of the nanofilaments typically show an average diameter of about 60 nm, while the diameter of the beads is in the range of 200-400 nm. By SEM and AFM analysis we find a necklace-like structure of the carbon nanofilaments. Raman spectra reveal that the beads are made of graphite, while the stems are multi-walled carbon nanotubes admixed with graphite and carbon fibers. The beaded carbon nanofilaments may have applications as reinforcing agents because the mechanical interlocking between beads can produce stronger interfacial adhesion.

HL 29.5 Tue 13:00 ER 164

AVD and ALD developments for next generation MIM capacitors and memory applications — Peter K. Baumann, Christoph Lohe, and •Michael Heuken — AIXTRON AG, Aachen, Germany

Atomic layer deposition (ALD) enables deposition of electrode, dielectric and barrier layers on high aspect ratio trench structures and has been widely used. However, due to its nature the throughput is typically limited. Atomic vapor deposition (AVD®) is a special type of metal organic vapor deposition (MOCVD) that enables deposition with high precursor gas phase saturation. This results in improved throughput while maintaining conformal deposition on moderate aspect ratio trench structures. Based on the International Roadmap for Semiconductors (ITRS) for front end, for DRAM at the 50nm and below technology node metal-insulator-metal (MIM) structures will be required [1]. Also conformal step coverage on structures with aspect ratios of 1:60 and higher as well as an equivalent oxide thickness (EOT) of less than 1nm will be necessary. Other memory applications (e.g. phase change memory) require less advanced aspect ratios, opening possibilities for AVD®. ALD and AVD® have been used to deposit electrode and dielectric films based on e.g. TiN, Ru, TaSiN as well as HfO_2, ZrO_2, Al_2O_2. Results for the different deposition techniques and various process conditions will be presented and compared considering use for memory applications.

[1] Front end, International Roadmap for Semiconductors (Semiconductor Industry Association, Palo Alto 2006 update).

HL 30: Quantum dots and wires: Transport properties II

Time: Tuesday 14:15–17:45 Location: ER 164

HL 30.1 Tue 14:15 ER 164

Mesoscopic Optoelectronic Transport Across Lithographically Defined Quantum Wires — •K.-D. Hof[1], S. Manus[1], W. Wegscheider[2], J. P. Kotthaus[1], and A. W. Holleitner[3] — [1]Fakultat fur Physik and Center for NanoScience, LMU Munich. — [2]Institut fur Angewandte Physik, University Regensburg. — [3]TU Munich, Walter Schottky Institut, Am Coulombwall 3, 85748 Munich.

We report on optoelectronic transport phenomena in quasi one-dimensional wires which are lithographically defined in a quantum-well semiconductor heterostructure. The main focus of our experiments is to study mesoscopic transport phenomena of an optically induced, non-equilibrium charge population in the diffusive and the ballistic regime at the transition from a two-dimensional to a one-dimensional electron system [1,2]. We optically excite charge carriers in the quantum well at a specific distance to a quantum wire and measure the photo-induced conductance across the quantum wire. The electron dynamics are studied as a function of the excitation distance, photon wavelength, source-drain voltage, an external magnetic field, and a gate voltage applied to an electrode close to the quantum wire. We discuss effects of heat dissipation, excess charge tunneling, exciton recombination and non-equilibrium transport dynamics.

We gratefully acknowledge financial support from BMBF (nanoquit), DFG (Ho 3324/4), the Center of NanoScience (CeNS) in Munich, and the Nanosystem Initiative Munich (NIM).

[1] A. W. Holleitner et al., Phys. Rev. Lett. 97, 036805 (2006).
[2] K.-D. Hof et al., Physica E, in press.

HL 30.2 Tue 14:30 ER 164

Coherent Spin Rotations in Double Quantum Dots — •Rafael Sanchez, Carlos Lopez-monis, and Gloria Platero — Instituto de Ciencia de Materiales, CSIC, Madrid 28049, Spain

We analyze coherent spin rotations in a DC biased double quantum dot driven by crossed DC and AC magnetic fields. In this configuration, spatial delocalization due to inter-dot tunneling competes with intra-dot spin rotations induced by the time dependent magnetic field, giving rise to a complicated time dependent behavior of the tunnelling current which strongly depends on the ratio between the different Rabi frequencies involved. When the Zeeman splitting has the same value in both dots and spin flip is negligible, the electrons remain in the triplet subspace performing coherent spin rotations and current does not flow. This electronic trapping is removed either by finite spin relaxation or when the Zeeman splitting is different in each quantum dot. In the last case, we will show that applying a resonant bi-chromatic magnetic field, the electrons become trapped in a coherent superposition

of states and electronic transport is blocked. Then, manipulating AC magnetic fields allows to drive electrons to perform coherent spin rotations which can be unambiguously detected by direct measurement of the tunnelling current.

HL 30.3 Tue 14:45 ER 164

Write/erase time of nanoseconds in quantum dot based memory structures — •Tobias Nowozin, Andreas Marent, Martin Geller, and Dieter Bimberg — Institut fuer Festkoerperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

We have developed a novel charge-storage memory concept based on III-V semiconductor quantum dots (QDs) [1] which has a number of fundamental advantages over conventional Si/SiO_2 floating gate memories (Flash): material-tunable and voltage-tunable barriers for improved intrinsic speed and/or storage time and high endurance. To investigate the potential of this new memory concept we have determined intrinsic write/erase times in memory structures based on InAs/GaAs and GaSb/GaAs QDs using capacitance-voltage spectroscopy. We measured a write time below 15 ns independent of the localization energy (i.e. the storage time) of the QDs. This write time is more than three orders of magnitude faster than in a Flash cell and already below the write time of a dynamic random access memory (DRAM). The erase time was determined to be 42 ns for InAs/GaAs QDs and 1.5 ms for GaSb/GaAs QDs for applied electric fields of 166 kV/cm and 206 kV/cm, respectively. From these results we derive an erase time of 1 ns in GaSb QDs for an electric field of 330 kV/cm.

[1] M. Geller, A. Marent, and D. Bimberg, "A non-volatile memory based on semiconductor nanostructure", CPT patent application, (2006).

HL 30.4 Tue 15:00 ER 164

Coulomb blockade energies in the shape-modified InAs quantum dots — •Razvan Roescu, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany

Rapid thermal annealing (RTA) and an Indium flush technique are methods commonly used to blue-shift the emission wavelengths for self-assembled InAs quantum dots (QDs). These methods induce modifications in the shape and the composition of the QDs. By employing capacitance-voltage spectroscopy we show that carrier-carrier interactions in such modified QDs are also affected. The Coulomb blockade energy in the ground state - the energy paid by the second electron (or hole) to enter the dot when there is already one carrier inside - is found to decrease significantly with decreasing emission wavelength if the RTA process was used, whereas it stays almost constant if the In flush technique was employed to shift the emission wavelength. These findings can be correlated to the differences in the resulting QD shape for the two different processes used. The decrease in Coulomb blockade energy for the RTA process is consistent with the results of wave function mapping, pointing to an increase in the wave function extension with decreasing emission wavelength.

HL 30.5 Tue 15:15 ER 164

Back-action of a biased quantum point contact on an unbiased double quantum dot — •Daniela Taubert[1], Daniel Harbusch[1], Hans-Peter Tranitz[2], Werner Wegscheider[2], and Stefan Ludwig[1] — [1]Center for NanoScience and Department für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We experimentally study the back-action of a quantum point contact (QPC) on a widely tunable double quantum dot (DQD) in the few electron regime. This nanostructure is electrostatically defined in the two-dimensional electron gas of a high mobility AlGaAs/GaAs heterostructure. The stability diagram of the unbiased DQD is measured using the QPC as charge detector. For this biasing the QPC is necessary, thus causing it to act additionally as a non-equilibrium energy source.

The influence of this source of energy can be seen in the stability diagram: In the regime of small tunnel coupling between one of the dots and the leads we observe disappearing charging linees. Increasing the QPC bias voltage causes reappearance and an additional shift of these charging lines which points to a non-equilibrium situation with modified tunneling rates.

Within a simple model we consider absorption of energy quanta originating from the non-equilibrium energy source by the DQD. The modification of tunneling rates caused by this energy transfer explains our findings.

HL 30.6 Tue 15:30 ER 164

Fermi-edge Singularity in 2D-0D Resonant Tunneling Through A Self-Assembled Quantum Dot — •Michael Rüth, Anatoliy Slobodskyy, Charles Gould, Georg Schmidt, and Laurens Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074

We report on transport experiments on a single self-assembled CdSe quantum dot. In this sample, the zero-field signal displays clear resonant tunneling behavior, with a peak-to-valley ratio of 6.7 at T=1K. Moreover, the I/V-curve is clearly indicative of the occurrence of Fermi-edge singularity behavior in this system. No other resonance signal can be found within a range of 100mV, therefore we assume that only one quantum dot contributes to the tunneling transport in this voltage range. The effect shows high temperature stabilty, the peak current only decreases by a factor of 4 from 1K to 40K. For magnetic fields up to 16T, applied perpendicular to the surface, we observe multiple Landau level structures in the current-voltage characteristics, which provides evidence that the electrons in the ZnSe contact are confined to 2 dimensions. The maximum peak current occurs at B≈12T, a possible cause being a field enhanced FES [1].

[1] E.E. Vodin, Yu. N. Khanin, O.Makarovsky, Yu. V. Dubrovskii, A. Patanè, L. Eaves, M. Henini, C.J. Mellor, K.A. Benedict and R. Airey, Phys. Rev. B75, 115315 (2007)

HL 30.7 Tue 15:45 ER 164

Two path transport measurements on a triple quantum dot — •Maximilian C. Rogge and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We present a novel triple quantum dot device made with local anodic oxidation on a GaAs/AlGaAs heterostructure. The geometry provides two path transport via a three lead setup with each lead connected to one of the three quantum dots. In addition charge detection is implemented via a quantum point contact. One lead is used as a common source contact, the other two are used as two separate drain contacts with independent current measurement. Thus two paths are formed with two dots in each path. Along both paths serial transport is observed at the triple points of the two corresponding dots. With four side gates a wide tunability is given. Thus the system can be tuned in and out of triple dot resonances. When all three dots come into resonance, quadruple points are formed with simultaneous transport along both paths. The data are analysed in combined two colour plots and compared to the charge detection showing sets of three different lines, one for each dot. This way the two path setup allows to investigate the transition from double dot physics to triple dot physics.

15 min break

HL 30.8 Tue 16:15 ER 164

A GaAs/AlAs vertical resonant tunneling nano-transistor: processing and electrical characterization — Jakob Wensorra[1], •Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1,2], Arno Förster[3], Hans Lüth[1], and Detlev Grützmacher[1] — [1]Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]FH Wiesbaden, University of Applied Sciences, Information Technology and Electrical Engineering, Am Brückweg 26, D-65428 Rüsselsheim — [3]FH Aachen, University of Applied Sciences and Technology, Ginsterweg 1, 52428 Jülich

For our experiment, vertical sub-100nm nanoculumns have been processed firstly, starting from an MBE grown GaAs/AlAs resonant tunneling heterostructure [1]. The top down approach is based on electron-beam (E-B) lithography of hydrogen silsesquioxan (HSQ), as mask material, and subsequent dry etching processes for the column definition. HSQ have been used also to planarize and isolate the device electrodes. Metallic gates have been positioned around the nanocolumns, at the level of the double barrier quantum well structure, by precise etching of the dielectric and E-B lithography, with alignment accuracy less then 8nm. The electrical transport properties of the resonant tunneling nano-transistors have been investigated using DC measurements at room temperature. Preliminary results indicate that the gate voltage modulates the peak current and the peak to valley current ratio in the device I-V characteristics. [1] J. Wensorra, K.M. Indlekofer, M.I. Lepsa, A. Förster, and H. Lüth, Nano Letters, 5, 2470 (2005).

HL 30.9 Tue 16:30 ER 164

Electron counting statistic on a triple dot device — •Christian Fricke[1], Maximilian Rogge[1], Frank Hohls[1], Werner Wegscheider[2], and Rolf Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg

Current fluctuations in mesoscopic conductors can be used to reveal information which is not accessible through dc conductance measurements. Combining the mean current with the second moment of the distribution function the zero frequency shot noise can provide an insight into tunnelling rates in semiconductor quantum dots. Beside a direct measurement of the resonant tunnelling current through a quantum dot one can measure also the charge on the quantum dot using a nearby quantum point contact. For sufficiently low tunnelling rates and high detector bandwidth this allows to resolve individual tunnelling events onto and off the dot. This technique was used to measure the distribution function for tunnelling through a single [1,2] and double quantum dot [3]. We present first measurements on a system of three dots. One quantum point contact is used as a charge detector. The time resolved current through the quantum point contact is measured and analyzed.

[1]Gustavsson et al. Phys. Rev. Lett. 96, 076605 (2006)
[2]Fricke et al. Phys. Rev. B 76, 155307 (2007)
[3]Fujisawa et al. Science 312, 1634 (2006)

HL 30.10 Tue 16:45 ER 164

Electron and phonon correlations in a driven two level quantum dot — •Rafael Sanchez[1], Gloria Platero[1], and Tobias Brandes[2] — [1]Instituto de Ciencia de Materiales de Madrid-CSIC — [2]Technische Universität Berlin

We propose a solid state analogue to Resonance Fluorescence systems in a two-level quantum dot irradiated by a time-dependent monochromatic ac field where the statistics of the spontaneously emitted phonons and the transmitted electrons can be studied. Recent experiments have achieved to measure high order moments for the non-driven electronic case in similar systems[1], but the phonon case is still unchallenged. We develope a method that allows us to extract *simultaneously* the full counting statistics of the electronic tunneling and relaxation (by phononic emission) events as well as their correlation. We find that the quantum noise of both the transmitted electrons and the emitted phonons and electron-phonon correlation can be controlled and tuned back and forth between sub and super-Poissonian values by the manipulation of the external parameters: the driving field intensity and the bias voltage[2].

[1] S. Gustavsson *et al.*, Phys. Rev. Lett. **96**, 76605 (2006).
[2] R. Sánchez, G. Platero and T. Brandes, Phys. Rev. Lett **98**, 146805 (2007).

HL 30.11 Tue 17:00 ER 164

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

Delivering a quantized number of electrons per cycle reliable and with very high repetition would allow to define a quantum standard for the ampere. Recently a new promising way was demonstrated to achieve quantized charge pumping of a current $I = Nef_p$ at very high pumping frequencies f_p [1].

We performed low frequency ($f < 20$ kHz) current noise measurements of such a pump. We observe a strong suppression of the noise power S_I when the pumped current is quantized. This agrees well with the prediction for an ideal pump: S_I is expected to vanish if exactly N electrons are transferred in each cycle of the driving frequency. Furthermore we study also the current dependence of the noise power in between quantized current plateaus and find good agreement with a theoretical model.

[1] Blumenthal *et al.*, Nat. Phys. 3, 343 (2007); Kaestner *et al.*, cond-mat-0707.0993.

HL 30.12 Tue 17:15 ER 164

Noise enhancement due to quantum coherence in coupled quantum dots — •Gerold Kiesslich[1], Eckehard Schöll[1], Tobias Brandes[1], Frank Hohls[2], and Rolf J. Haug[2] — [1]Institut für Theroretische Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Leibniz Universität Hannover

We show that the intriguing observation of noise enhancement in the charge transport through two vertically coupled self-assembled quantum dots [1] can be explained by the interplay of quantum coherent coupling between the dots and strong Coulomb blockade. We demonstrate that this novel mechanism for super-Poissonian charge transfer is very sensitive to decoherence caused by electron-phonon scattering as inferred from the measured temperature dependence [2].

[1] P. Barthold, F. Hohls, N. Maire, K. Pierz, and R. J. Haug, Phys. Rev. Lett. **96**, 246804 (2006).
[2] G. Kießlich, E. Schöll, T. Brandes, F. Hohls, and R. J. Haug, to be published in Phys. Rev. Lett. **99** (2007), cond-mat/0706.1737.

HL 30.13 Tue 17:30 ER 164

Spin properties of two electron lateral coupled quantum dots — •Fabio Baruffa[1], Peter Stano[2], and Jaroslav Fabian[1] — [1]Institute of Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Research center for quantum information, Slovak Academy of sciences, Bratislava, Slovakia

We report our numerical calculations of the exchange coupling in single and double quantum dots defined in GaAs heterostructures. In particular we examine the dependence of the exchange on the magnetic field. We use the exact diagonalization technique based on the finite-difference method, to solve for single-electron states, as well as the configuration interaction expansion to treat the two-electron system. Our results are of practical importance for quantum dot electron spin based quantum information processing. The work is supported by GRK 638 and SPP 1285.

HL 31: Poster II

Time: Tuesday 16:30–19:00 Location: Poster D

HL 31.1 Tue 16:30 Poster D

Temperature dependency of valence and conduction bands studied by means of synchrotron spectroscopic ellipsometry — •Christoph Cobet[1], Christoph Werner[1], Munise Rakel[1], Wolfgang Richter[2], and Norbert Esser[1] — [1]ISAS- Institute for Analytical Sciences, Department Berlin, Albert-Einstein-Str. 9, D-12489 Berlin — [2]Dipartimento di Fisica, Roma II (Tor Vergata), Via della Ricerca Scientifica 1, I-00133 Rome, Italy

A common experimental approach to study temperature effects on the electronic band structure is using spectroscopic ellipsometry. Thereby the energy shift and broadening of interband transition features in the dielectric function is determined. A major problem in the interpretation is related to the fact that the observed transitions correspond to pairs of valence and conduction bands i.e. the joint density of states. Therefore, only a sum of the respective contributions is measured. In the presented work we utilize the strongly localized semicore Ga3d states in GaN, which are almost unaffected by the electron-phonon interaction, as an energy reference. Excitations from these Ga3d levels to conduction bands occur in the dielectric function above 20eV. In this spectral range temperature related shifts and broadening of transition features thus only relate to changes in conduction bands. In a critical-point analysis we finally separate temperature effects i.e. electron phonon coupling constants for conduction and valence band states. These experiments can be used as a critical test for existing empirical models and newly developed parameter-free ab-initio calculations.

HL 31.2 Tue 16:30 Poster D

Indium-oxide polymorphs from first principles: Quasiparticle electronic states — •Frank Fuchs and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik and European Theoretical Spectroscopy Facility (ETSF), Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena, Germany

The electronic structure of In_2O_3 polymorphs is calculated from first-

principles using density functional theory (DFT) and many-body perturbation theory (MBPT). DFT calculations with a local exchange-correlation (XC) functional give the relaxed atomic coordinates of the two stable polymorphs. Their electronic structure, i.e., the band structure, and density of states are studied within MBPT. The quasiparticle equation is solved in two steps. As the zeroth approximation for the XC self-energy the non-local potential resulting from a HSE03 hybrid functional is used. In the sense of a self-consistent procedure G_0W_0 quasiparticle corrections are computed on top. The calculated direct quasiparticle gaps at Γ amount to 3.3 eV (rhombohedral) and 3.1 eV (cubic). The rhombohedral polymorph is found to exhibit a near degeneracy of the valence-band maxima at the Γ point and on the Γ-L line, while the valence band maximum of the cubic polymorph lies close to Γ. This partially contrasts the results of a recent LDA+U study [1]. The results for gaps, *d*-band positions, density of states, and optical properties are compared with available experimental data.

[1] P. Erhart et al., Phys. Rev. B **75**, 153205 (2007).

HL 31.3 Tue 16:30 Poster D

Excitonic electroreflectance spectra of hexagonal GaN — •Steve Lenk and Erich Runge — Institut für Physik, Technische Universität Ilmenau, Germany

We calculate the bandstructure near the Γ-point of A-, B-, and C-excitons in hexagonal GaN in the presence of an external electric field. The parametrization of Chuang and Chang [1] is used. The importance of excitons for the interpretation of electroreflectance spectroscopy was emphasized by several experimental groups, but only recently theoretical calculations were presented [2]. We derive the imaginary part of the dielectric function from a numerical solution of the excitonic Schrœdinger equation in a finite field, taking into account the full 6x6 valence band structure. Via Kramers-Kronig-Relation the real part of the dielectric function is evaluated. The derivative of the dielectric function yields the ER spectra. In particular, we compare the theoretical field-dependent oscillator strengths with experimental data.

[1] S.L. Chuang, and C.S. Chang, Phys. Rev. B **54**, 2491 (1996).

[2] A.T. Winzer, G. Gobsch, and R. Goldhahn, Phys. Rev. B **74**, 125207 (2006).

HL 31.4 Tue 16:30 Poster D

Cascade of Y-shaped spin filters in InAs — •Jan Jacob[1], Sebastian Peters[1], Toru Matsuyama[1], Ulrich Merkt[1], Guido Meier[1], Aron Cummings[2], Richard Akis[2], and David Ferry[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Center for Solid State Electronics Research, Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-5706

For spintronic devices highly spin-polarized currents are required. While the theoretically predicted values for the injection rate of polarized currents in ferromagnet-semiconductor hybrid devices are low, Y-shaped all-semiconductor structures using the Rashba spin-orbit interaction are predicted to provide a high spin polarization at the outputs of these three-terminal devices [1,2]. The spin-filter effect has been shown by simulations [3] and we will present first measurements here. Quantum-point contacts formed by sidegates are employed to decrease the number of conductance channels in the two-dimensional electron system of an InAs channel inserted into an $In_{0.75}Al_{0.25}As/In_{0.75}Ga_{0.25}As$ structures. The devices with channel widths down to 100 nm are prepared by electron-beam lithography and reactive ion-etching to generate. Adding a second filter operating as a detector allows an all-electric measurement of the spin polarization. Cascading more filters will lead to a higher degree of polarization.

[1] M. Yamamoto et al., Phys. Rev. B **72**, 115321 (2005)
[2] M. Yamamoto et al., Physica E **32**, 462 (2006)
[3] A. Cummings et al., Appl. Phys. Lett. **89**, 172115 (2006)

HL 31.5 Tue 16:30 Poster D

Landauer-Büttiker study of transport in a two-dimensional electron gas with spin-orbit coupling — •maria silvia garelli and John Schliemann — Institut für Theoretische Physik, Universität Regensburg

We investigate spin transport properties in a two-dimensional electron gas in the presence of spin-orbit interaction. Using Landauer-Büttiker transport formalism in a four-probe arrangement we study the dependence of the anomalous Hall effect and the spin Hall effect on the size and geometry of the system.

HL 31.6 Tue 16:30 Poster D

Spin Injection in GaAs by Cleaved-Edge-Overgrowth — •Arne Ludwig[1], Carsten Godde[2], Sani Noor[2], Stephan Hövel[3], Dirk Reuter[1], Andreas D. Wieck[1], Ulrich Köhler[2], and Martin Hofmann[3] — [1]Lehrstuhl für Angewandte Festkörperphysik — [2]Experimentalphysik IV - AG Oberflächenphysik — [3]Arbeitsgruppe Optoelektronische Bauelemente und Werkstoffe, all Ruhr-Universität Bochum, D-44780 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 classic 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 barrier 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 are evaporated before transferring the sample to a metal-MBE, where it is cleaved under ultra high vacuum conditions. Then, the FM-contacts are evaporated in situ on the cleavage plane. In addition to Schottky barrier contacts, MgO tunnel-barriers have been prepared. We will discuss the properties of the different contact configurations.

HL 31.7 Tue 16:30 Poster D

Shear deformation and relaxed lattice constant of (Ga,Mn)As layers on GaAs(113)A — •Lukas Dreher, Joachim Daeubler, Michael Glunk, Wladimir Schoch, Wolfgang Limmer, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm, Germany

The shear deformation and the relaxed lattice constant of compressively strained (Ga,Mn)As layers with Mn concentrations of up to 5%, pseudomorphically grown on GaAs(113)A and GaAs(001) substrates by low-temperature molecular-beam epitaxy, have been studied by high resolution X-ray diffraction (HRXRD) measurements. Rocking curves reveal a triclinic distortion of the (113)A layers with a shear direction towards the [001] crystallographic axis, whereas the (001) layers are tetragonally distorted along [001]. The relaxed lattice constants were derived from ω-2Θ scans for the symmetric (113) and (004) Bragg reflections, taking the elastic anisotropy of the cubic system into account. The increase of the lattice constant with Mn content has been found to be smaller for the (113)A layers than for the (001) layers, presumably due to the enhanced amount of excess As in the (113)A layers.

HL 31.8 Tue 16:30 Poster D

Spin-orbit coupling in InGaSb/InAlSb and InGaAs/InP 2DEGs — •Vitaliy A. Guzenko[1], Masashi Akabori[2], Thomas Schäpers[1], Sergio Estévez[1], Hilde Hardtdegen[1], Taku Sato[2], Toshi-kazu Suzuki[2], and Syoji Yamada[2] — [1]Institute of Bio- and Nanosystems (IBN 1), Research Centre Jülich, 52425 Jülich, Germany — [2]Center for Nano-Materials and Technology (CNMT), Japan Advanced Institute of Science and Technology (JAIST), 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan

Spin-orbit interaction in high-mobility two-dimensional electron gases (2DEGs) formed in high indium content InGaAs-based and InGaSb-based quantum wells was studied. Magnetotransort measurements were performed at low temperatures in a wide range of magnetic field. Characteristic beating pattern in the Shubnikov–de Haas oscillations as well as the enhancement of magnetoconductance at $B = 0$ T due to weak antilocalization (WAL) effect were observed. A comparison of the values of the Rashba spin-orbit coupling parameters estimated from analysis of the beatings with the ones obtained from the fit of the WAL curves showed a good agreement. A control over the strength of the Rashba coupling parameter in the InGaAs 2DEG was achieved by applying a gate voltage. We found that in particular range of the negative gate voltages no beatings can be observed anymore, whereas the weak antilocalization becomes more pronounced. Under such conditions analysis of the WAL is a reliable method to determine the strength of the spin-orbit interaction in 2DEGs.

HL 31.9 Tue 16:30 Poster D

Magnetotransport through lateral (001)-(Ga,Mn)As structures with nanoconstriction — •Markus Schlapps[1], Teresa Lermer[1], Daniel Neumaier[1], Rashid Gareev[1], Janusz Sadowski[2],

Werner Wegscheider[1], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik , Universität Regensburg, Germany — [2]Max-Lab, Lund University, Sweden

The resistance measured across a small (Ga,Mn)As island detached by nanoconstrictions from (Ga,Mn)As input leads displays unusual magnetoresistance (MR) behavior [1,2,3]. In previous studies [1,3] a huge magnetoresistance was found for nanoconstrictions in the tunneling regime. We have already reported on investigations of the angular dependence of the MR in such double-constricted devices and discussed its correlation with the Tunneling Anisotropic Magneto Resistance (TAMR) effect [4]. Here we focus on MR measurements carried out on (Ga,Mn)As wires with only one nanoscale constriction. Samples with different constriction-resistances are compared. Strongly nonlinear I-V characteristics depending on the magnetization orientation have been observed for a high resistive sample that also shows very large MR-effects of up to 6000%. We discuss the possibility of a metal-insulator transition being responsible for the observed effects.

[1] C. Ruester et al: PRL 91, 216602 (2003) [2] A. D. Giddings et al: PRL 94, 127202 (2005) [3] M. Schlapps et al: phys. stat. sol. (a) 203, No. 14, 3597 (2006) [4] M. Ciorga et al: New J. Phys. 9, 351 (2007)

HL 31.10 Tue 16:30 Poster D

TMR and highly anisotropic magnetoresistance effects in (Ga,Mn)As based trilayer structures — •Eva Brinkmeier[1], Rashid Gareev[1], Matthias Sperl[1], Ursula Wurstbauer[1], Janusz Sadowski[2], Dieter Schuh[1], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Institut fuer experimentelle und angewandte Physik, Universitaet Regensburg, Germany — [2]Institute of Physics, Polish Acadamy of Sciences, Warsaw, Poland

We investigated tunneling trilayer structures built of (Ga,Mn)As as ferromagnetic electrode and GaAs or (Al,Ga)As as barrier materials. Tunnel stacks were fabricated for magnetoresistance measurements in a current-perpendicular-to-plane (CPP) geometry.

The Tunneling Magneto-Resistance (TMR) of the junctions shows a pronounced dependence on voltage and temperature. When the orientation of the magnetic field is being changed, a complex switching behaviour shows up which can be explained by the switching of the (Ga,Mn)As layers as it was also shown by previous studies for similar systems [1].

In trilayer systems containing a GaAs barrier a highly anisotropic junction resistance with respect to the orientation of a high external magnetic field appears. Detailed investigations of this tunneling anisotropic magnetoresistance show its strong dependence on voltage, temperature and strength of the applied magnetic field.

[1] Y. Higo et al. APL 89, 6745 (2001)

HL 31.11 Tue 16:30 Poster D

Characterization and Weak-Antilocalization measurements of InGaAs/InP quantum wire structures — •Markus Hagedorn, Masashi Akabori, Hilde Hardtdegen, Vitaliy Guzenko, and Thomas Schäpers — Institute of Bio- and Nanosystems (IBN-1) and Centre of Nanoelectronic Systems for Information Technology (CNI), Research Centre Jülich, 52425 Jülich, Germany

We report on the investigation of InGaAs/InP quantum wire structures with respect to a general characterization and spin-related effects such as weak-anti-localization (WAL) by performing magnetoresistance measurements at low temperatures. The thickness of the InGaAs channel layer (Indium content of 77%) is varied systematically in the range of 2 to 10 nm in order to study the influence of the quantum well width on the WAL and therefore on the spin-orbit-coupling. By means of a He3-cryostat, low temperature transport measurements (around 0.6K) were performed using e-beam written array wire structures which allow to study a set of different wire widths in the range of 100 to 1000nm. Additionally each structure has also a Hall bar to provide further analysis of beating pattern nodes and heterostructure properties such as mobility and carrier concentration. Analysis of the WAL on the one hand and the node position shift in the beating pattern observed in the Shubnikov-de Haas oscillations on the other hand, show clearly that the smallest channel layer thickness correspond to a large Rashba spin-orbit coupling.

HL 31.12 Tue 16:30 Poster D

Optical detection of spin polarisation in a lateral spin-transport device with (Ga,Mn)As injecting contacts — •Andreas Maurer, Michael Griesbeck, Thomas Kufner, Andreas Einwanger, Tobias Korn, Mariusz Ciorga, Dieter Schuh, Werner Wegscheider, Dieter Weiss, and Christian Schüller — Uni Regensburg

Understanding of spi-polarised injection into semiconductor materials and resulting spin-polarised transport is a crucial factor in developing future spintronic devices.

Here we report on the design and fabrication of a lateral spin injection/transport device using ferromagnetic GaMnAs contacts as spin injectors. As a channel we use slightly n-doped GaAs ($n = 2 \times 10^{16}$ cm^{-3}), where extremely long spin-lifetimes (> 100 ns) could be observed previously [1]. In order to be able to detect the spin polarization in the channel via optical microscopy, channel lengths of several hundred μm are used. In this device the lateral spin injection shall be monitored via Kerr microscopy in analogy to the experiment of Crooker *et al.* [2].

In this contribution, we report about the design, fabrication and characterisation of the spin injectors and the measurements of the spin lifetime in the channel material, employing time resolved Kerr experiments. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB689.

[1] Kikkawa et al., PRL **80** 4313 (1998)
[2] Crooker et al., Science **309** 2191 (2005)

HL 31.13 Tue 16:30 Poster D

SAW-mediated single-electron transport through carbon nanotubes — •Markus Regler[1,2], Jens Ebbecke[1,2,3], and Achim Wixforth[1,2] — [1]Lehrstuhl für Experimentalphysik 1, Institut für Physik, Universität Augsburg, Universitätsstr.1, 86159 Augsburg — [2]Center for Nanoscience, Geschwister-Scholl-Platz 1, 80539 München — [3]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, UK

Carbon nanotubes (CNT) are ideal one-dimensional conductors. Depending on their chirality they behave metallic or semiconducting and with their size on the nanometer scale they are very promising candidates for future electronic devices.

Surface acoustic waves (SAW) are earthquake-like waves on a piezoelectric substrate and are therefore always accompanied by an electric field. This lateral, dynamically induced potential can be used to manipulate charges as well as potential landscapes.

SAW and CNT combined provide novel prospects for future devices. For instance quantum dots can be created in a CNT just by contacting it with metal electrodes or by biasing gate electrodes on top of the CNT. The confining barriers of such quantum dot are manipulated by a properly designed SAW. The entrance and exit barriers are alternately modulatied and an electron can pass the lowered barrier easily. The resulting, SAW-driven few electron current turns out to be given by I=e*f with e: elementary charge and f: SAW-frequency. At high frequencies, it may reach nanoamperes. A current standard would be a possible application for these turnstile devices.

HL 31.14 Tue 16:30 Poster D

Local and remote bend resistance characteristics in the hot-electron regime — •Matthias Wiemann[1], Ulrich Wieser[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas D. Wiek[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Nonlinear bend resistance characteristics are investigated in the hot-electron regime in a six-terminal mesoscopic ballistic GaAs/AlGaAs cross junction. The lateral geometry is given by a central orthogonal cross junction and two additional voltage probes which orthogonally merge into the vertical bar on both sides of the central junction. Non-equilibrium electrons are generated by a voltage drop across a gate-tunable quantum point contact (QPC) embedded in the vertical bar near the cross junction. If an input bias is applied between the vertical bar embedding the QPC and an orthogonal lead of the central cross junction, a negative bend resistance is found in the I-V transfer characteristic, where V describes the potential difference between the voltage probes opposite to the current leads (local configuration). The absolute value of the bend resistance enhances with increasing electron excess energy if the electrons are injected through the constriction. If the transfer voltage is detected between two orthogonal voltage probes far from the QPC (remote configuration) ballistic effects are observed only for small electron excess energies. Both, local and remote bend resistance characteristics show pronounced oscillations if the electrons are injected through the QPC constriction.

HL 31.15 Tue 16:30 Poster D

Imaging electron flow via magnetic focusing: Theory and

Experiment — •Tobias Kramer[1,2], Eric Heller[1], and Robert Parrott[1] — [1]Department of Physics, Harvard University, USA — [2]Institut I: Theoretische Physik, Universität Regensburg

The theoretical description of magnetic focusing requires to obtain Green functions for the transport through impurity potentials and quantum point contacts in a magnetic field. By solving the time-dependent Schrödinger equation, we have developed an accurate and effective method to calculate the energy-dependent Green function [1]. From the Green function, we obtain the microscopic local current flow through the device. The theoretical method is very versatile and adapted to systems, where standard diagrammatic approaches diverge and periodic boundary conditions yield non-physical results. In combination with a sophisticated disorder model, the results are in excellent agreement with the experimental images obtained by Scanning Probe Microscopy [2].

[1] An efficient an accurate method to obtain the energy-dependent Green function for general potentials T. Kramer, E. Heller, and R. Parrott submitted (2007)

[2] Imaging Magnetic Focusing of Coherent Electron Waves K. Aidala, R. Parrott, T. Kramer, R. Westervelt, E. Heller, M. Hanson, and A. Gossard Nature Physics, 3, 464-468 (2007)

HL 31.16 Tue 16:30 Poster D

Transport Through Single-Level Quantum Dots: Increase of Differential Conductance Peaks by Spin Relaxation — •Daniel Becker and Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Hamburg, GERMANY

Coulomb-blocked non-equilibrium transport through a single-level quantum dot at low temperatures is discussed. To calculate the occupation probabilities and the tunneling current including sequential tunneling, cotunneling and intrinsic spin-flip relaxation, we use a master equation approach based on the diagrammatic Keldysh formalism. The Coulomb diamond can be subdivided into parts differing in at least one of two respects: what kind of tunneling processes (i) determine the single-particle occupations and (ii) mainly contribute to the current. In the *core* and a *shell region* the single-particle occupations are determined by sequential and cotunneling, respectively. Therefore, no finite systematic expansions of the occupations and the current can be found that connects both regions. Alternatively, we construct a non-systematic solution, which is physically correct and perturbative in the whole cotunneling regime, while smoothly crossing-over between core and shell region. With this solution the impact of an intrinsic spin-flip relaxation on the transport is investigated. We focus on peaks in the differential conductance that mark the onset of cotunneling-mediated sequential transport and are located in the intermediate region between core and shell. It is shown, that these peaks are maximally pronounced at a relaxation roughly as fast as sequential tunneling

HL 31.17 Tue 16:30 Poster D

Full Counting Statistics of Electron Transport trough Quantum Dots — •Ingmar Neumann, Christian Fricke, Frank Hohls, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We study electric transport properties of quantum dots (QDs) by means of a quantum point contact (QPC). These devices are made of GaAs/AlGaAs-heterostructures containing a two-dimensional electron system. The QD and the QPC are defined with an atomic force microscope using local anodic oxidation. Charge fluctuations on the dot result in current fluctuations trough the QPC, this provides a noninvasive way of charge detection. We measure the timeresolved QPC current, which allows us to detect single electron tunneling events onto and of the dot. The full counting statistics (FCS) of the tunneling events provides additional information on the electron transport through the dot. Also, characteristic tunneling times for our systems are yielded, varying parameters such as gate-voltages or magnetic field.

HL 31.18 Tue 16:30 Poster D

Magnetotransport studies of tunneling mechanisms in vertical quantum dot — •Oleksiy B. Agafonov[1], Tomohiro Kita[2], Hideo Ohno[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, Appelstraße 2, D-30167 Hannover — [2]Semiconductor Spintronics Project, ERATO, JST, Japan and LNS RIEC, Tohoku University, Japan

The electronic properties of a vertical quantum dot fabricated of an asymmetrical InGaAs/AlGaAs double-barrier resonant tunneling heterostructure are investigated using magnetotunneling spectroscopy. The magnetic field is oriented perpendicular to the plane of the tunnel barriers. At a temperature of 15 mK we have observed a series of small current peaks in the vicinity of a resonance peak corresponding to the tunneling over the ground state in the quantum well. The voltage positions of some current peaks are strongly dependent on the applied magnetic field and yield straight lines of a various slope, if represented versus the strength of the magnetic field. The appearance of these lines is related to the tunneling of electrons between the Landau levels in the source electrode and the quantum dot in the presence of the external magnetic field. The voltage positions of several other current peaks show a weaker field dependence. A part of these peaks are caused by the longitudinal optical phonon-assisted tunneling process. The origin of the other peaks is related to electrostatic effects (charging effects and Coulomb blockade). The presence of Coulomb blockade in this sample is confirmed through the observation of characteristic Coulomb-diamond pattern.

HL 31.19 Tue 16:30 Poster D

Spin-splitting in the magnetotransport of tunnel-coupled AlGaAs/GaAs quantum point contacts — •S. S. Buchholz[1], P. S. Zapp[1], S. F. Fischer[1], U. Kunze[1], D. Schuh[2], and G. Abstreiter[3] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Experimentelle und Angewandte Physik, Universität Regensburg — [3]Walter-Schottky Institut, Technische Universität München

Spin-split subbands of one-dimensional electron systems are particularly interesting in order to investigate spin-related phenomena in coherent electron transport. In this work we study quantum point contacts (QPCs) prepared from double quantum well AlGaAs/GaAs-heterostructures by atomic force microscopy and wet chemical etching [1]. In such systems mode coupling can occur and be manipulated in longitudinal magnetic fields [2,3]. Here, we focus on transport properties and mode spectroscopy in perpendicular magnetic fields. A top gate voltage (V_{tg}) controls the occupation of 1D subbands in both stacked QPCs, a back gate voltage (V_{bg}) influences the occupation of mainly the bottom QPC, and cooling under back gate voltage allows the tuning of the bottom QPC confining potential. We record the conductance and transconductance with respect to V_{tg}, V_{bg} and magnetic fields. We observe a rich variety of level splittings and seek understanding of mode coupling between spin-subbands. [1] S.F. Fischer *et al.*, Nature Physics **2**, 91 (2006). [2] S.F. Fischer *et al.*, Phys. Rev. B **74**, 115324 (2006). [3] L.G. Mourokh *et al.*, Appl. Phys. Lett. **90**, 132108 (2007).

HL 31.20 Tue 16:30 Poster D

Suspended carbon nanotube quantum dots — •Andreas K. Hüttel and Herre van der Zant — Molecular Electronics and Devices, Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA Delft, The Netherlands

The vibrational modes of single suspended carbon nanotubes (CNT's) are studied in low temperature transport measurements. The low-energy single electron tunneling excitation spectrum of the quantum dots embedded in a suspended single wall CNT displays harmonic excited states at an energy scale compatible to the longitudinal (stretching) mechanical mode. Agreement with Franck-Condon theory has been observed.

Our work targets this interplay of electrical and mechanical effects, also towards resolving the transversal (bending) mechanical mode of the nanotube in electronic transport. Several approaches in terms of sample geometry and fabrication technique are presented, e.g. using very short nanotube segments as single quantum dots to enhance level spacing, or using double quantum dots to enhance spectroscopic resolution. Measurements indicate for a certain nanotube suspension length range a current suppression at low bias, consistent with "phonon" or "distortion" blockade mechanisms due to the transversal vibration mode. Further data will be presented.

HL 31.21 Tue 16:30 Poster D

Top down processing and electrical characterisation of InAs nanocolumns — Jakob Wensorra[1], •Sonja Heiderich[1], Mihail Ion Lepsa[1], Klaus Michael Indlekofer[2], Hans Lüth[1], and Detlev Grützmacher[1] — [1]1Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, D-52425 Jülich — [2]FH Wiesbaden, University of Applied Sciences Information Technology and Electrical Engineering, Am Brückweg 26, D-65428 Rüsselsheim

Semiconductor nanocolumns and carbon nanotubes have attracted

large interest in recent years both for fundamental and application oriented research. Especially, nanocolumns from low band gap semiconductor materials like InAs, with high electron mobility and a surface accumulation layer, are possible candidates for novel nanodevice concepts. We report on a reproducible top-down processing technique of vertical InAs nanocolumns. With the help of electron beam lithography and using high resolution Hydrogen Silsesquioxan (HSQ) as mask material, vertical InAs columns with lateral dimensions down to 50 nm have been realized by ion beam and reactive ion etching. HSQ is also used to planarize and physically isolate the devices. For contacting the nanocolumns, Ti/Au ohmic contacts have been processed. The electrical transport properties of the resulting nanostructures have been analyzed by means of DC measurements at room temperature. The I-V characteristics is ohmic and indicate a very low resistance for all processed InAs nanocolumns. A linear dependence of the resistance on the lateral nanocolumn dimension has been observed.

HL 31.22 Tue 16:30 Poster D

Spin dependent transport in a lateral few electron quantum dot — •Theo Ridder[1], Maximilian C. Rogge[1], Dirk Reuter[2], Andreas D. Wieck[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr Universität Bochum, Germany

We investigate spin blockade effects on a lateral few electron quantum dot and observe the influence of the injection of spin polarized currents.

Our quantum dot is built on a GaAs/AlGaAs heterostructure with a 2DEG 57 nm below the surface. For the fabrication of our device we use electron beam lithography. We measure the differential conductance depending on the magnetic field with standard lock-in technique in a 4He/3He dilution refrigerator at a base temperature of around 30 mK.

We investigate the dot properties showing that one can tune the dot from zero to more than 40 electrons. The proof of the last electron is given by Coulomb diamonds measurements. In addition we show spin blockade effects in the few electron regime.

Spin polarization can be achieved in high magnetic fields in using metallic gates covering the leads of the dot. We investigate the transport properties of our quantum dot with regard to spin polarized currents.

HL 31.23 Tue 16:30 Poster D

Modelling of nanowiretransistors in Landauer-Büttiker formalism — •Paul Nicolae Racec[1,2] and Elena Roxana Racec[3,4] — [1]Weierstrass Institute for Applied Analysis and Stochastics, Mohrenstr. 39, 10117 Berlin, Germany — [2]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [3]Brandenburg Technical University Cottbus, Faculty 1, Postfach 101344, 03013 Cottbus, Germany — [4]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania

We present a quantum mechanical modeling of I-V characteristics of a nanowiretransistor without gate leackage current. The model is suitable also for nanowire heterostructures, including a resonant structure along the nanowire. For the description of the quantum transport we use the Landauer-Büttiker formalism. The cylindrical symmetry of the nanowire has reguired a formulation of the scattering theory in cylindrical coordinates. The two dimensional (2D) many-channels scattering problem is solved efficiently within the R-matrix formalism. The interaction between electrons is considered in the Hartree approximation. We use analytical solutions for the three-dimensional electrostatic problem and also for the two-dimensional quantization on the transversal directions.

HL 31.24 Tue 16:30 Poster D

Diagrammatic Technique for Frequency-dependent Full Counting Statistics — •D. Marcos[1], C. Emary[2], T. Brandes[2], and R. Aguado[1] — [1]Departamento de Teoría de la Materia Condensada. Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco 28049. Madrid, Spain — [2]Institut für Theoretische Physik, Hardenbergstr. 36, TU Berlin, D-10623 Berlin Germany

The theory of Full Counting Statistics has recently emerged as a powerful tool to fully characterize correlations in nanoscopic transport problems [1,2]. In the same way, experiments have been reported, and the new information contained in high order current cumulants has become apparent [3]. In this work, we present results for the frequency-dependent second and third currrent cumulants in a single resonant level and a double quantum dot. To this end, we have worked out a physically-interpretable diagrammatic technique, based on the density matrix approach [4] and a projectors method [5], such that only the stationary solution of the problem is needed.

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HL 31.25 Tue 16:30 Poster D

Micro-Raman studies of the formation of ternary and quaternary II-VI nanocrystals in borosilicate glass — •Yuriy Azhniuk[1], Vasyl Lopushansky[1], Yuriy Hutych[1], Ivan Turok[1], Larysa Prots[1], Alexander Gomonnai[1], and Dietrich R T Zahn[2] — [1]Institute of Electron Physics, Uzhhorod, Ukraine — [2]Chemnitz University of Technology, Chemnitz, Germany

Diffusion-limited growth in a silicate glass is a well-elaborated technique for obtaining II-VI semiconductor nanocrystals (NCs). The dependence of NC size on the growth conditions (heat treatment duration and temperature) has been studied extensively. Much less investigated is the variation of the chemical composition of ternary and quaternary II-VI NCs with heat treatment parameters. This can effectively be performed using Raman scattering.

Here we present resonant micro-Raman studies for an extensive set of NCs of the ternary $CdS_{1-x}Se_x$, $Cd_{1-x}ZnS_x$, $CdSe_{1-x}Te_x$ and quaternary $Cd_{1-y}Zn_yS_{1-x}Se_x$ systems grown in borosilicate glass by thermal treatment at 625 to 700^{o}C. Measurements were performed using a Dilor XY 800 spectrometer and different Ar^+ laser lines for excitation. For $CdS_{1-x}Se_x$ NCs the content of Se is shown to grow with the heat treatment duration and temperature. For zinc-containing ternary and quaternary NCs the Zn content increases with heat treatment duration and temperature up to 0.3 due to the migration of Zn atoms from the matrix to the NCs. Raman features observed at the initial stages of heat treatment as well as at elevated heat treatment temperatures are discussed in view of possible selenium cluster segregation.

HL 31.26 Tue 16:30 Poster D

Electrical integration of semiconductor nanowires — •Katharina Wegener[1], Sven Müller[1], Daniel Stichtenoth[1], Wilma Dewald[1], Carsten Ronning[1], Christoph Gutsche[2], Andrey Lysov[2], Kai Blekker[2], Werner Prost[2], and Franz Josef Tegude[2] — [1]II. Institute of Physics, University of Göttingen, Germany — [2]Solid-State Electronics Department, University of Duisburg-Essen, Germany

Nanowires have a very high surface-to-volume ratio and are therefore very promising candidates for sensing applications. Configured as a field-effect transistor (FET) with their surfaces acting as gates, nanowires exhibit a strong conductivity change in response to surface variations. The binding of a certain molecule can therefore be detected with very high sensitivity.

When building a sensor, the electrical integration of the nanowires is an important step. Two contacting methods will be compared: (1) platinum patterns have directly been written using a focused ion beam system and (2) leads have been deposited via e-beam lithography with subsequent metal deposition and lift-off technology. First results of the electrical measurements will be shown. Furthermore, we have implemented zinc oxide nanowires into FET devices. The carrier type and mobility could be extracted by fitting a long channel metal-insulator-semiconductor FET model to the experimental results.

HL 31.27 Tue 16:30 Poster D

Growth and faceting of self-assembled GaAs quantum dots — •Andrea Stemmann, Christian Heyn, Andreas Schramm, and Wolfgang Hansen — Universität Hamburg, Institut für Angewandte Physik, Jungiusstrasse 11, 20355 Hamburg

Strain-free GaAs quantum dots (QDs) are grown in a self-assembled fashion by applying Ga droplet epitaxy. Dependent on growth temperature and Ga flux, QDs with different size and density are grown. The QDs are studied using electron diffraction (RHEED) and atomic force microscopy. We find two distinct regimes for the QD shape. QDs whose volume exceeds approximately 3x10^5 Ga atoms are shaped like truncated pyramids with side facets having an angle α of about 55° corresponding to (111)-type side facets. Smaller QDs are pyramid like with $\alpha = 25°$ and (113)-type facets.

HL 31.28 Tue 16:30 Poster D

Magnetization measurements on field-effect induced quan-

tum dots — •G. Stracke[1], N. Ruhe[1], J. Topp[1], S. Mansfeld[1], Ch. Heyn[1], D. Heitmann[1], M.A. Wilde[2], and D. Grundler[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung der Universität Hamburg, Jungiusstr. 11, D-20355 Hamburg — [2]Physik Department E10, Technische Universität München, D-85748 Garching

We have studied the de Haas-van Alphen (dHvA) effect of field-effect induced quantum dots at temperatures down to 300 mK. The dots were formed by depleting a two-dimensional electron system (2DES) with a large-area field-effect electrode. This metallic gate covered in particular a periodic array of PMMA nanocolumns on a modulation-doped GaAs/AlGaAs heterostructure. Each column had a diameter of 280 nm and a height of 120 nm. The dot density was $4.6 \cdot 10^8$ cm^{-2}. Using a fiber-optics based magnetometer we measured the dHvA effect as a function of, both, carrier density n_s and magnetic field B up to 10 T. The high sensitivity of $4.5 \cdot 10^{-16}$ J/T at $B = 10$ T allowed us to detect the dHvA signal for n_S ranging from $3.2 \cdot 10^{11}$ cm^{-2} in the 2DES down to 20 electrons per dot. In this way, we report for the first time magnetization data which reflect the crossover from a 2D to a 0D electron system.

The authors thank A. Schwarz for experimental support, the DFG for financial support via SFB 508 and the German Excellence Initiative for financial support via the "Nanosystems Initiative Munich (NIM)".

HL 31.29 Tue 16:30 Poster D

Molekularstrahlepitaxie-kompatible Nanostrukturierung von GaAs durch Lokale Anodische Oxidation mit einem Rasterkraftmikroskop — •Daniel Laipple, Andrea Stemmann, Christian Heyn und Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg

Bei der anodischen Oxidation dient der natürliche Wasserfilm auf der Substratoberfläche als Elektrolyt und Sauerstoffreservoir. Zur gezielten lokalen Oxidation wird mit einem kommerziellen Rasterkraftmikroskop (AFM) an eine leitfähige Spitze eine, bezüglich dem zu oxidierenden GaAs Wafer, negative Spannung angelegt. Bei einer relativen Luftfeuchtigkeit von ca. 40% entstehen Oxidstrukturen von bis zu 25nm Höhe.

Nach thermischer Desorption des Oxids unter Vakuum invertieren die aus der Oberfläche ragenden Strukturen zu Gräben in der Oberfläche. Die Grabentiefe ist ähnlich der Höhe der ursprünglichen Oxidstrukturen. Interessanterweise werden auch vom Oxid eingeschlossene Flächen bis zu einer gewissen Größe abgetragen.

In einem weiteren Schritt werden durch thermische Desorption in der Wachstumskammer erzeugte Grabenstrukturen mittels Molekularstrahlepitaxie mit GaAs überwachsen, wodurch Stufenkanten, z.B. für die laterale Anordnung von selbstorganisierten InAs Quantenpunkten, entstehen.

HL 31.30 Tue 16:30 Poster D

Low contact resistance for dielectrophoretically aligned carbon nanotubes — •Anindya Majumder[1], Markus Regler[1,2], and Achim Wixforth[1,2] — [1]Lehrstuhl fuer Experimentalphysik 1, Institut fuer Physik, Universitaet Augsburg, Universitaet. 1, 18569 Augsburg — [2]Center fir Nanoscience, Geschwister-Scholl-Platz 1, 80539 Muenchen

Reduction of contact resistance between carbon nanotubes (CNT) and metal electrodes holds significance for its application in nanoscale electronic devices. Presently, this resistance is very high for samples where dielectrophoresis (DEP) for CNT alignment between contact electrodes is employed. Thus, we need to have more transparent contacts.

In this work, electrodes of different material (Pd, Au, Ti, Al) were processed on a piezoelectric LiNbO3- substrate. The CNT have been aligned between them by DEP. These were subjected to annealing in the temperature range of 300-700° C in vacuum and different background gases. The resistance was then measured at room temperature, where a significant change in the contact resistance between the CNT and the electrodes was found. The goal was to optimize the annealing parameters, improve stability and reproducibility and look for other probable techniques.

HL 31.31 Tue 16:30 Poster D

Kapazitätsspektroskopische Untersuchungen an doppel- und mehrfachlagigen Quantenpunkten — •Sascha Bohse[1], Andreas Schramm[2], Christiane Konetzni[1], Andrea Stemmann[1], Christian Heyn[1] und Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Optoelectronics Research Center, Tampere University of Technology, Finland

Wir untersuchen die elektronische Struktur von doppel- und mehrfachlagigen Quantenpunkten (QP) in Abhängigkeit vom Lagenabstand. Die QP werden mittels Molekularstrahlepitaxie im Stranski-Krastanov Wachstumsmodus hergestellt und sind in eine Schottkydiode aus n-dotiertem GaAs eingebettet. Die von uns verwendeten Untersuchungsmethoden sind die Kapazitäts-Spannungs-Spektroskopie (CV-Spektroskopie), die Deep Level Transient Spectroscopy (DLTS) und die Tunnel Transient Spectroscopy (TTS). Mit der CV-Spektroskopie kann der Ladezustand der QP in unterschiedlichen Schichten in Abhängigkeit von der angelegten Gatespannung beobachtet werden. Mittels DLTS werden die Energien der QP-Niveaus bestimmt. Von besonderem Interesse ist dabei wie sich die quantenmechanische Kopplung zwischen QP aus verschiedenen Lagen bei Variation des Lagenabstandes und eines angelegten elektrischen Feldes ändert. Weiterhin werden Spektren von TTS-Messungen gezeigt. TTS wird bei Temperaturen T=5K durchgeführt, um thermische Emissionsprozesse aus den QP weitestgehend zu unterdrücken. Dadurch wird eine Betrachtung allein der Tunnelprozesse aus den QP möglich.

HL 31.32 Tue 16:30 Poster D

Vergleich von transienten Kapazitätsspektroskopie-Methoden an selbstorganisierten Quantenpunkten — •Christiane Konetzni[1], Andreas Schramm[2], Christian Heyn[1] und Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Optoelectronics Research Center, Tampere University of Technology, Finland

Die Ladungsträgeremission sowie -Injektion in selbstorganisiert gewachsene InAs Quantenpunkte (QP) wird mit transienter Kapazitätsspektroskopie studiert. Die QP sind in Schottkydioden aus n-dotiertem GaAs eingebettet, die mittels Molekularstrahlepitaxie auf GaAs-(001)-Oberflächen hergestellt worden sind. Um an diesen Heterostrukturen die s- und p-artigen Quantenpunktniveaus sowie der Wettinglayerzustände zu studieren verwenden wir neben der konventionellen Deep Level Transient Spectroscopy (DLTS) verschiedene Methoden transienter Kapazitätsspektroskopien: die so genannte Reverse Deep Level Transient Spectroscopy (RDLTS) und die Constant Capacitance Deep Level Transient Spectroscopy (CC-DLTS) sowie die Tunneling Transient Spectroscopy (TT-DLTS). Die Kapazitätstransiente wird in den DLTS-, CC-, und TT-DLTS-Messungen von der Emissionsrate der in den QP befindlichen Ladungsträgern bestimmt, bei RDLTS-Messungen hingegen von deren Einfangrate. Wir vergleichen Spektren dieser Messverfahren und stellen die Vorteile der verschiedenen Messmethoden für unsere Untersuchungen vor.

HL 31.33 Tue 16:30 Poster D

Very small ZnO nanoparticles and their organic ligands studied by Raman spectroscopy and X-ray diffraction — •Maxim Raskin[1], Marcel Schumm[1], Nicole Pfeiffer[2], Julia Harz[2], Khellil Bouamama[3], Reinhard B. Neder[2], and Jean Geurts[1] — [1]Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Institut für Mineralogie, Universität Würzburg, Am Hubland, 97074 Würzburg — [3]Département de physique, Université Ferhat Abbas, 19000 Sétif, Algeria

ZnO nanoparticles were synthesized with a new wet-chemical method, using 1,3,5-Pentanetrione as ligand molecules. Refinement fits of X-ray powder diffraction diagrams of the particles reveal the expected Wurtzite structure. They also show a nearly spherical particle shape with 2.2 nm diameter, the smallest value for ZnO nanoparticles achieved up to now. The inter-atomic distances match ZnO bulk without relaxation. To study the interface between the ZnO core and the Pentanetrione ligand, we use Raman spectroscopy. The vibration spectra of the ligands bound to the particles differ significantly from the pure ligand ones, i.e. the binding changes the molecule vibration eigenmodes. To interpret these changes in detail, we apply DFT calculations for the structure and the vibration modes of the ligands. The calculations show that (i) the middle oxygen atom in the ligand molecule occupies an exposed position, and (ii) the modes involving this exposed atom are predominantly attenuated by the bonding. This insight into the bonding should allow a systematic selection of further ligand candidates for ultra-small nanoparticle synthesis.

HL 31.34 Tue 16:30 Poster D

Memory effect in MOS structures containing amorphous or crystalline silicon nanoparticles — •Sebastian Meier[1], Rudolf Brüggemann[1], Gottfried Heinrich Bauer[1], Nicola Nedev[2], Emmo Manolov[3], Diana Nesheva[3], and Zelma Levi[3] — [1]Institute of physics, Carl von Ossietzky University Oldenburg, D-26111 Old-

enburg, Germany — [2]Istituto de Ingenieria, Universidad Autonoma de Baja California, Benito Juarez Blvd., s/n, C.P. 21280, Mexicali, Baja California, Mexico — [3]Insitute of solid state physics, Bulgarian Academy of Science, 72 Tzarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria

Amorphous and crystalline silicon nanoparticles (Si-NPs) embedded in a SiO_2 matrix are fabricated by thermal annealing of Metal/SiO_2/SiO_x/c-Si structures (x= 1.15) at 700°C or 1000°C in N_2 atmosphere for 30 or 60 minutes. High frequency C-V measurements show that the samples can be charged negatively or positively by applying a positive or negative bias voltage to the gate. A memory effect, due to the Si-NPs in the SiO_2 matrix, is observed. The method of measurement with open circuit between two measurements leads to the retention characteristic where the structures retain about 50% of negative charge trapped in Si-NPs for 24 hours. A second method, where the flat-band voltage is applied as bias voltage, shows shorter retention characteristics. There the Si-NPs retain 50% of their charge after 10 hours.

HL 31.35 Tue 16:30 Poster D

Kinetics of Si quantum dot formation in thermally deposited SiO_x layers upon vacuum annealing — •Bert Stegemann, Daniel Sixtensson, Andreas Schöpke, and Manfred Schmidt — Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Kekuléstraße 5, 12489 Berlin

Si quantum dots embedded in an amorphous SiO_2 matrix were prepared under ultrahigh vacuum conditions by thermal annealing of evaporated substoichiometric SiO_x (x = 1.3) layers with thicknesses between 3 and 10 nm. By codeposition of Si or O atoms the initial amount of O was varied between x=0.9 and 1.5. An ultrathin SiO_2 capping layer grown by plasma oxidation with atomic oxygen turned out to prevent SiO_x sublimation upon annealing. The kinetics of the decomposition of the constituting suboxides into Si and SiO_2 was analyzed by X-ray photoelectron spectroscopy as a function of the post deposition annealing temperature. Peak analysis of the Si 2p transition revealed the evolution of relative fractions of the different oxidation states Si^{n+} (n = 0...4) with increasing temperature. For all investigated initial compositions phase separation started at about 600°C and was completed at 850°C. Annealing temperature also controls the quantum dot structure: crystallization sets on above 800°C as evidenced by cross-sectional TEM and photoelectrical measurements.

HL 31.36 Tue 16:30 Poster D

Cd-loss of CdSe quantum dots in ZnSe during MBE growth — •Utz Bass, Jean Geurts, Fabian Eschenbach, Suddhasatta Mahapatra, and Karl Brunner — Universität Würzburg, Physikalisches Institut, Experimentelle Physik III, Am Hubland, 97074 Würzburg

CdSe quantum dots (QD) on ZnSe grown by a special MBE technique are distinct QDs with lateral sizes up to 50 nm in AFM, a necessary property for application as single photon sources. In contrast, those QDs when capped with ZnSe appear significantly smaller in TEM-Images, indicating a severe segregation of Cd during overgrowth. This behaviour was analyzed by X-ray diffraction and Raman spectroscopy.

A detailed analysis by X-Ray interferometry for a series of samples with $0<d_{CdSe}<3$ ML reveals an increasing loss of Cd (Δd_{CdSe}) up to 0.7 ML for d_{CdSe} of 2.6 ML within the Cd(Zn)Se layer.

The segregation of Cd into the ZnSe layer was also evaluated by Raman spectroscopy. The frequency shift of the ZnSe LO phonon amounts to 3 cm^{-1} for $\Delta d_{CdSe} = 0.7$ ML, corresponding to a Cd content of 20%. This result indicates a strongly inhomogeneous segregation, resulting in Cd-rich regions above the QDs, which contribute predominantly under our nearly resonant Raman excitation conditions.

The combined analysis gives a congruent picture of Cd segregation in the ZnSe capping layer.

HL 31.37 Tue 16:30 Poster D

Polarisation properties of single lateral InGaAs quantum dot molecule photoluminescence — •Marcus Witzany[1], Claus Hermannstädter[1], Gareth Beirne[1], Lijuan Wang[2], Armando Rastelli[3], Oliver Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Helmholtzstr. 20, 01069 Dresden

The photoluminescence of single lateral InGaAs quantum dot molecules (QDM) grown by a unique combination of molecular beam epitaxy and in-situ etching has been investigated with respect to polarisation. The molecules are composed of two quantum dots that are coupled along the [1-10] crystal direction via electron tunneling. An electric field along the coupling axis can be applied in a lateral geometry by depositing lithographically processed gold electrodes on the sample surface. An anomalous Stark shift and a change in relative intensities of the excitonic emission lines may be obtained by applying an electric field parallel to the molecule axis. This has been shown to indicate that the coupling mechanism (electron tunneling) can be controllably manipulated [Phys. Rev. Lett. 96, 137401]. We have performed linear polarisation dependant PL measurements on single molecules under the influence of different field strengths and directions. The degree of linear polarisation observed substantiates that the electronic wavefunction is elongated along the molecule axis.

HL 31.38 Tue 16:30 Poster D

Measurements of the second order intensity correlation of quantum dots in GaAs/AlGaAs microcavities — •Marc Assmann, Thorsten Berstermann, and Manfred Bayer — Experimentelle Physik II, TU Dortmund, 44221 Dortmund

The second order intensity correlation function g_2 as defined by optical coherence theory is one of the main tools to classify photon emitters. We present g_2-measurements of the emission of an ensemble of InGaAs quantum dots embedded as an active medium in high-Q micropillar laser structures. With increasing excitation density a transition into the lasing regime can be observed as a decrease of photon bunching from a value of $g_2(0)$=1,84 towards a value of $g_2(0)$=1. A change from Bose-Einstein statistics towards Poissonian statistics in the underlying photon number distribution can be seen as well. The results also show a strong dependence of the emission characteristics on the microcavity diameter. The experimental setup involves a streak camera which is modified such that a signal at fixed wavelength can be monitored after each pulsed laser excitation. The correlations are evaluated by averaging over an ensemble of such pulses. From these measurements insights into the quantum optical properties of light emission from semiconductor nanostructures can be taken.

HL 31.39 Tue 16:30 Poster D

Influence of spin-orbit coupling and crystal-field splitting on the electronic and optical properties of nitride quantum dots with a wurtzite structure — •Stefan Schulz[1], Stefan Schumacher[2], and Gerd Czycholl[1] — [1]Institute for Theoretical Physics, University of Bremen — [2]College of Optical Sciences, University of Arizona, Tucson, USA

In recent years, semiconductor quantum dots (QDs) have been the subject of intense experimental and theoretical research. As a new material system, group-III nitride based devices are of particular interest due to their wide range of emission frequencies from infrared to ultraviolet and their potential for high-power electronic applications.

We present an sp^3 tight-binding model for the calculation of the electronic and optical properties of InN/GaN quantum dots (QDs). The tight-binding model takes into account piezoelectricity, spin-orbit coupling and crystal-field splitting. Excitonic absorption spectra are calculated using the configuration interaction scheme. We study the electronic and optical properties of InN/GaN QDs and their dependence on structural properties, crystal-field splitting, and spin-orbit coupling.

HL 31.40 Tue 16:30 Poster D

Optical Bloch equations for coupled nanosystems: linear spectra, saturation dynamics and pump-test spectra — •Marten Richter[1], Thomas Renger[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany — [2]Institut für Chemie und Biochemie, Freie Universität Berlin, Germany

Bloch equations for optical and electronic processes in Coulomb-coupled nanostructures (like pigments in pigment protein complexes or semiconductor quantum dots) are presented. The theory includes Förster coupling induced excitation transfer between the nanostructures, electron-vibrational coupling between the nanosystems and their environment as well as the interaction with arbitrary strong external optical fields. The theory is based on many particle Liouville and correlation expansion techniques. In the case of photosynthetic antenna complexes the parameters of the theory are derived from crystal structure data. As a typical example, a comparison of simulated data and experimental results for the intensity dependent fluorescence yield of

the light harvesting complex of photosystem II is discussed.

HL 31.41 Tue 16:30 Poster D

Theory of quantum light harvesting of coupled quantum dot systems — •Alexander Carmele, Marten Richter, and Andreas Knorr — Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Within a density-matrix approach for the coupled electron-photon dynamics, we compare the excitation of Coulomb-coupled quantum dots [1] with classical and non-classical light [2]. The theory evaluates the impact of the different photon-statistics of the exciting light (e.g. sub-poissonian or squeezed light) on the creation and annihiliation of optically active excitons. In particular, to understand the light harvesting dynamics of Förster-coupled nanosystems under realistic conditions we examine the exciton generation via thermal light.

[1]M. Richter, K.J. Ahn, A. Knorr, A. Schliwa, D. Bimberg, M. E.-A. Madjet, T. Renger, Phys.Stat.Sol.(B), 243(10):2302-2310, 2006
[2]M. Kira, S.W. Koch, Phys. Rev. A 73, 013813 (2006)

HL 31.42 Tue 16:30 Poster D

Time-resolved electroluminescence (TREL) measurements of InAs quantum-dot spin-injection LEDs — •H. Flügge, W. Löffler, P. Asshoff, C. Gohn, M. Hetterich, and H. Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH) and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe, Germany

We investigated the temporal behavior of the electro-luminescence in InAs quantum-dot spin-injection light-emitting diodes. We have recently demonstrated near-unity spin-injection fidelity in some quantum dots using a semi-magnetic spin aligner. To better understand the observed dependence of the polarization degree on emission energy we study the temporal characteristics of the polarized luminescence. In contrast to all-optical devices, where the relevant time-scale is the pico-second range, in electrical devices capacitive effects (among other things) come into play. We describe the time-correlated single-photon counting setup for the time-resolved measurements in the near infrared under pulsed current pumping. We expect the TREL technique to be able to reveal the dynamics of the relevant relaxation channels.

HL 31.43 Tue 16:30 Poster D

Effective-bond-orbital-Modellierung von Halbleiter-Quantenpunkten — •Daniel Mourad und Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen

Die Berechnung elektronischer Einteilchenzustände von niederdimensionalen Strukturen (z.B. Halbleiter-Quantenpunkten) erfolgt häufig entweder mit Kontinuumsmodellen wie dem $\mathbf{k}\cdot\mathbf{p}$-Modell oder sogenannten empirischen Tight-Binding-Modellen (ETBM), die von lokalisierten atomaren Orbitalen ausgehen. Beide Ansätze wählen zweckmäßigerweise eine Parametrisierung, welche innerhalb gewisser Grenzen die Bulk-Bandstruktur der betreffenden Materialien reproduziert. Das ETBM passt die Bandstruktur selbstkonsistent an, während das $\mathbf{k}\cdot\mathbf{p}$-Modell einen festen Satz von Materialparametern verwendet, allerdings in seiner Anwendbarkeit prinzipiell auf einen kleinen Bereich der Brillouin-Zone beschränkt ist. Das Effective-Bond-Orbital-Modell (EBOM) ist ein Tight-Binding-Modell, welches die atomare Basis des Festkörpers vernachlässigt und das elektronische Problem auf dem unterliegenden Bravais-Gitter diskretisiert, allerdings mit Hilfe der $\mathbf{k}\cdot\mathbf{p}$-Parameter. Es liefert befriedigende Resultate für die gesamte Brillouin-Zone. Wir benutzen das EBOM mit übernächster-Nachbar-Kopplung zur Berechnung der Einteilchenzustände von in Zinkblende-Struktur kristallisierenden Halbleiter-Quantenpunkten (CdSe in ZnSe und GaN in AlN). Zusätzlich wird aufgezeigt, dass die Vernachlässigung kleiner Spin-Bahn-Wechselwirkungen nicht ad hoc gerechtfertigt werden kann.

HL 31.44 Tue 16:30 Poster D

Many-body model for the simulation of few-electron THz response in gated nanowires — •Radoslav Németh and Klaus Michael Indlekofer — CNI/JARA, IBN-1, Research Center Jülich GmbH, D-52425 Jülich, Germany

We consider a THz probe technique for the spatially resolved analysis of electronic spectra in nanowire-based transistors employing a multi-segment gate design [1]. We simulate the THz response of few-electron quantum states within the nanowire channel by use of a recently developed numerical many-body technique [2,3]. The discussed example demonstrates that signatures of Wigner-like charge density waves can be identified by use of this method, which lies beyond the scope of standard meanfield approaches. As such, the proposed multi-gate THz probe technique might prove useful in a future experimental realization as a means to characterize nanoscale devices which are dominated by quantization and few-electron Coulomb effects.

[1] K. M. Indlekofer, et al., DRC2007, IEEE Cat. 07TH8948, 179 (2007)
[2] K. M. Indlekofer and R. Németh, cond-mat/0609540, submitted (2007)
[3] K. M. Indlekofer, J. Knoch, and J. Appenzeller, Phys. Rev. B 72, 125308 (2005)

HL 31.45 Tue 16:30 Poster D

Optical Investigations of the Temperature Behavior of InP Quantum Dots Embedded in Different Shaped ($\mathbf{Al}_x\mathbf{Ga}_{1-x}$)InP Barriers — •Moritz Bommer, Matthias Reischle, Wolfgang Michael Schulz, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart

InP quantum dots (QD) are promising sources of single photons in the red part of the visible spectrum, and thus in the range of the highest sensitivity of current silicon detectors. Providing a single–photon source working at temperatures achievable by thermo–electric–cooling is the main goal of our current work.

The QDs were grown by self assembled metal organic vapor phase epitaxy and afterwards processed with chromium masks or mesas to allow for μ–PL measurements on single QDs. We have investigated the influence of aluminum (Al) containing barriers, raising the confinement of charge carriers in the QDs, to allow for operation at higher temperatures. Therefore, we have compared different barrier confinement potential shapes for different Al contents. With this approach we obtained single–dot photoluminescence at temperatures up to 140 K and could measure antibunching above liquid nitrogen temperature.

HL 31.46 Tue 16:30 Poster D

Inhomogeneous broadening of Raman LO/TO line in silicon nanowire samples — •Harald Scheel, Sevak Khachadorian, and Christian Thomsen — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

We studied the Raman spectra of silicon nanowires as a function of excitation power, and find red-shifted and inhomogeneously broadened lines with increasing laser excitation power. A study of the local temperature by Stokes to anti-Stokes intensity ratios in our Raman spectra is inconsistent with temperatures determined by the Raman peak position considering anharmonic effects. We discuss this inconsistency and present an approach to merge the different results.

HL 31.47 Tue 16:30 Poster D

Influence of the Coulomb interaction on linear and nonlinear optical properties of single-wall carbon nanotubes — •Matthias Hirtschulz[1], Frank Milde[1], Ermin Malic[1], Stefan Butscher[1], Christian Thomsen[2], Stefanie Reich[3], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Germany. — [2]Institut für Festkörperphysik, Technische Universität Berlin, Germany. — [3]Fachbereich Physik, Freie Universität Berlin, Germany.

We present an optical Bloch equation approach to linear and nonlinear optical properties of single-wall carbon nanotubes. Within a density matrix theory the equations of motion for the coherent interband transitions and electron band occupations are obtained. The electron-electron interaction is treated on both the mean-field (screened Hartree-Fock approximation) and the correlation level. This approach allows to describe linear absorption as well as ultrafast nonlinear dynamics of these quasi one-dimensional systems. Linear excitonic absorption spectra are used to benchmark our approach. We find a band renormalization and the formation of excitons in carbon nanotubes on the mean-field level. To elucidate ultrafast and nonequilibrium effects, we will give several examples for the ultrafast nonlinear dynamics including the optical Stark effect. Finally, we will give an outlook on the influence of Coulomb scattering on the nonlinear optical properties of carbon nanotubes.

HL 31.48 Tue 16:30 Poster D

Optical Control of electron spin qubit in InAs self-assembled quantum dots — •Clive Emary[1] and Lu Jeu Sham[2] — [1]TU Berlin, Sekr. PN 7-1, Institut für Theoretische Physik, Hardenbergstr. 36, D-10623 BERLIN, Deutschland — [2]Department of Physics, University

of California San Diego, La Jolla, California 92093, USA

The spin of an electron trapped in a self-assembled quantum dot is viewed as a promising quantum bit. We present here a theory of the control of such qubits using short laser pulses to excite virtual trion states within the dots. We describe mechanisms for qubit initialisation and for performing universal one and two qubit operations. We show that, for InAs dots, initialisation can be achieved on the nanosecond time-scale, and that coherent operations can performed with laser pulses with durations of tens of picoseconds. These results are of direct relevance to current experiments.

HL 31.49 Tue 16:30 Poster D

Enhanced charge carrier confinement in quantum dots and wires fabricated by cleaved edge overgrowth — •Jörg Ehehalt, Christian Neugirg, Dieter Schuh, and Werner Wegscheider — Universität Regensburg, Germany

The Cleaved Edge Overgrowth technique (CEO) is used to fabricate quantum wires and dots with precisely controlled sizes and positions. These structures are formed by quantum mechanical bound states at the intersection of two or three perpendicular quantum wells.

Confinement energies of up to 54 meV for wires and 10 meV for dots have been reported. However, a larger confinement is needed in oder to study excited states, apply external fields without loosing confinement and for application in room-temperature devices. This can be achieved by asymmetric intersections and tensile strain between materials with different lattice constants.

Using a combination of these techniques, the confinement energy can be significantly improved. The properties of these nanostructures are studied by photoluminescence and photoluminescence excitation spectroscopy and the results compared to theoretical simulations.

These results are also applied to fabricate novel electrically-pumped quantum wire lasers operating at higher temperatures and lower threshold currents. In addition, single and coupled CEO quantum dots with higher confinement energies are promising candidates for research in areas like quantum information processing.

HL 31.50 Tue 16:30 Poster D

Theoretical investigations of the photoluminescence from Si nanocrystals — •Davoud Pouladsaz[1], Michael Schreiber[1], and Reinhard Scholz[2] — [1]Institut für Physik, Technische Universität Chemnitz — [2]Walter Schottky Institut, Technische Universität München

The photoluminescence (PL) of H-passivated tetrahedral silicon nanocrystals up to a diameter of 2.5 nm has been investigated by optimizing the geometries in the electronic ground state and in the relaxed excited state with density functional theory (DFT) and time-dependent DFT, respectively. In the excited state, the modified occupation numbers of the frontier orbitals define an anisotropic change of the electronic charge density, so that the deformation in the relaxed excited state consists of a symmetry conserving part and a tetragonal distortion. From a comparison of our calculations with measured PL bands obtained on clusters with known size distribution, we find an agreement of the PL energies within better than 0.2 eV. Moreover, our calculated PL lineshapes give clear evidence that the large linewidth of the PL band is an intrinsic property of each individual cluster, not the result of an average over an ensemble of different cluster geometries. In the relaxed excited geometries, some low-frequency *e*-symmetric vibrations are elongated so strongly that their broad Poisson progression inhibits the observation of distinct vibronic subbands of modes at high frequencies.

HL 31.51 Tue 16:30 Poster D

Coupling of quantum-dot excitons with nanoantennas — •Markus Pfeiffer[1,2], Thomas Zentgraf[1,2], Markus Lippitz[1,2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart — [2]Max Planck Institut für Festkörperforschung, Stuttgart

Our goal is to increase the coupling efficiency of single quantum systems to light with optical nanoantennas. As particle plasmon polaritons in metal nanostructures show a strong coupling to the light field, they seem to be promising candidates for this. We try to engineer the emission properties of quantum objects, such as excitons in semiconductor quantum dots, by utilizing the local field enhancement of metal nanostructures. For the experimental investigation of the emission rate, we use a streak camera which provides spectral and temporal resolution of the photoluminescence of the quantum dots. From such measurements the ensemble luminescence lifetime can be determined with an (multi)exponential fit of the spectrally integrated intensity profile. The goal is to increase the radiative decay rate of the excitons in the quantum dots by designing the local field enhancement of metal nanostructures. For different quantum dot systems, the dependence of the coupling process on the thickness of the capping layer between quantum dots and metal structures is studied. We will demonstrate limitations of these ensemble measurements and show first steps towards characterization of well defined single quantum dot–nanoantenna pairs.

HL 31.52 Tue 16:30 Poster D

Structural Change and Power Factor Enhancement of Thermoelectric p-type Films — •Katrin Rothe[1], Matthias Stordeur[2], Hartmut Leipner[1], Frank Heyroth[1], and Bernd Engers[2] — [1]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität 06099 Halle — [2]angaris GmbH, Heinrich-Damerow-Str. 1, 06120 Halle

By sputter-deposition thin films of the thermoelectric effective p-type compound semiconductor $(Bi_{0.15}Sb_{0.85})_2Te_3$ were prepared. For the first time a distinct increase of the electrical conductivity σ was observed after heating of the as-deposited films and afterwards cooling. For the enlightenment of this typical behavior, which seems to be similar found for phase change materials consisting of (Ge, Sb, Te)-alloys, also the Seebeck (S) and the Hall coefficient were measured. It was established that the increase of the electrical conductivity is not connected with an expected decrease of the Seebeck coefficient, because the charge carrier density is reduced but at the same time the hole mobility is increasing. Corresponding analytical investigations by XRD, EDX, and REM shows that besides a grain growth in the polycrystalline films a Te-rich phase appears after the heat treatment. The increase of the electrical conductivity at nearly unchanged Seebeck coefficient can be exploited for the enhancement of the film power factor $(S^2\sigma)$. This is important for the efficiency of thermoelectric thin films devices as miniaturized coolers, generators, and sensors. Nevertheless for a quantitative interpretation of the presented new experimental results further investigations and theoretical considerations are required.

HL 31.53 Tue 16:30 Poster D

Electrical and Mass transport in multi-wall carbon nanotubes — •Markus Löffler, Uhland Weissker, Thomas Mühl, Thomas Gemming, Rüdiger Klingeler, and Bernd Büchner — IFW Dresden, D-01069 Dresden, Germany

Electrical transport and concomitant mass transport in multi-wall carbon nanotubes (MWCNT) has been studied in a transmission electron microscope (TEM) using the tip of an in-situ scanning tunneling microscope (STM). Mass transport driven by electromigration has been observed. Contact resistances, which are of great influence in 2-point measurement setups, have been reduced by current-driven annealing. Furthermore, breakdown current densities of empty MWCNT have been determined. This work presents a starting point for measuring important electronic and electromechanical properties of filled and/or doped carbon and oxide-based nanoscale materials.

HL 31.54 Tue 16:30 Poster D

Substrate induced low-dimensionality in few-layer graphene — •Jörg Kinzel[1], Jens Ebbecke[1,2,3], and Achim Wixforth[1,2] — [1]Lehrstuhl für Experimentalphysik 1, Universität Augsburg, Germany — [2]Center for NanoScience, München, Germany — [3]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom

Since the first fabrication of few- and single-layer graphene many surprising properties have been discovered in this material.

By using a special technique for exfoliation, we were able to produce few-layer graphene (FLG) on top of a rather rough SiO_2 surface. Such FLG devices already exhibit some of the extraordinary properties of a single-layer graphene flake. In our case, surface roughness induced humps locally distort the graphene layers and bend their nearly flat hexagonal topology, inducing local strain and stress modulations.

Conduction measurements at liquid helium temperatures exhibit the typical graphene V shaped conductivity with a minimum at finite gate bias which, however, is superimposed by Coulomb blockade like oscillations.

HL 31.55 Tue 16:30 Poster D

Lateral electrical contacts to single bismuth-selenide nanowires — •Saskia F. Fischer[1], Markus Wahle[1], Shadyar Farhangfar[2], Jana Sommerlatte[2], and Kornelius Nielsch[2,3]

— [1]Electronic Materials and Nanoelectronics, Ruhr-University of Bochum, D-44780 Bochum, Germany — [2]Max-Planck Institute of Microstructure Physics, D-06120 Halle, Germany — [3]Institute of Applied Physics, University of Hamburg, D-20355 Hamburg, Germany

Nanoscale thermoelectric materials are of high interest to science and technology dealing with the conversion of heat to electricity, and vice versa. Recent increases in thermoelectric efficiency have been achieved in sub-micrometer scaled structures [1-3]. Bismuth telluride and bismuth selenide are particularly interesting for applications at room temperature [4]. Bismuth selenide nanowires arrays were grown by electrochemical deposition into anodic alumina templates with pore diameters of 25 nm, 50 nm, and 100 nm and lengths of 2 μm up to 10 μm. Subsequently the anowires were dissolved from the template in an aqueous NaOH solution and applied to prepatterned Si_2O/Si substrates. Single nanowires were laterally contacted in four-terminal geometry by electron-beam lithography, Ti/Au electron-beam evaporation and lift-off processing. Electrical characterizations of the nanowire arrays and single nanowires are currently in progress. [1] R. Venkatasubramanian et al., Nature 413, 597 (2001), [2] T.C.Harman, et al. Science 297, 2229 (2002), [3] Y.-M. Lin and M.S. Dresselhaus, Phys. Rev. B 68, 075304 (2003). [4] H.J. Goldsmid, Thermoelectric Refrigeration (Plenum New York, 1964).

HL 31.56 Tue 16:30 Poster D

Carbon doped high mobility 2D hole gas in GaAs/AlGaAs heterostructures — Christian Gerl, •Marika Kubová, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg

Carbon as an acceptor in GaAs/AlGaAs heterostructures provides significant advantages in comparison with Si and Be acceptor materials. C-doped structures exhibit high mobility of two-dimensional hole gases (2DHGs) beyond 10^6 cm^2/Vs. It is possible to prepare structures in standard growth directions (in the (001) and (110) crystal plane) in contrast to Si-doped GaAs (311)A. Utilizing a carbon filament doping source, ultra high mobility quantum wells and modulation doped single interface structures in the GaAs/AlGaAs material system were prepared by molecular beam epitaxy (MBE). Hole mobility strongly depends on quantum well width and spacer thickness. Both parameters were optimised. Magnetotransport measurements at low temperatures show hole mobilities of 1.2*10^6 cm^2/Vs on GaAs (001) substrates. The carrier density reveals a hysteretic behaviour when tuned with an external electric field.

HL 31.57 Tue 16:30 Poster D

Magnetic properties of amorphous, p-type conducting $CuCr_{0.95}Mg_{0.05}O_2$ and $CuCr_{0.93}Mg_{0.05}Mn_{0.02}O_2$ — •Qingyu Xu[1], Heidemarie Schmidt[1], Shengqiang Zhou[1], Kay Potzger[1], Manfred Helm[1], Holger Hochmuth[2], Michael Lorenz[2], Christoph Meinecke[2], and Marius Grundmann[2] — [1]Forschungszentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung,Bautzner Landstraße 128, 01328 Dresden, Germany — [2]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

$CuCr_{0.95}Mg_{0.02}O_2$ is p-type oxide semiconductor with the highest conductivity [1]. We prepared conductive, polycrystalline and amorphous $CuCr_{0.95}Mg_{0.05}O_2$ and $CuCr_{0.93}Mg_{0.05}Mn_{0.02}O_2$ films on a-plane sapphire substrates by pulsed laser deposition under different O_2 partial pressure and substrate temperature. Hall measurements were performed to study the majority free charge carrier type in these films. The polycrystalline $CuCr_{0.95}Mg_{0.05}O_2$ and $CuCr_{0.93}Mg_{0.05}Mn_{0.02}O_2$ films are n-type conducting up to 290 K, while in amorphous $CuCr_{0.95}Mg_{0.05}O_2$ and $CuCr_{0.93}Mg_{0.05}Mn_{0.02}O_2$ films the type of majority free charge carriers changes from n-type to p-type around 270 K. The antiferromagnetic to paramagnetic transition was observed in both polycrystalline and amorphous $CuCr_{0.95}Mg_{0.05}O_2$ films at 25 K, while the $CuCr_{0.93}Mg_{0.05}Mn_{0.02}O_2$ films revealed no antiferromagnetic ordering. [1] R. Nagarajan et al. J. Appl. Phys. 89, 8022 (2001)

HL 31.58 Tue 16:30 Poster D

Transport Measurements of Graphene — •Hennrik Schmidt, Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We study electronic transport properties of few layer graphene. Similar to a mono layer, even a small stack of a few layers exhibits a strong field effect while changing the type and amount of charge carriers by applying a backgate voltage. Our samples are made by micromechanical cleavage of natural graphite and are deposited on top of a silicon wafer with a 330 nm thick silicon oxide. The flakes are contacted using electron-beam lithography and structured using plasma etching. Our measurments have been carried out in a bath cryostat with temperatures down to 1.5 Kelvin. The electric field effect is measured while changing temperature and magnetic field. Magneto-transport with a applied field up to 13 Tesla shows Shubnikov-de Haas oscillations depending on the backgate voltage and thereby on the carrier concentration. Additionally, the Hall effect was measured. The change of the type of charge carriers from electrons to holes and of their density is observed in both measurements.

HL 31.59 Tue 16:30 Poster D

Classical ballistic transport in a triangular shaped cavity — Roland Ketzmerick and •Martin Richter — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Recent magneto-resistance measurements on semiconductor heterostructures with a triangular shaped gate revealed unexpectedly detailed features in R(B) [D. Maryenko et al., unpublished] beyond simple commensurabilities. We explain this by classical ballistic transport and demonstrate the importance of the phase-space structure, the width of the openings, and the softness of the potential.

HL 31.60 Tue 16:30 Poster D

Magneto-Transport in Two-Dimensional Electron Systems beneath Ferromagnetic Nanostructures — •Ralf Dinter[1], Holger Stillrich[1], Christian Heyn[1], Andreas Frömsdorf[2], Hans Peter Oepen[1], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Institut für Physikalische Chemie, Universität Hamburg, Bundesstr. 45, 20146 Hamburg

We study the magneto-transport of two-dimensional electron systems (2DEG's), which are subjected to laterally modulated magnetic fields. Our goal is to investigate the energy splitting of the Landau levels due to field modulations with periods less than 100 nm. Shallow GaAs/AlGaAs High Electron Mobility Transistors are grown with MBE, where the 2DEG's are located down to less than 20 nm beneath the sample surface. In order to achieve a modulated magnetic potential, a nano-structured Co/Pt multilayer is prepared directly on the samples. Hereby, a monolayer of micelles, consisting of diblockcopolymers, is used as a template. The micelles arrange in a hexagonal lattice with short-range order. The magnetic properties of the ferromagnetic material are studied with the magneto-optical Kerr effect. The magneto-transport is investigated in Hall bar geometry at temperatures between 4.2 K and 20 mK. We present magneto-transport measurements on Hall bars with a modulated magnetic potential.

HL 31.61 Tue 16:30 Poster D

Structural, optical and electrical properties of novel phase change alloys — •Sarah Gindner, Michael Woda, Stephan Kremers, Michael Klein, and Matthias Wuttig — I. Physikalisches Institut (1A), RWTH Aachen, 52056 Aachen

Phase Change Materials (PCM) are Te or Sb containing alloys, which show a remarkable property combination. They possess a very large property contrast, e.g. electrical resistivity and optical reflectivity between the amorphous and crystalline state. At the same time they can be switched between these two states very rapidly on a ns timescale using either a laser or current pulse. Hence they are used in rewriteable optical storage media such as DVDs and Blue-ray disks and are promising candidates for non-volatile electronic memories such as Phase Change Random Access Memory (PCRAM). From a scientific point of view it is important to determine their structural properties. In this study possible new PCM including $CuInTe_2$ and $Ge_3Sb_6Te_5$ are investigated by a variety of techniques to understand the effect of stoichiometric change upon physical properties. From these techniques the suitability of new materials for phase change application is derived and will be discussed. Temperature dependent resistivity is investigated with the van der Pauw technique. XRD measurements reveal the structural properties of the amorphous and crystalline state. The structural changes causing changes in film thickness and density are measured with x-ray reflectometry. Optical properties (0,02 eV to 5.3 eV) of the PCM are determined by FTIR and ellipsometry measurements.

HL 31.62 Tue 16:30 Poster D

Experimental verification of the lens effect of a fractal structured LHM in the microwave regime — •Ernst Lenz, Benjamin Meier, and Heino Henke — TU Berlin, Fachgebiet Theoretische Elektrotechnik EN-2, Einsteinufer 17, 10587 Berlin, Germany

Left-handed material (LHM) is a novel artificial structure with outstanding properties, such as the predicted lens effect [1,2,3]. In this presentation we show experimental data, confirming the lense effect for the microwave regime. The used test structure was originally suggested by Ziolkowski et al. [4].

The experimental proof of the lens effect was achieved by a variation of the angle of incidence of the electromagnetic radiation. In addition we investigate a new constructed metamaterial where we have replaced the split ring resonator by Koch snowflakes [5,6]. The data emphasize the changes in the scattering, diffraction, and absorption behavior compared to the test structure.

[1] V. G. Veselago, Sov. Phys. Usp. **10**, 509 (1968). [2] J. B. Pendry, Phys. Rev. Lett **85**, 3966 (2000). [3] N. Engheta et al., IEEE-TMTT **53**, 1535 (2005). [4] R. W. Ziolkowski, IEEE-TAP **51**, 1516 (2003). [5] J. B. Pendry et al., IEEE-TMTT **47**, 2075 (1999). [6] K. J. Falconer, *Fraktale Geometrie*, Spektrum, Berlin (1990).

HL 31.63 Tue 16:30 Poster D

Resonant behavior of fractal shaped metamaterials — •Benjamin Meier, Ernst Lenz, and Heino Henke — TU Berlin, Fachgebiet Theoretische Elektrotechnik EN-2, Einsteinufer 17, 10587 Berlin, Germany

Resonant fractal meta structures are investigated with the aim of drastically reducing the resonance frequency. A Koch snowflake is used as fractal structure [1]. We show that an essential reduction of resonant frequency in the microwave regime could be achieved for fractals of higher orders without changing the maximal spatial extent.

This offers the possibility of higher homogenization of metamaterials by using smaller unit cells [2,3]. Consequently scattering and diffraction of the impinging electromagnetic waves are reduced.

As an example the dispersion curve for the fourth order fractal meta structure is calculated, resulting in the typical metamaterial behavior [4].

[1] K. J. Falconer, *Fraktale Geometrie*, Spektrum (1990). [2] A. Semichaevsky et al., Prog.ER **71**, 129 (2007). [3] M. G. Silveirinha, PRB **75**, 115104 (2007). [4] D. R. Smith et al., PRL **84**, 4184 (2000).

HL 31.64 Tue 16:30 Poster D

Mix-and-Match process for ballistic devices on epitaxial few-layer graphene — •Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Konstantin V. Emtsev[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, D-91058 Erlangen

In this work we demonstrate a technique for the preparation of ballistic devices with precise geometric definition from epitaxial few-layer graphene. The technique combines the basic strategies for the fabrication of a strongly confined low-dimensional system: a) positive definition of nanostructures, b) a simple mix-and-match process for definition of contact areas and leads, c) a low-damage single-step plasma etch transfer. Starting material is few-layer graphene grown epitaxially on SiC(0001) by graphitization of the surface [1]. In a first process step alignment marks are realized by conventional UV-lithography and lift-off technique. Nanostructures are defined in a 70 nm-thick negative-tone resist (ma-N 2401) by high-resolution e-beam lithography. In the following process-step the geometries of the contact areas and leads are realized by conventional UV-lithography. The resulting resist structure is transferred by low-damage plasma etching using an inductively coupled O_2/He plasma. A minimal line-width of 30 nm was achieved reproducibly. The reliability of the process is shown by the fabrication of cross-junctions formed by orthogonal adiabatically shaped leads.

[1] Th. Seyller et al., Surface Science **600**, 3906 (2006).

HL 31.65 Tue 16:30 Poster D

Electrically induced phase transition in GeSbTe alloys — •Gunnar Bruns, Carl Schlockermann, Michael Woda, and Matthias Wuttig — I. Physikalisches Institut Ia, RWTH Aachen, 52056 Aachen

While phase change materials have already successfully been applied in rewriteable optical data storage, they are now also promising to form the basis for novel non-volatile electrical data storage devices. To understand the physical concepts of these so-called Phase Change Random Access Memory (PCRAM) it is mandatory to gain a deeper insight into the switching process between the highly resistive amorphous and the lowly resistive crystalline phase.

The fast phase transitions between the amorphous and crystalline state of GeSbTe-based alloys has so far often been studied using pulsed laser irradiation. In this work an alternative approach is employed to investigate this transition. Electrical pulses are used to rapidly and reversibly switch between the two states.

For these experiments a setup was built with a specially designed contacting circuit board to meet the requirements of electrical measurements on a nanosecond timescale. The influence of the pulse parameters on the change of device resistance was determined for different initial states. Furthermore the high time resolution of 0.4 ns allows investigation of transient electrical effects like the so-called threshold switching first described by Ovshinsky in the late 1960s. [S.R. Ovshinsky. Reversible Electrical Switching Phenomena in Disordered Structures. *Physical Review Letters*, 21(20):1450-1453, 1968.]

HL 31.66 Tue 16:30 Poster D

Investigation of charge transfer in organic-inorganic hybrid composites — •Marc Daniel Heinemann, Karsten von Maydell, Ingo Riedel, Joanna Kolny-Olesiak, Holger Borchert, and Jürgen Parisi — Energy- and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, Carl-von-Ossietzky-Straße 9-11, D-26111 Oldenburg

This contribution reports on investigations of the charge transfer process in hybrid solar cells using II-VI semiconductor nanocrystals as acceptor material. CdSe-nanocrystals within this polymer-based-composite have the capability to increase the light absorption compared to standard fulleren-derivatives.

The charge transfer between the conjugated polymer and the nanocrystal will be characterized by Light-induced Electron Spin Resonance (LESR) spectroscopy and Optical Detection of Magnetic Resonance (ODMR). Additionally the polaronic states will be detected by Photoinduced Absorption.

These measurements will be expanded to other hybrid composites.

HL 31.67 Tue 16:30 Poster D

Development of mesoporous TiO_2-electrodes as ordered acceptor matrix for organic-inorganic bulk-heterojunction solar cells — •Jan Friedmann[1], Bettina Herbig[3], Maria Hammer[1], Andreas Sperlich[1], Moritz Liedtke[2], Ingo Riedel[1], Carsten Deibel[2], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilian University of Würzburg, Am Hubland, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D97074 Würzburg, Germany — [3]Fraunhofer Institut für Silicatforschung, Neunerplatz 2, D97082 Würzburg, Germany

There is a vast variety of intriguing concepts for the improvement of organic photovoltaic devices. One approach focuses on the application of mesoporous acceptor-type metal oxides (e.g., TiO_2) infiltrated by a donor-type conjugated polymer (P3HT) forming a hybrid bulk heterojunction. To establish efficient dissociation of photogenerated excitons in the polymer phase the porosity of the acceptor-template is to be optimized for twice the exciton diffusion length. We realized mesoporous TiO_2-electrodes derived from a sol-gel process using structure-directing block-copolymers and evaporation induced self assembbley technique. The structure of the mesoporous films was characterized by XRD-analysis and TEM-imaging. We experimentally verified the efficiency of this elementary via photoluminescence quenching experiments and photoinduced absorption spectroscopy to qualify the formation of long-lived excited states such as polarons, triplet excitons.

HL 31.68 Tue 16:30 Poster D

Development of Al-doped ZnO-nanocrystals for applications in advanced cell concepts of organic photovoltaics — •Daniel Rauh[1], Volker Lorrmann[1], Maria Hammer[2], Andreas Sperlich[2], Moritz Liedke[1], Carsten Deibel[2], Ingo Riedel[1], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research (ZAE Bayern), Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg — [2]Experimental Physics VI, Physical Institute, Julius-Maximilian University of Würzburg, Am Hubland, D-97074 Würzburg

We developed Al doped ZnO-nanocrystals (nc-ZnO:Al) via wet chemical synthesis. XRD-analysis, electron spin (ESR) and electron-nuclear

spin double resonance (ENDOR) confirm that nc-ZnO:Al grows in Wurtzite structure and aluminium enters the crystal on site of the Zn-atom. ESR experiments on blends of P3HT and nc-ZnO:Al confirm light-induced charge separation with resonances assigned to polarons on P3HT and electrons in the nc-ZnO:Al domain. Photoinduced absorption spectroscopy was applied to rationalize infiltration of P3HT into porous nc-ZnO:Al matrix: Spectra of bilayer structures reveal coexistence of positive polarons and triplet excitons while strong polaron formation is accompanied with complete quenching of triplet excitons (TE) for infiltrated ZnO:Al-matrices. Polaron formation and quenching of TE is ascribed to the enlarged interface in the bulk heterojunction. ENDOR-measurements as well as photoluminescence studies on pure ZnO:Al confirm that sodium, incorporated during synthesis, result in deep-level acceptor states in the middle of the band gap.

HL 31.69 Tue 16:30 Poster D

Application of Al-doped ZnO-nanocrystals for novel organic–inorganic hybrid solar cells — •Stefan Geissendörfer[1], Daniel Rauh[1], Ingo Riedel[1], Carsten Deibel[2], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research (ZAE Bayern), Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg — [2]Experimental Physics VI, Physical Institute, Julius-Maximilian University of Würzburg, Am Hubland, D-97074 Würzburg

Hybrid solar cells based on polymers and metal oxides combine the advantages of organic and inorganic materials such as high absorption coefficients, efficient charge generation as well as solution-processability. Doped metal oxides are of particular interest as they are inexpensive, environmentally friendly and can be obtained in versatile shapes (dots, rods, porous films). We synthesized aluminium-doped ZnO-nanocrystals (4–7nm) to use them as electron acceptors in hybrid bulk heterojunction devices. For this, a mesoporous matrix is prepared from ZnO:Al-nanoparticle dispersions to be infiltrated by a conjugated polymer acting as electron donor. We present first realizations of hybrid ZnO:Al-poly(alkylthiophene) bulk heterojunction solar cells and discuss their photovoltaic performance in respect of modified active layer morphology and electrode materials.

HL 32: Quantum dots and wires: preparation and characterization I

Time: Wednesday 14:15–17:45 Location: ER 270

HL 32.1 Wed 14:15 ER 270

Towards quantification of the In-distribution in embedded InGaAs quantum dots — •Holger Blank[1], Dimitri Litvinov[1], Reinhard Schneider[1], Dagmar Gerthsen[1], Thorsten Passow[2], and Kurt Scheerschmidt[3] — [1]Laboratory for Electron Microscopy (LEM), University Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Institute for Applied Physics and Center for Functional Nanostructures (CFN), 76128 Karlsruhe, Germany — [3]Max Planck Institute for Microstructure Physics, 06120 Halle, Germany

The composition of InAs quantum dots (QDs) grown by molecular-beam epitaxy was studied by high-resolution transmission electron microscopy (TEM) using the composition evaluation by lattice fringe analysis (CELFA) technique [1]. Significant deviations between real and nominal QD composition occur frequently due to In-segregation during GaAs cap layer growth. To understand the opto-electronic properties of the QDs, the real composition needs to be determined. The application of TEM to three-dimensional structures is hampered by the averaging effects over the TEM specimen thickness. This lowers artificially the measured In-concentration in QDs which are embedded in a GaAs matrix. We solve the averaging problem by determining the QD shape and size as well as the TEM sample thickness. We show that QDs deposited at a very low InAs growth rate of 0.0056 ML/s contain a core of almost pure InAs.

[1] A. Rosenauer, D. Gerthsen, Ultramicroscopy 76 (1999), 49-60

HL 32.2 Wed 14:30 ER 270

Nanoparticle size separation in a drying fluid droplet — •Matthias Offer[1], Cedrik Meier[1], Stephan Lüttjohann[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics, Universität Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [2]Institute of Combustion and Gas Dynamics, Universität Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany

We study the deposition of optically active nanoparticles with a broad size distribution in a drying fluid droplet on a solid surface. The nanoparticles are dispersed in a drying droplet and migrate to the edge of the droplet to form ring-like structures on the surface. After deposition we find a particle size separation, i.e., different particle diameters are deposited in different spatial locations. This leads to a position-dependent energy shift in the micro-photoluminescence signal. Furthermore, the observed photoluminescence peak of the deposited nanoparticles has a significantly lower full width at half maximum (FWHM) than the nanoparticle powder used for dispersion. The spatial size separation is caused by an outward flow within the droplet. The flow is driven by the loss of solvent during the evaporation phase. Nanoparticles with small masses are more stable in the dispersion than particles with large masses. There fore large particles are deposited first. We compare the deposition results for silicon nanoparticles, which are synthesized from the gas-phase, to results obtained using commercially available PbS nanoparticles with functionalized surfaces.

HL 32.3 Wed 14:45 ER 270

Optical and structural properties of transition metal implanted ZnO nanowires — •Sven Müller[1], Carsten Ronning[1], MinJie Zhou[2], and Quan Li[2] — [1]II. Physikalisches Institut, Georg-August Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Department of Physics, Chinese University of Hong Kong, Shatin, New Territory, Hong Kong

Room temperature ferromagnetism has been proposed for Transitions metal (TM) doped ZnO, and therefore ZnO:TM is of high potential for spintronic applications [1]. Additionally, TM-doped semiconductors show optical active and sharp intra-3d-transition with long life-times. Such intra-shell transitions are usually forbidden, but due to the incorporation into a suitable matrix the crystal field splitting leads to long-life partly allowed transitions [2,3]. Fe, Ni or Co-ions were implanted into VLS-grown ZnO nanowires [4] with a box like profile and different fluences to obtain TM concentrations of 1, 2 and 4 at.%. The nanowires were annealed at 700°C for 30min in air. The morphology was examined by SEM and HR-TEM, revealing an intense damage of the nanowires surface and the crystal lattice. EDX and EELS measurements showed effective incorporation of the TM elements with the desired concentrations. The optical properties were investigated using PL/CL and show sharp intra-3d transitions of the corresponding TM.

[1] K. Sato et al., Phys. Status Solidi B 229, 673 (2002)
[2] H.A. Weakliem, J. Chem. Phys. 36, 2117 (1962)
[3] R. Heitz et al., Phys. Rev. B 45, 8977 (1992)
[4] C. Borchers et al., J. Phys. Chem. B 110, 1656 (2006)

HL 32.4 Wed 15:00 ER 270

Ion implanted GaAs nanowire pn junctions — •Katharina Wegener[1], Daniel Stichtenoth[1], Carsten Ronning[1], Christoph Gutsche[2], Werner Prost[2], and Franz Josef Tegude[2] — [1]II. Institute of Physics, University of Göttingen, Germany — [2]Solid-State Electronics Department, University of Duisburg-Essen, Germany

Ion beam doping of materials offers advantages in comparison to doping during growth or by diffusion. First, the impurity concentration as well as the lateral and depth distributions of the dopants are precisely controllable, and secondly, almost all elements can be implanted isotope-selective even beyond any solubility limit.

We present studies on ion implanted gallium arsenide (GaAs) nanowire pn junctions. Nominal intrinsic GaAs nanowires were grown by the vapour-liquid-solid mechanism using gold nanoparticles on top of GaAs (100) substrates. Sulphur, being a donor in GaAs, was implanted into the nanowires using different ion energies resulting in a uniform concentration profile. The now n-type doped nanowires were then reinserted into the metal organic vapour phase epitaxy system. After an annealing procedure, the growth of the nanowires was continued under the addition of an acceptor. Finally, the fabricated nanowire pn junctions were shaved from the growth substrate and processed with contacts on top of insulating carrier substrates. First results on the electrical characterization of these structures will be shown.

HL 32.5 Wed 15:15 ER 270

InAs/GaAs(001) quantum dots, investigation of dot shape and composition with synchrotron X-ray diffraction. — •Andriy Zolotaryov, Andreas Schramm, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Quantum dot fabrication with molecular beam epitaxy (MBE) utilizes the three-dimensional self-organization of lattice-mismatched III-V heterostructures grown in Stranski-Krastanov mode. During MBE-growth of InAs QDs on GaAs a high amount of substrate material diffuses inside the QDs. This strongly modifies the QD strain status and thus, the process of QDs formation. The intermixing in the InAs/GaAs(001) QD systems is a complex function of growth parameters such as substrate temperature, InAs growth rate etc. and is still matter of scientific discussions. Our synchrotron X-ray studies of MBE grown InAs/GaAs(001) quantum dots reveal information about their composition and shape. The dot average chemical composition is quantitatively estimated by comparison to finite-element based calculations. A study of dots grown with varying amount of deposited InAs establishes that the composition remains constant within the whole probed InAs deposition region. Furthermore, the increase of deposited InAs amount entirely leads to a proportional increase of the surface dot density and does not significantly influence the dot size.

HL 32.6 Wed 15:30 ER 270

Influence of the deposition rate on the InP quantum dot formation in $Al_{0.20}GaInP$ barriers — •Bjoern Jakobi — Universität Stuttgart, IHFG, Institut für Halbleiteroptik und funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany

The preconditions for high efficient quantum dot (QDs) devices and single photon emitters are high luminescence efficieny at elevated temperatures. We examine InP QDs capped $Al_{0.20}GaInP$ barriers in order to achive these requirements for the red spectral range.
Major influence for the temperature stability can be attributed to band offsets between the barrier and the QDs, the confinement energy. This is mainly influenced by deposition parameters like the growth time and the growth rate of the InP QDs. In our experiment we hold the total amount of material of 2.1 monolayers (ML) constant and vary the growth rate between 2.1 ML/s and 0.525 ML/s. The samples in this series were grown at 650 °C to avoid Al incorporation into the dots. The dots were capped by 30 nm $Al_{0.20}GaInP$ barriers.
The spectral analysis was done with photoluminescence (PL) measurements. Further we show the influence of the growth rate on the power and temperature dependent behavior of our structures by time-resolved and quasi continous PL-measurements with a pulsed Ti-Saphire laser. With these methods we deduced the confinement energy and differ the wetting layer from dots. The samples show a temperature stability to 80 K partly up to 90 K. Allthough a bimodal size distribution of the dots could have been expected, the presented series shows only small A-type QDs.

HL 32.7 Wed 15:45 ER 270

Low strain AlGaInAs Quantum Dots for Cavity Quantum Electrodynamic Experiments — •Christian Schneider, Andreas Loeffler, Stephan Reitzenstein, Sven Hoefling, and Alfred Forchel — Universitaet Wuerzburg, Germany

We present a novel kind of quantum dots (QDs) suitable for short-wavelength cavity QED (quantum electrodynamics) applications in the GaAs material system. Using the ability of the AlGaInAs material system to tailor the QD morphology and emission wavelength independently, we realized QDs with enlarged dimensions emitting below 900 nm by solid source MBE growth. Despite adding low amounts of aluminum into the QDs, the QD density could be reduced to $3*10^9 cm^{-2}$ by enhancing the surface diffusion length of the deposited atoms. The QDs showed elongations along the [0-11] direction of more than 100 nm, widths of 40 nm and heights of less than 5 nm. Low temperature photoluminescence measurements revealed that the QDs emit below 900 nm with an inhomogeneous broadening of 45 meV. Tuning low density QD arrays with enlarged dimension into the emission range below 900 nm, where highly sensible streak cameras and Si APDs have increased efficiencies, makes them promising candidates for cavity QED experiments. In a first approach we embedded a single QD layer in an AlAs/GaAs micropillar cavity with quality factors exceeding 50000 for a 4 μm pillar. By temperature tuning a single QD in resonance with the fundamental mode of the cavity we could measure a clear enhancement of the spontaneous emission rate in a micro PL study.

15 min. break

HL 32.8 Wed 16:15 ER 270

Formation, atomic structure, and electronic properties of GaSb/GaAs quantum rings — •Rainer Timm[1], Andrea Lenz[1], Lena Ivanova[1], Holger Eisele[1], Ganesh Balakrishnan[2], Diana L. Huffaker[2], Ian Farrer[3], David A. Ritchie[3], and Mario Dähne[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Center for High Technology Materials, University of New Mexico, Albuquerque, USA — [3]Cavendish Laboratory, University of Cambridge, UK

The growth of semiconductor quantum dots (QDs) and their transition into quantum rings (QRs) upon overgrowth have attracted large interest during the last years. In the GaSb/GaAs material system, which is very promising for charge storage devices due to its type-II band alignment [1], a spontaneous transition of QDs into QRs during fast overgrowth has been observed.

Using cross-sectional scanning tunneling microscopy and spectroscopy [2], we were able to study the atomic structure, chemical composition, and electronic properties of GaSb/GaAs QRs grown by MBE using various growth conditions. Typical QR baselengths vary between 10 and 20 nm with inner diameters amounting to about 40% of the outer ones, at densities of up to 9×10^{10} cm^{-2}.

A strong Sb segregation upon GaAs overgrowth is observed, which is assumed to be the driving force for ring formation together with the large strain within the nanostructures.

[1] M. Geller et al., Appl. Phys. Lett. **82**, 2706 (2003).
[2] R. Timm et al., Appl. Phys. Lett. **85**, 5890 (2004).

HL 32.9 Wed 16:30 ER 270

X−ray investigations on $CoSi_2$ nano wires manufactured by focused ion beam synthesis — •Jörg Grenzer[1], Lothar Bischoff[1], and Andreas Biermanns[2] — [1]Forschungszentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research 01314 Dresden, Germany — [2]FB7 - Physik, Universität Siegen, ENC - B012, 57068 Siegen, Germany

Nanowires and chains of nanoparticles are of emerging interest in nanoelectronics, nano-optics and plasmonics as well as for their monolithic integration into microelectronic devices; $CoSi_2$ is a promising material due to its CMOS-compatibility in micro-electronics technology. It shows metallic behaviour with low resistivity and high thermal stability. It is well known that cobalt disilicide films can be formed in silicon by implanting Co in stoichiometric concentration and a subsequent annealing procedure. Ion beam synthesis allows the fabrication of epitaxial buried or surface $CoSi_2$ layers on silicon. Sub-micron patterns with feature dimensions much smaller than $100nm$ can be directly produced by writing focused ion beam (FIB) cobalt implantation.

We have studied the strain of the Si host lattice in the surrounding area of a single nanostructures depending on their crystallographic orientation using high resolution x-ray diffraction in combination with a highly focused ($\approx 3\mu m$) x-ray beam at the beam line ID1 at the ESRF. The pattern measured directly on the wire shows a small peak indicating tensile strain (approx. -1.4%). This feature can be only found if the beam focused on a nano wire whereas its intensity changes with the layer width.

HL 32.10 Wed 16:45 ER 270

Limitations of In(Ga)As/GaAs quantum dot growth — •Andrea Lenz[1], Rainer Timm[1], Holger Eisele[1], Lena Ivanova[1], Roman L. Sellin[1], Huiyun Liu[2], Mark Hopkinson[2], Udo W. Pohl[1], Dieter Bimberg[1], and Mario Dähne[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Germany — [2]University of Sheffield, Dept. of Electronic and Electrical Engineering, UK

Large In(Ga)As/GaAs quantum dots (QDs) with an emission wavelength of 1.3 μm are of widespread interest for devices in optoelectronics. Two different growth strategies to achieve those larger QDs are - among others - the overgrowth with a strain-reducing InGaAs layer [1] or the growth of InAs QDs within InGaAs quantum wells [2].
Using cross-sectional scanning tunneling microscopy (XSTM) we studied such In(Ga)As QD samples grown with MOCVD and MBE. In both cases the intended size increase of the QDs is confirmed, but it is accompanied by some QDs containing a material hole, and hence will not contribute to the luminescence. We will present atomically-resolved XSTM images of these defects and discuss the similarities and differences between the two samples. In addition, we developed growth

models considering the strain and the limited growth kinetics during capping, demonstrating the limits of larger QD growth.
This work was supported by the DFG by projects Da 408/12, Da 408/13, and Sfb 296, TP A4 and A7, as well as the SANDiE Network of Excellence of the EC.
[1] A. Lenz et al., Appl. Phys. Lett. **85**, 3848 (2004)
[2] H. Y. Liu et al., Appl. Phys. Lett. **89**, 073113 (2006)

HL 32.11 Wed 17:00 ER 270

Electroluminescence of InP-quantum dots in $Al_{0.20}GaInP$-barriers — •Wolfgang-Michael Schulz, Robert Rossbach, Björn Jakobi, Michael Wiesner, Michael Jetter, and Peter Michler — Universität Stuttgart, Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany

The use of electrically pumped single-photon emitters (SPE) in the red spectral range is of high interest for future quantum information technologies, as modern APDs have their maximum sensitivity in the visible red. With InP-quantum dots (QDs) in AlGaInP-barriers, these wavelengths are quite easily reachable.

On the way to the rather complex structure of such an SPE, one has to carefully adjust the electrooptical properties of the active region.

Within this contribution we present the continuously driven ensemble electroluminescence characteristics of InP-quantum dots embedded in an $Al_{0.20}GaInP$-barrier with $Al_{0.50}GaInP$-cladding in a pin-LED-structure. With a total confinement energy of around 300 meV for the Quantum dots, it was possible to achieve bright electroluminescence from 5 K up to 320 K. The growth process of the QDs on the Al-containing barriers implies usually a bimodal distribution, which just can be observed in the low temperature electroluminescence-spectra. At higher temperatures the emission of the lower energetic QDs is suppressed.

HL 32.12 Wed 17:15 ER 270

Self-assembled quantum dots grown by Molecular Beam Epitaxy on InP-substrate for single photon application at 1.55 μm — •Daniela Baierl, Roland Enzmann, Christian Jendrysik, Christian Seidel, Susanne Dachs, Gerhard Böhm, Ralf Meyer, Jonathan Finley, and Markus-Christian Amann — Walter Schottky Institut

Quantum key distribution requires practical sources of single photons with the standard telecommunication wavelength 1.55 μm, thus they can be efficiently transmitted through fiber optics. Self-assembled InAs-quantum dots allow the observation of single photons as long as their surface density is small enough (approximately 1 dot/μm^2). To achieve emission at 1.55 μm it is necessary to use InP(001) as substrate material instead of GaAs - dots on GaAs can not provide higher wavelength than 1.3 μm. But instead of dot formation the deposition of InAs on InP or lattice-matched AlInAs and GaInAs matrix-materials leads to elongated structures, so called "'quantum dashes"'. The mechanism which drives this asymmetric growth is not fully understand, but Indium on the surface, where dot-formation starts, plays an important role. By avoiding Indium in the uppermost layers we show the formation of quantum dots, even with low density. We present several realizations of In-free materials, e. g. a thin sublayer GaSb which suppresses In-segregation from the subjacent Indium-containing matrix-material. We also discuss the photoluminescence characteristics which are different to dots on GaAs, because combining Antimony-containing materials with InAs often results in a type-II band-alignment.

HL 32.13 Wed 17:30 ER 270

Growth of Sub-Monolayer Quantum Dots by MOCVD — •Franziska Luckert, Konstantin Pötschke, Till Warming, and Dieter Bimberg — Technical University of Berlin, Institute of Solid State Physics, Sekr. EW 5-2, Hardenbergstr. 36, D-10623 Berlin, Germany

Sub-monolayer (SML) deposition is an alternative approach for the self-organised formation of quantum dots (QDs) different from the Stranski-Krastanow growth mode. The deposition of a SML InAs on GaAs (001) surface results in the formation of distinct monolayer (ML) high InAs islands which influence, after overgrowth with GaAs, the deposition of the next SML by non-uniform lateral strain.

In this study the growth of the SML QDs was done by metal-organic chemical vapour deposition. Several samples with varying: -thickness of the GaAs spacer, -amount of InAs ($<$ 1 ML) and -number of repetitions of InAs/GaAs cycles were grown and examined with Photoluminescence (PL) at 10K. The emission wavelength was observed to be tuneable from 900 to 1000 nm, depending on the growth parameters. The peaks observed in the PL spectra are characterised by a very small full width at half maximum of 4-12 meV. The detailed mathematical analysis of the line shape of these peaks yields that the SML heterostructures can be described as a quantum-dot in a quantum-well structure. This implies that there are regions with a high In concentration in a lower In-content quantum well which show a Gaussian PL shape.

HL 33: III-V semiconductors II

Time: Wednesday 14:15–18:30 Location: EW 201

HL 33.1 Wed 14:15 EW 201

Measurement of 002 structure factors for GaAs from electron spot diffraction patterns — Knut Müller[1], •Marco Schowalter[1], Andreas Rosenauer[1], Jacob Jansen[2], John Titantah[3], and Dirk Lamoen[3] — [1]Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee1, 28359 Bremen — [2]National Centre for HREM, Laboratory of Materials Science, Delft University of Technology, Lorentzweg 1, 2628 Delft, The Netherlands — [3]Departement Fysica, Universiteit Antwerpen, Groenenborgerlaan 171, B-2020 Antwerpen, Belgium

Accurate knowledge of chemically sensitive structure factors (SF) is essential e.g. for quantitative analysis of the composition in ternary semiconductor nanostructures, such as InGaAs, by TEM. Recent calculations also account for the electron redistribution due to bonding effects and are to be proven experimentally. A new method was developed to measure SF from Bragg intensities in TEM diffraction patterns. An appropriate microscope setup for nanodiffraction under parallel illumination has been worked out. Using the program package ELSTRU, the procedure first extracts the integrated intensities of each Bragg spot and subtracts the background. In the first of two refinements, the local thickness and orientation of the specimen as well as the Debye-Waller factors are refined by the routine MSLS. For the second refinement of one SF in question, a Bloch-wave simulation program was developed that fits experimental and calculated intensities. The method was succesfully tested on simulated images with background.

HL 33.2 Wed 14:30 EW 201

Optical studies on surface passivation by both wet-chemical sulfur treatment and epitaxial core-shell growth of GaAs Nanowires — •Steffen Münch[1], Niklas Sköld[2], Stephan Reitzenstein[1], Johanna Trägardh[2], Alexander Gorbunov[1,3], Martin Kamp[1], Lars Samuelson[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]The Nanometer Structure Consortium, Lund University, 22100 Lund, Sweden — [3]Institute for Solid State Physics, Russian Academy of Science, 142432 Chernogolovka, Russia

We report on the optical characterization of chemical and core-shell passivation techniques applied to GaAs nanowires (NWs). In particular, standard and time resolved micro photoluminescence (PL) spectroscopy was employed to investigate the effect of surface passivation on GaAs NWs. In case of GaAs surface passivation is of particular interest due to the large surface recombination velocity inherent to this material system. Chemical and core-shell passivation techniques were applied to GaAs NWs grown on a (111)B GaAs substrate using Au as catalysts. The core-shell NWs were realized by overgrowing a GaAs core in a MOVPE reactor with a 50 nm thick $Al_{0.5}In_{0.5}P$ shell. Surface treatment results in an enhancement of free excitonic emission by a factor of about 40 and 110 for sulfur passivated and core-shell NWs, respectively. Furthermore, the effect of surface passivation is reflected in a strong reduction of the surface recombination velocity S to 2.5 x 10^4cm/s for the core-shell NWs compared to typical values of about 1 x 10^6cm/s reported for untreated GaAs NWs.

HL 33.3 Wed 14:45 EW 201

Swift heavy ion irradiation for recovery from implantation defects of GaN — •Anne-Katrin Nix[1], Sven Müller[1], Carsten Ronning[1], Andrey Kamarou[2], Elke Wendler[2], Werner Wesch[2], Christina Trautmann[3], and Hans Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller Universität, Jena, Germany — [3]Gesellschaft für Schwerionenforschung, Darmstadt, Germany

Doping GaN by ion implantation (100 keV Mg-ions) is a desired task for the realization of lateral optoelectronic devices, but results in a high level of lattice defects. Thermal annealing can be used for recrystallisation, but surface melting and dopant diffusion hampers the annealing effect. Here, we present an alternative annealing method. The GaN crystals are irradiated with swift heavy ions, thus, the sample is locally heated during a timespan of 10^{-12} seconds , surrounding material stays unaffected. Mg ions were implanted into GaN with fluences of 3x10^{13} ions/cm^2 and 10^{14} ions/cm^2. These samples were irradiated with several ion species at different energies (578 MeV Cr, 55 MeV Xe, 140 MeV Kr, 1GeV Xe and 593 MeV Au), thus the electronic energy loss is varied (8 keV/nm, 17 keV/nm, 19 keV/nm, 27 keV/nm, 43 keV/nm). Directly after implantation and after irradiation, the photoluminescence was examined at low temperature (12 K), the obtained spectra are compared to well known spectra of GaN and GaN:Mg. For an annealing effect is seen after Cr-irradiation, GaN samples were irradiated with 668 MeV Ni (9 keV/nm) with varying fluences to examine a fluence dependence of the annealing process.

HL 33.4 Wed 15:00 EW 201

Effects of localized Boron states on the transport properties of n-BGaInAs — •Jörg Teubert[1,2], Peter J. Klar[2], Wolfram Heimbrodt[1], Andrew Lindsay[3], and Eoin P. O'Reilly[3] — [1]Department of Physics and Material Sciences Center, Philipps-University Marburg, Germany — [2]Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany — [3]Tyndall National Institute, Lee Maltings, Cork, Ireland

The incorporation of isovalent boron on cation sites of GaAs results in strongly localized electronic states resonant with the conduction band. All present experimental and theoretical results indicate that these states have only minor influence on the conduction band structure. We show however that such states strongly affect the electronic transport behaviour of this unusual semiconductor alloy. We study the influence of these boron cluster states on the electronic transport of n-type BGaInAs-layers. We performed magnetotransport measurements at temperatures from 1.6 K to 300 K using magnetic fields up to 10 T and hydrostatic pressure up to 20 kbar. At ambient pressure and low carrier concentration both strong negative MR effects at low fields and a giant exponential positive MR at high magnetic fields can be observed. The latter is regarded as proof of a hopping transport mechanism and is interpreted as a metal insulator transition under the influence of an external magnetic field. Under hydrostatic pressure the results are dominated by the complex interplay between extended band states, localized boron states and dopant states.

HL 33.5 Wed 15:15 EW 201

Optical properties of InN layers grown by high pressure CVD — •Ronny Kirste[1], Mustafa Alevli[2], Markus R. Wagner[1], Christian Thomsen[1], Nikolaus Dietz[2], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics and Astronomy, Georgia State University (GSU), Atlanta, GA

Including Indium Nitride (InN) into the ternary $Ga_{1-x}Al_xN$ system enables the fabrication of tunable emitters operating from the infrared to the ultraviolet wavelength regime. At present, the growth of InN with chemical vapour deposition is still a great challenge due to low growth temperatures required to stabilize the compound. The use of a novel high pressure chemical vapour deposition (HPCVD) system allows to grow single crystalline high quality InN at temperatures up to 950°C at reactor pressures around 15 bar. We present micro-Raman analysis results on InN samples fabricated under different growth conditions and on different substrate templates. Analyzing the non-polar strain sensitive E_2(high) mode we evaluate the crystalline quality and strain in those samples. Additionally, luminescence measurements on those samples were performed. We discuss the spectra regarding the band edge and correlate the results with the data obtained from Raman spectroscopy.

15 min. break

HL 33.6 Wed 15:45 EW 201

Morphologische und strukturelle Untersuchungen an AlInN auf GaN/Si(111) — •Aniko Gadanecz, Jürgen Bläsing, Armin Dadgar, Christoph Hums, Thomas Hempel, Jürgen Christen und Alois Krost — Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Fakultät für Naturwissenschaften, Universitätsplatz 2, 39016 Magdeburg, Germany

AlInN ist ein, u.a. für elektrische und optoelektronische Anwendungen hochinteressanter III-V-Halbleiter, wie z.B. für Hochleistungs-FETs und Bragg-Spiegel. Mittels metallorganischer Gasphasenepitxie (MOCVD) gewachsene AlInN-Schichtserien auf GaN/Si(111) verschiedener Schichtdicken bis max. 100 nm und mit In-Konzentrationen im Bereich von 9% bis 36% wurden untersucht. Als besondere Eigenschaft von AlInN gilt das gitterangepasste Wachstum auf GaN bei einem In-Gehalt von 17,4 %; eine Abweichung der Konzentration von 17,4% verursacht im Falle eines auf GaN voll verspannten Gitters eine kompressive oder tensile Verspannung. Überschreitet zusätzlich die Schichtdicke einen kritischen Wert, sind die Schichten bereits nach dem Wachstum teilrelaxiert bzw. vollständig relaxiert. Je stärker ausgeprägt die Relaxation der Schichten, umso größer die Tendenz für eine Entmischung, wodurch phasenseparierte Gebiete unterschiedlicher In-Konzentrationen entstehen und die Qualität deutlich verschlechtert wird. Die morphologischen und strukturellen Eigenschaften, wie Relaxation, Phasenseparation und Oberflächenmosaizität wurden mittels hochauflösender Röntgenbeugung, Röntgenreflektometrie und Feldemissions-Rasterelektronenmikroskopie (FEREM) untersucht.

HL 33.7 Wed 16:00 EW 201

Eigenschaften des In-Defekt-Komplexes im III-V-Halbleiter AlN — •Bettina Steitz und Reiner Vianden — Helmholtz-Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn

Nach Implantation des Isotops ^{111}In in einen AlN-Film auf Saphir-Substrat kann man mittels der Methode der gestörten Winkelkorrelation (PAC) beobachten, dass sich die radioaktiven Sonden nach einer Ausheiltemperatur von 1273K in unterschiedlichen Umgebungen befinden. Frühere Messungen zeigten, dass neben einem Anteil von 45%, der ein Verhalten aufweist, wie er für Indium auf einem ungestörten Al-Gitterplatz zu erwarten ist, der Rest erfährt eine weitere Wechselwirkung, wie sie für einen In-Defekt-Komplex typisch ist.

Um dessen Natur näher zu untersuchen, wurden die AlN-Proben zusätzlich mit verschiedenen Dosen von ^{115}In und ^{24}Mg implantiert. Dies führte zu der Beobachtung, dass bei Implantation von ^{115}In mit der Dosis $10^{14}\,\frac{\text{Ionen}}{\text{cm}^2}$ sowohl der Anteil der Sonden, auf die der Defekt wirkte, sank, wie auch die Gitterfrequenz sich verlangsamte. Im Gegensatz dazu führte eine Implantation von Mg mit der Dosis $10^{14}\,\frac{\text{Ionen}}{\text{cm}^2}$ zwar ebenfalls zu einer Abnahme des Defektanteils der Sonden, jedoch zu einem Anstieg der Gitterfrequenz.

HL 33.8 Wed 16:15 EW 201

Strain fields in the vicinity of nanoindentions on (100) surfaces of GaAs — •Christian Röder[1], Gert Irmer[1], Michael Schaper[2], Ralf Hammer[3], and Manfred Jurisch[3] — [1]Institut für Theoretische Physik, TU Bergakademie Freiberg, Leipziger Straße 23, 09596 Freiberg, Germany — [2]Institut für Werkstoffwissenschaft, TU Dresden, Helmholtzstraße 7, 01062 Dresden, Germany — [3]Freiberger Compound Materials GmbH, Am Junger Löwe Schacht 5, 09599 Freiberg, Germany

We present results of micro-Raman and micro-photoluminescence (PL) investigations on undoped GaAs samples with Vickers indentations on (100) surfaces generated with low indentation loads down to 5 mN. Because of the slight indentation loads cracks did not occur. In the vicinity up to 10xD of such indentations with a diagonal length of D we observed a characteristic shift of the Raman LO phonon mode. Converting this shift we found a strain field pattern reflecting the crystal symmetry. Referring to the [011] and [0-11] directions the observed residual stress is different indicating various stress relaxation mechanisms. Furthermore the Raman spectra provide information about the crystallinity and stress induced defect density. It is assumed that GaAs is in an amorphous state below the indenter top. PL measurements were performed at 293 K with the special emphasis on the study of the strain induced splitting between the heavy and light hole valence bands. The observed splitting of the PL signal is discussed in correlation to theoretical stress models and the Raman results.

HL 33.9 Wed 16:30 EW 201

Nanofabrication of surface templates for low and high density quantum dots formation — •Tino Pfau, Aleksander Gushterov, and Johann Peter Reithmaier — Technische Physik, INA, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

To overcome statistical variations of the dot position and the dot size in a self-assembled dots formation process, surface templates with nanoscale dimensions are developed based on electron beam lithography and wet-chemical etching. In comparison to dry etching, wet chemical etching avoids crystal damage and defect related non-radiative recombination processes should play a much smaller role. Here, different wet chemical surface preparation methods are examined to create atomically flat surfaces on GaAs as well as to create etched hole densities higher than $10^{10}\mathrm{cm}^{-2}$ as growth templates. The surfaces are characterized by scanning electron microscopy (SEM) and atomic force microscopy (AFM).

HL 33.10 Wed 16:45 EW 201

Enhancing nitrogen solubility in diluted nitrides by surface kinetics: An *ab initio* study — •Hazem Abu-Farsakh[1,2] and Jörg Neugebauer[1,2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [2]Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

$GaAs_{1-x}N_x$ alloys with low N content have recently attracted a lot of attention as material system of choice for making infrared laser diodes relevant e.g. for optical fiber communications. A specific challenge for practical applications is the low equilibrium solubility of N in bulk GaAs at typical growth temperatures (500 K). Interesting options to enhance N solubility are: (i) employing surface kinetics and (ii) growing quaternary $In_yGa_{1-y}As_{1-x}N_x$ alloys. In order to further explore/optimize these methods it is crucial to identify the atomistic growth processes of N adatoms on/in the GaAs surface.

We have therefore employed density functional theory to calculate the complete surface phase diagram of N at GaAs(001) surfaces, considering all relevant reconstructions and different layers. Besides, we studied the kinetic barriers and surface segregation of N on these surfaces and found clear evidence that N can be incorporated only in the topmost surface layer [1]. Using the phase diagrams we provide an estimate of N concentration as function of growth conditions. The surface solubility shows a rich behavior depending strongly on the specific surface structure. Based on these results we have been able to identify optimal growth conditions allowing for maximum N incorporation.

[1] M. Albrecht, H. Abu-Farsakh *et al.*, Phys. Rev. Lett. **99**, (2007).

15 min. break

HL 33.11 Wed 17:15 EW 201

MOVPE Growth of Antimonides on InP Substrate — •Christian Grasse, Ralf Meyer, Gerhard Böhm, and Markus-Christian Amann — Walter Schottky Institut, Technische Universität München

Electrically tunable Lasers like the Tunable Twin Guide Laser play an important role in the optical fiber telecommunication and are based on the principle of the plasma effect. Due to the injection of carriers in a tuning zone with a separate controllable current the emission wavelength of the lasers can be changed. To avoid heating of the laser, which would counteract the electrically tuning effect, requires to decrease the recombination of holes and electrons in the tuning zone, so that just a little current is needed for wavelength matching. A Typ-II heterostructure accomplishes this task due to the local separation of the carriers. For good partition high bandoffsets are needed, which is achieved by the aluminium free combination of GaInAsP and the barely explored alloy GaInPSb.

Growth via a MOVPE reactor and characterisation of GaInPSb on InP substrate in a temperature range of 500 to 575°C are presented. As precursors TMGa, TEGa, TMIn, TMSb and Phosphin are used with hydrogen as carrier gas. SIMS-, XPS-, Hall-, and photoluminescence measurements show an unexpected growth behaviour and evidence of clustering, which would limit an application in a device. To illustrate the difficulties of growing materials, which contain phosphor and antimony, comparative growth studies of GaPSb, InPSb, GaAsSb and GaInAsSb have been done and will be discussed.

HL 33.12 Wed 17:30 EW 201

Core levels, valence band structure and unoccupied states of clean InN surfaces — •Marcel Himmerlich, Anja Eisenhardt, Juergen A. Schaefer, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany

In this study we used a surface analytics system directly connected to a MBE growth module to study the surface properties of thin InN films. The samples were prepared by plasma assisted molecular beam epitaxy on $GaN/Al_2O_3(0001)$ templates and exhibited a 2×2 reconstruction after growth. The prepared samples were analysed by photoelectron spectroscopy as well as electron energy loss spectroscopy (EELS). For the occupied states, a very good agreement to available theoretical calculations is found [1,2]. Although, the valence band maximum is located at 1.6 eV, indicating strong downward band bending of ~ 0.9 eV, photoemission is detected up to E_F. This indicates that the Fermi level is pinned above the conduction band minimum, as recently predicted [1]. The spin-orbit splitting of the In4d level at 17.8 eV could be resolved using He II radiation. Furthermore, from the fine structure of the secondary electron cascade peak we extract the energy of different unoccupied states 0 eV to 9 eV above the vacuum level. These measurements enable us to identify features in the InN EELS spectra, with a loss energy larger than 16 eV, as interband transitions from the In4d level.

[1] D. Segev and C.G. Van de Walle, Europhys. Lett., 76 (2006) 305
[2] P.D.C. King et al., Appl. Phys. Lett., 91 (2007) 092101

HL 33.13 Wed 17:45 EW 201

Increased binding energy of impurities near a semiconductor-vacuum interface — A.P. Wijnheijmer[1], •J.K. Garleff[1], P.M. Koenraad[1], K. Teichmann[2], M. Wenderoth[2], S. Loth[2], and R.G. Ulbrich[2] — [1]PSN, Eindhoven University of Technology, the Netherlands — [2]IV. Phys. Inst., Georg-August Univ. Göttingen, Germany

We have recently shown that a STM tip can be used as a tool to manipulate the charge state of individual impurities below the cleavage surface of a semiconductor. This manipulation allowed us to determine the binding energy of single donors and acceptors as a function of their depth (up to 1 nm) below the surface. We found that the binding energy strongly increases near the surface. In the case of a Si-donor in GaAs the binding energy increases continuously from 5.6 meV in the bulk to about 150 meV close to the surface. Our STM techniques also allowed for the determination of the size and shape of the Coulomb field of single ionized donors. We found that the range of the potential is strongly reduced relative to the bulk value. Both the reduced range of the Coulomb potential and the increased binding energy can be related to a reduced dielectric constant and increased effective mass near the surface. We will discuss the implications of these findings. This work was supported by NWO, VICI project and DFG SFB 602 TP A7 and DFG SPP 1285.

HL 33.14 Wed 18:00 EW 201

Manipulation of charge on a single donor atom by Scanning Tunneling Microscopy — •K. Teichmann[1], M. Wenderoth[1], S. Loth[1], R.G. Ulbrich[1], J.K. Garlef[2], A.P. Wijnheijmer[2], and P.M. Koenraad[2] — [1]IV. Phys. Inst. Georg-August-Universität Göttingen — [2]PSN, Eindhoven University of Technology, the Netherlands

We investigated Silicon donors in highly doped GaAs by spatially resolved Scanning Tunneling Spectroscopy at 6 K. Recently it was shown by Feenstra [1], that the shape of the tip has a strong influence of the extension of the tip induced bend bending (TIBB) in the semiconductor. Sharp tips produce a lateral extension of TIBB in the semiconductor within the range of nanometers. The charge of an individual impurity can be manipulated by the TIBB in the following way: Donors, away from the tip, will be neutral, as the thermal energy at 6K is much smaller than the ionisation energy of the donor. The bands and the donor energy levels are lifted for positive sample voltage. At a certain amout of TIBB the donor ground state is lifted above the onset of the conduction band and the donor will be ionised. In the measurement the ionisation of the donor is seen as a peak in the dI/dV signal. In spatially resolved dI/dV maps the signal has a ring like structure. For higher applied voltages the diameter of the ring increases. By comparing the calculated TIBB and the voltage dependence of the lateral displacement of the measured peak a value of about 150 meV for the donor level can be extracted. This work was supported by DFG SFB 602 and DFG SPP 1285.

[1] R. M. Feenstra, J. Vac. Sci. Technol. B21(5) 2080 (2003)

HL 33.15 Wed 18:15 EW 201

Selective etching of independent contacts in a double quantum-well structure: quantum-gate transistor — •Stefan

Lang, Lukas Worschech, Monika Emmerling, Micha Strauss, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Double GaAs quantum wells (QWs) embedded between modulation-doped AlGaAs barriers with different Al contents were grown by molecular beam epitaxy.Independent electric contacts to each well were realized by applying different etching techniques without substrate removal. In particular the lower quantum well was electrically pinched off by a local undercut of the lower AlGaAs barrier. The upper QW was locally depleted by top etched trenches. Transistor operation of quantum wires defined in such bilayers is demonstrated at room temperature with one GaAs serving as channel controlled by the other nearby GaAs layer as efficient gate.

HL 34: Semiconductor Laser

Time: Wednesday 14:15–17:30 Location: EW 202

HL 34.1 Wed 14:15 EW 202

GaSb-based short cavity lasers using two-dimensional photonic crystal mirrors — •Adam Bauer, Mirjam Müller, Thomas Lehnhardt, Karl Rössner, Michael Hümmer, and Alfred Forchel — Technische Physik Universität Würzburg, Am Hubland, 97074 Würzburg

The realization of two-dimensional (2D) photonic crystals (PhCs) on the GaSb material system is presented using a Cl_2/Ar dry etch process. This allows the fabrication of PhCs covering air fill factors of $f = 20\% - 50\%$, lattice periods of a = 400-500 nm and aspect ratios of 5:1.

Quality and reflectivity of these structures are evaluated by incorporating the PhCs as high reflective rear mirrors in GaSb-based ridge waveguide lasers with cavity lengths between 100 μm and 1100 μm with cleaved front facets. The shortest devices show remarkable threshold currents well below 20 mA and efficiencies of 0.23 W/A, yielding a maximum output power of about 6 mW. These results prove the applicability of the developed fabrication technique to numerous further device concepts based on 2D PhCs on the GaSb material system.

A further example that illustrates the merit of being able to fabricate monolithically integrated 2D PhCs devices on GaSb is shown in terms of lasers with coupled cavities. These show single mode emission with side mode suppression ratios of 35 dB and discrete tuning behaviour over a wide driving current range.

To the best of the authors' knowledge, this is the first time 2D PhCs have successfully been integrated in optoelectronic devices on the GaSb material system.

HL 34.2 Wed 14:30 EW 202

Monolithic integration of pump lasers and high-power semiconductor disk lasers — •Wolfgang Diehl[1,2], Tony Albrecht[1], Peter Brick[1], Michael Furitsch[1], Stefan Illek[1], Stephan Lutgen[1], Ines Pietzonka[1], Johann Luft[1], and Wolfgang Stolz[2] — [1]Osram Opto Semiconductors, Regensburg, Germany — [2]Philipps Universität Marburg, Marburg, Germany

High output power combined with good beam quality and the possibility for wavelength engineering are the main reasons for the great interest in semiconductor disk lasers. One of the major disadvantages is the need for an external optical pump source that requires additional space and precise alignment. Therefore, integration of the pump laser and the disk laser is most desirable.

We demonstrate a novel design to integrate the pump laser monolithically with the semiconductor disk laser in a one-step epitaxy. By careful adjustment of the integrated pump laser and stacking sequence, it is possible to excite different mesa sizes, thus realizing power scalability. In particular, we show experimental results, demonstrating the power scalability and versatility of this design. Results are shown at 1000nm emission wavelength with high output power out of active regions with mesa diameters of 100μm to 400μm. We have demonstrated 1W out of a 100μm mesa and 2.5W out of a 200μm mesa in pulsed operation. Additionally, devices mounted on copper submounts have achieved more than 0.6W in cw operation using a 400μm structure.

In summary, we have pioneered an innovative approach for truly monolithic integration of a semiconductor disk laser with pump lasers.

HL 34.3 Wed 14:45 EW 202

Laser properties of (GaIn)Sb heterostructures - a microscopic evaluation — •Christina Bückers[1], Angela Thränhardt[1], Stephan W. Koch[1], Jörg Hader[2], Jerome V. Moloney[2], Marcel Rattunde[3], Nico Schulz[3], and Joachim Wagner[3] — [1]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universität Marburg, Renthof 5, 35032 Marburg, Germany — [2]Optical Sciences Center, University of Arizona, Tucson, Arizona 85721, USA — [3]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastraße 72, 79108 Freiburg, Germany

Semiconductor lasers emitting around 2 microns are of considerable interest in medical diagnostics, material processing or spectroscopic trace gas detection. GaSb-based (GaIn)Sb quantum well lasers are well suited for this wavelength range and promise excellent laser performance. On the basis of a microscopic many-particle theory, we predict optical gain spectra of such a (GaIn)Sb laser structure. The calculations show good agreement with the measurement, verifying that our model describes the material system with high precision. The obtained gain amplitude of the material system is remarkably large und we are enabled to attribute this feature mostly to band structure properties by a detailed comparison to simulations for an equivalent standard (GaIn)As structure.

HL 34.4 Wed 15:00 EW 202

Influence of low-absorption laser facets on catastrophic optical damage in AlGaInP lasers — •Marwan Bou Sanayeh[1], Peter Brick[1], Martin Reufer[1], Bernd Mayer[1], Martin Müller[1], Wolfgang Schmid[1], Mathias Ziegler[2], Jens W. Tomm[2], and Gerd Bacher[3] — [1]OSRAM Opto Semiconductors GmbH, Leibnizstrasse 4, 93055 Regensburg, Germany — [2]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin, Germany — [3]Universität Duisburg-Essen, Bismarckstrasse 81, 47057 Duisburg, Germany

AlGaInP lasers have emerged as the best candidates in the red spectral range for high-power applications like photodynamic therapy. However, catastrophic optical damage (COD) sets the ultimate limit for extracting high optical power out of the laser diodes. Over the past two decades, understanding and improving the COD effect has always been a challenge for scientists. In this work, complete characterization, detailed analysis, and performance improvement of AlGaInP lasers during COD are presented.

To study COD, microphotoluminescence mapping and focused ion beam analyses enabled the localization of the defects inside the resonator. Micro-Raman spectroscopy and real-time thermal imaging were used to study the physics behind COD, its related temperature dynamics, as well as associated defect and near-field patterns.

The knowledge of physics behind COD triggered a change in design of the near-facet region. We found that lasers with low-absorption facets design led to an increased COD level and an improvement in high-power laser performance.

HL 34.5 Wed 15:15 EW 202

Reliability of red 660 nm AlGaInP-VCSEL — •Marcus Eichfelder, Michael Wiesner, Robert Rossbach, Michael Jetter, and Peter Michler — Universität Stuttgart, Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, D-70569 Stuttgart

Vertical cavity surface-emitting lasers (VCSEL) based on AlGaInP material system have attracted much interest as potential key components for low-cost optical data communication via plastic optical fibres (POF). Therefore, in this talk we discuss the degradation mechanisms of AlGaInP-based red VCSEL as there is only little known about this topic. Our oxide-confined VCSEL have a high optical output power, low threshold current and high-temperature stability. In aging studies the degradation behaviour of VCSEL was investigated. To determine the different aging processes we stressed the devices at high temperatures and at high currents. These measurements gave us a first hint on acceleration factors for life-time testing. These studies show a remarkable progress in reliability of latest VCSEL compared to older ones due to improvements of the VCSEL structure implemented

during the last years. These optimized VCSEL were aged for more than 1000 hours and did not show any degradation.

As the degradation mechanisms are still under discussion, we try to exclude the degradation of the active region by time resolved experiments.

In the future the VCSEL cavity is used to serve as resonator for electrically pumped InP-quantum dots.

HL 34.6 Wed 15:30 EW 202

Temperature stable 920-nm quantum dot material for high power laser applications — •Emil Mihai Pavelescu and Johann Peter Reithmaier — Technische Physik, Institute of Nanostructure Technologies and Analytics, University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Besides high output powers, a stable emission wavelength is the main prerequisite for using laser diodes to pump solid state lasers or fiber amplifiers, such as ytterbium at the 920 nm wavelength range. Using a less temperature sensitive gain material, such as InGaAs/GaAs quantum dots, 920-nm laser diodes with a higher acceptable tolerance of their operation temperature were realized.The laser structure was grown by solid source molecular-beam epitaxy and consists of 820 nm core waveguide composed of GaAs/Al0.57Ga0.43As short period superlattices and 1600 nm thick Al0.60Ga0.40As cladding layers. The InGaAs self-organized quantum dots were formed at 500 °C by an alternating submonolayer deposition of InAs and In0.16Ga0.84As, corresponding to a nominal indium content of 52 % and a thickness of 5.4 monolayers. At room temperature the lasers showed good properties with lasing wavelengths near 920 nm. The laser structure had a strong dependence of its lasing wavelength with cavity length, a finger print of QD lasers due to a broader gain as compared to QW lasers. Notably, the lasers revealed small coefficients (< 0.19 nm/K) of wavelength variation with temperature, whose values decreased with increasing cavity length down to a remarkably value of around 0.08 nm/K.

15 min. break

HL 34.7 Wed 16:00 EW 202

Tapered Quantum Cascade Lasers — •Julia Semmel[1], Lars Nähle[2], Wolfgang Kaiser[1], Sven Höfling[1], and Alfred Forchel[1] — [1]Technische Physik Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Nanoplus GmbH, Oberer Kirschberg 4, 97218 Gerbrunn

Quantum Cascade Lasers (QCLs) are unipolar devices that have shown excellent performance in the mid-infrared wavelength range. For most applications, however, the beam divergence of the devices is a limiting factor, since it affects the coupling efficiency and resolution. In order to improve the horizontal far field characteristics, gain guided tapered sections have been introduced in 1996 [1]. They allow the fundamental mode to expand towards a broader output facet, which leads to a narrow far field.

In QCLs the gain guided approach can not be realized, since the laser structure displays an anisotropic electrical conductivity, which makes etching through the whole active region a necessity.

We report on index guided quantum cascade tapered lasers, which are based on a 2LO-Phonon-Resonace design [2]. The one-step dry-etching process provides etching depths of up to 12 μm with smooth, perpendicular edges. The output power of the tapered lasers at room temperature is as high as 300 mW and the FWHM angle of the horizontal far field scan is as small as 6.6 ° for a device with a 100 μm wide output facet.

References: [1] J. N. Walpole, Optical and Quantum Electronics, 28 (1996) 623; [2] Liu et al., Phot. Technol. Lett., 18 (2006) 1347

HL 34.8 Wed 16:15 EW 202

Coherence in Optics and Transport in Quantum Cascade Lasers — •Carsten Weber[1], Andreas Wacker[1], and Andreas Knorr[2] — [1]Mathematical Physics, Lund University, Box 118, 221 00 Lund, Sweden — [2]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Quantum cascade lasers have been extensively investigated as prototypes for terahertz and far-infrared intersubband systems in both the transport as well as the linear and nonlinear optical regime. Recent experiments have shown coherent signatures in the optical pump-probe signals, while it is known that in certain regimes, a fully coherent calculation (i.e. beyond Wannier-Stark hopping) is required for a sufficient description of the current. Here, we investigate within a microscopic density-matrix theory the regimes where a coherent description of the optical dynamics and transport properties is necessary. We find that, in general, a coherent description is necessary in order to fully account for the combination of nonlinear dynamical optical and transport properties of the system.

HL 34.9 Wed 16:30 EW 202

Wavelength stabilized high-brightness tapered quantum dot lasers — •Christian Zimmermann[1], Pia Weinmann[1], Wolfgang Kaiser[1], Johann-Peter Reithmaier[2], Martin Kamp[1], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]INA, Universtität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

In high-brightness semiconductor lasers, the use of quantum dots (QD) as active material has a number of advantages over the use of quantum wells (QW), e.g. lower threshold densities, reduced carrier diffusion and filamentation. Another beneficial property of QD lasers is their reduced temperature dependence of the emission wavelength. The decrease of the bandgap with increasing temperature is partially counterbalanced by a shift of the gain maximum caused by the increasing losses. This reduces the change of the emission wavelength $\Delta\lambda/\Delta T$ by a factor of two compared to quantum well devices.

We have investigated the performance of quantum dot based tapered lasers emitting at 920 nm. The devices have output power of more than 3W with a good beam quality. The extra losses of the taper have an impact on the operation point of the laser on the gain curve, leading to a dependence of $\Delta\lambda/\Delta T$ on the taper angle. A minimum value of 0.16 nm/K was measured for lasers with a 1^o taper. In addition, this effect was used to determine the taper losses for various taper angles. A further stabilization of the emission wavelength can be achieved by the incorporation of distributed Bragg reflectors (DBRs). These devices emit on a single wavelength with more than 1W output power.

HL 34.10 Wed 16:45 EW 202

Dynamic Response of Quantum-Dot Lasers – Influence of Nonlinear Electron-Electron Scattering — •Kathy Lüdge, Ermin Malić, Andreas Knorr, and Eckehard Schöll — Institut für Theoretische Physik, Sekr. EW7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We show that the dynamic response of electrically pumped quantum dot lasers can be quantitatively understood by including the strongly nonlinear character of electron-electron scattering processes. The numeric simulations presented here combine a microscopic approach used for calculating the non-radiative scattering rates with a rate equation model used for modeling the complex dynamic turn-on behavior. The quantum-dot laser is described by a 5-dimensional system, where the electrons and holes are first injected into a wetting layer before being captured into the quantum dot. The latter is considered as a two-level system for electrons and holes.

The calculated electron-electron scattering rates show a strongly nonlinear dependence on the electron and hole densities in the wetting layer which is found to be responsible for the strong damping of the relaxation oscillations of the laser. Furthermore we demonstrate the importance of the mixed (e-h) Auger capture processes that depend on both the electron and the hole density in the wetting layer. Finally we are able to explain experimental data over a wide range of different pump currents.

HL 34.11 Wed 17:00 EW 202

High Performance AlGaInAs Quantum Dot Lasers in the Visible Wavelength Region (λ =760 nm) — •Sven Gerhard, Thomas W. Schlereth, Wolfgang Kaiser, Sven Höfling, and Alfred Forchel — Technische Physik Universität Hubland 97074 Würzburg

Since the commonly for quantum dot (QD) lasers employed GaInAs QDs do not allow for laser operation below ≈ 900 nm which is essential for a number of applications we incorporated the high bandgap material AlAs into GaInAs QDs forming $Al_xGa_{1-x-y}In_yAs$ QDs to reach short wavelengths. It was recently shown for 920 nm QD lasers that the insertion of Al into GaInAs QDs leads to lower threshold current densities J_{th} and increased material gain due to decreased QD sizes and increased QD densities [1]. We fabricated broad area (BA) lasers and distributed feedback (DFB) lasers based on $Al_xGa_{1-x-y}In_yAs$ QDs emitting in the wavelength region of ≈ 760 nm. The BA devices exhibit a high internal quantum efficiency η_i of 87 %, an absorption α_i of ≈ 6 cm^{-1}, a transparency current density J_{tr} of 132 Acm^{-2} and a

modal gain coefficient Γg_0 of ≈ 37 cm^{-1}. The DFB laser diodes show typical threshold currents I_{th} of 32 mA and slope efficiencies of 0.3 W/A. Exhibiting a single emission line at 763.7 nm with a sidemode suppression ratio (SMSR) of at least 40 dB and single mode operation with output powers up to 25 mW per facet these DFB devices are suitable for oxygen gas detection.

References: [1] T.W. : Schlereth et al. Applied Physics Letters 90, 221113 (2007)

HL 34.12 Wed 17:15 EW 202

What can we learn from passive mode-locking of quantum dot (QD) based two-section semiconductor lasers? — •Stefan Breuer[1], Wolfgang Elsässer[1], Mark Hopkinson[2], and Michel Krakowski[3] — [1]Institute of Applied Physics, Darmstadt University of Technology, Schlossgartenstr. 7, D-64289 Darmstadt, Germany — [2]Electronic and Electrical Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, United Kingdom — [3]Alcatel Thales, III-V Lab, Route départementale 128, 91767 Palaiseau, France

The unique properties of QD based semiconductor laser sources in passively mode-locked operation have stimulated comprehensive studies of their picosecond pulsed emission. Towards a better understanding of the mode-locking process, two-section lasers based on dot-in-well (DWELL) layers as active media were closely investigated. Proper mode-locking at the cavity beat frequency was achieved by forward biasing the gain section and reverse biasing the absorber section, respectively. We have performed systematic measurements of the pulsed emission properties focusing on temporal characterisations using both a high-sensitivity intensity autocorrelation technique as well as an optical cross-correlation technique. The results, also from substantial radio-frequency domain investigations and spectral domain characterisations, will be presented. We will address the influence of gain current and reverse bias voltage especially on the evolution of the optical pulse duration, the repetition rate, the spectral width and the pulse-to-pulse timing jitter. This work has been performed within the scope of the European Union funded STREP project NANO UB-SOURCES.

HL 35: Spin controlled transport II

Time: Wednesday 14:15–17:45 Location: ER 164

HL 35.1 Wed 14:15 ER 164

Carrier and magnetization dynamics of magnetic resonant tunneling heterostructures — •Christian Ertler and Jaroslav Fabian — Institut für Theoretische Physik, Universität Regensburg, Universitätstrasse 31, D-93040 Regensburg, Germany

The invention and development of magnetic semiconductors has opened up a vast playground for exploiting the possibilities of utilizing the carriers spin in semiconductor electronics. Especially heterostructures made of both magnetic and nonmagnetic layers bring in many opportunities for controlling spin-dependent transport properties [1]. For example, the spin dependent resonant tunneling in magnetic double barrier structures has been exploited to realize high efficient spin valves or spin filtering devices. In this talk the rich dynamics of an asymmetric double barrier system with a ferromagnetic quantum well is theoretically investigated. In such low dimensional semiconductor systems the transport and magnetic characteristics become closely intertwined, since the magnetic state in the quantum well is mediated by the itinerant carriers. The highly nonlinear coupling of the magnetic, electrostatic, and transport properties can lead to astonishing dynamic behaviours. For instance, a robust oscillating current mode accompanied by an oscillating well magnetization shows up at a constant bias voltage. We demonstrate under which conditions this d.c. driven "breathing" magnetization mode occurs and propose different device setups, which should allow for an experimental observation. This work is supported by the SFB-project 689.

[1] J. Fabian et al., Acta Physica Slovaca, 57, 565-907 (2007).

HL 35.2 Wed 14:30 ER 164

Quasiclassical approach and spin-orbit coupling — •Cosimo Gorini[1], Peter Schwab[1], Michael Dzierzawa[1], and Roberto Raimondi[2] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]Dipartimento di Fisica "E. Amaldi", Università di Roma Tre, 00146 Roma, Italy

We discuss the quasiclassical Green function method for a two-dimensional electron - or hole - gas in the presence of spin-orbit coupling, with emphasis on the meaning of the ξ-integration procedure. As an application we study spin and charge dynamics in such a system, with both magnetic and non-magnetic impurities present. We demonstrate in particular that, within our approach, the spin-Hall conductivity can easily be obtained from the spin-density continuity equation.

HL 35.3 Wed 14:45 ER 164

Phonon-induced spin relaxation in graphene — •Sergej Konschuh, Christian Ertler, and Jaroslav Fabian — Institut der Theoretischen Physik, University of Regensburg, Regensburg, Germany

Motivated by the recent experiments on spin injection and spin transport in graphene 1, we investigate spin relaxation (so called T1) processes in this material within the framework of the Elliott-Yafet mechinanism: spin ralaxes via momentum spin-flip scattering processes due to the intra-atomic spin-orbit coupling. At room temperature the momentum scatting is ultimately limited by the phonons. A contuinuum model for the electron-phonon and the effective spin-orbit couplings is derived using a realistic tight-binding model 2, which is employed to calculate the spin relaxation times.

This Work is supported by SPP 1285 and SFB 689.

1 N.Tombros, C. Jozsa, M. Popinciuc, H.T. Jonkman and B.J.van Wees, Nature 448,571-574 (2007). 2 Y. Yao, F. Ye, X. Qi, S. Zhang and Z. Fang, cond-mat/0606350v3 (2007).

HL 35.4 Wed 15:00 ER 164

Microscopic theory of intrinsic spin-Hall effect in semiconductor nanodevices — •Tillmann Kubis and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We have calculated spin-orbit induced spin polarizations in confined mesoscopic systems at low temperatures and in the presence of external magnetic fields. To this end, we have implemented the spin-dependent non-equilibrium Green's function method (NEGF) in open nanometer quantum systems and take into account the coupling of non-equilibrium spin occupancies and spin-resolved electronic scattering states. We have employed both the conventional continuum approximation of the spin-orbit interaction in the envelope function approximation as well as a microscopic relativistic tight-binding approach. The latter ensures the spin-orbit effects are properly taken into account for any degree of charge confinement and localization and to all orders in the electron wave vector. While the quantitative results differ, we show that both methods yield the same qualitative trends in the calculated spin polarization, its dependence on confinement, on the spin-orbit interaction strength and on the charge density. In addition, we show that very significant spin polarizations near spin-neutral contacts can be generated in 3-terminal devices without any external magnetic fields. These devices appear to be promising candidates for efficient semiconductor based spin-polarizers.

HL 35.5 Wed 15:15 ER 164

Dyakonov-Perel Spin Dynamics in Bulk GaAs — •Michael Krauss and Hans Christian Schneider — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

We study theoretically the spin-dependent carrier dynamics due to the Dyakonov-Perel mechanism in undoped and n-doped bulk GaAs. By solving a dynamical equation for the k-dependent spin-density matrix including Boltzmann scattering integrals we obtain quantitative results for spin relaxation and dephasing times after optical excitation. We study the influence of excitation conditions, i.e., optical excitation at the band gap vs. excitation in the band, and temperatures on the spin-dependent carrier dynamics. In particular, we find that different excitation conditions lead to relaxation times that differ by up to two orders of magnitude.

HL 35.6 Wed 15:30 ER 164

Observation of Spin Pair Generation with Pulsed Electrically Detected Magnetic Resonance — •Jan Behrends[1],

Christoph Boehme[1,2], Manfred Schmidt[1], and Klaus Lips[1] — [1]Abt. Silizium-Photovoltaik, Hahn-Meitner-Institut Berlin, Berlin, Germany — [2]Department of Physics, University of Utah, Salt Lake City, UT, USA

Due to its high sensitivity, pulsed electrically detected magnetic resonance (pEDMR) has proven to be an effective method to study paramagnetic defects in semiconductor devices. PEDMR measures changes in the (photo-) conductivity resulting from a spin-resonant alteration of charge carrier transport or recombination rates. The annihilation (recombination, dissociation) dynamics of spin pairs that form during the capture of charge carriers at localised defects have previously been studied in various materials and device structures. In contrast, the creation dynamics of spin pairs has not been investigated with pEDMR since it hardly influences the dynamic parameters measured. We demonstrate in this study a novel pEDMR rotary echo pulse sequence that allows such a quantitative analysis of spin pair generation. This procedure can be applied in principle to all materials and devices that are suitable for pEDMR measurements. The experiments presented here use this new approach for the investigation of the generation of electron spin pairs in amorphous silicon conduction band tail states in the emitters of crystalline silicon/ amorphous silicon heterostructure solar cells. The results will be discussed with regard to findings from previous pEDMR studies on hopping transport in similar devices.

HL 35.7 Wed 15:45 ER 164

Spin-Relaxation Dynamics due to Hole-Band Mixing in Bulk GaAs — Michael Krauss and •Hans Christian Schneider — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

We study theoretically the spin-dependent hole dynamics in undoped bulk GaAs. The influence of the spin-orbit interaction on the band structure is included by using an 8-band Luttinger Hamiltonian. We calculate the k-dependent occupation numbers for hole-band energy dispersions after optical excitation using Boltzmann scattering integrals. From the microscopic occupation numbers we obtain both the ensemble spin dynamics and the dynamics of the average spin at individual k-points: By examining the ensemble spin dynamics we can compare with exponential fits and determine the validity of a relaxation-time approximation for the hole spin. By examing the average spin at different k-vectors we can determine whether the dynamics is dominated by spin precession (Dyakonov-Perel like) or spin-dependent scattering (Elliott-Yafet like).

15 min. break

HL 35.8 Wed 16:15 ER 164

Optimization of InP/GaInAs structures with respect to Rashba spin-orbit coupling — •Masashi Akabori, Markus Hagedorn, Vitaliy Guzenko, Thomas Schäpers, and Hilde Hardtdegen — Institute of Bio- and Nanosystems (IBN-1) and Centre of Nanoelectronic Systems for Information Technology (CNI), Research Centre Jülich, 52425 Jülich, Germany

In this report we investigated the influence of the channel layer thickness on spin-orbit coupling. To this end a modulation doped heterostructure was deposited by MOVPE which consisted of a 350 nm InP buffer, a 10 nm n-supply layer a 20 nm InP spacer, d nm GaInAs channel layer with 77% In content, and a 150-d nm lattice-matched GaInAs sub-channel, and 10 nm InP cap. The channel thickness d was varied between 2 and 10 nm. We first determined the mobility at room temperature and 77K with van der Pauw geometry: it decreases monotonically with the channel thickness. The result is reasonable because the thinner the channel becomes, the more the electron wave function extends into the GaInAs lattice matched sub-channel. In magnetoresistance measurements around 0.5K, we confirmed a clear shift of the first node position toward high magnetic field in a Hall-bar of the 2 nm channel sample, which indicates large Rashba spin-orbit coupling in spite of the thin high indium content channel. The behavior also agreed well with the theoretical estimation from the calculated band profile of the heterostructure, therefore the Rashba spin-orbit coupling in our InP/GaInAs heterostructures can be enhanced by tuning the channel layer thickness.

HL 35.9 Wed 16:30 ER 164

Spin-dependent transport in Si quantum dots — •Konrad Klein[1], Rui N. Pereira[1], Andre R. Stegner[1], Hartmut Wiggers[2], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Garching — [2]Universität Duisburg-Essen, Inst. for Combustion and Gas Dynamics, Duisburg

Phosphorus-doped silicon nanocrystals (Si-ncs) can be used as a model system for studying the electronic transport through doped quantum dots. Electrically-detected magnetic resonance (EDMR) is employed to study the spin-dependent transport in thin films composed of Si-ncs with diameters in the range 4-50nm. We have recently demonstrated that Si dangling bonds and substitutional phosphorus donors contribute to electronic transport through films composed of large ensembles of doped and undoped Si-ncs. As a more detailed understanding of the fundamental transport mechanisms in Si-ncs can only be obtained using a small number of nanocrystals, we have developed methods to perform EDMR measurements on a very small number of Si-ncs. The results of downscaled samples and those observed for large networks of Si-ncs, e.g. quantum-confinement causing an enhancement of the coupling between the electron and the nuclear spin of ^{31}P, are discussed. Already for Si-ncs with a diameter of 17 nm, we observe a significant confinement-induced enhancement of the ^{31}P hyperfine coupling constant by 15% with respect to the bulk value. This is in clear contrast to changes observed in optical transitions such as the bandgap or luminescence peak positions, for which a significant increase is only observed for nanocrystal diameters below 5 nm.

HL 35.10 Wed 16:45 ER 164

Robust remanent spin injection in light emitting diodes via Schottky- and MgO-barriers at room temperature — •Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2], Andreas D. Wieck[2], Ellen Schuster[3], and Werner Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-University Bochum, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-University Bochum, Germany — [3]Laboratorium für Angewandte Physik, University Duisburg-Essen, Germany

We report on robust room temperature spin injection in GaAs/AlGaAs-light emitting diodes (LEDs) in a Faraday-geometry. Two different injectors based on a Fe/Tb-multilayer which exhibits a strong perpendicular magnetization in remanence have been grown [1]. Spin injection is accomplished by the Schottky-diode generated by the lowest Fe-layer and the n-AlGaAs and by a MgO-tunnel-barrier between the metal and semiconductor, respectively. For both cases a circular optical polarization degree of 4% is detected up to room temperature even at remanent magnetization, but the results of the tunneling-diode suggest a more stable behaviour of the injecting interface. This work has been supported by the DFG within the SFB491.

[1] N.C. Gerhardt et al, Appl. Phys. Lett. 87, 032502 (2005)

HL 35.11 Wed 17:00 ER 164

Spin-orbit interaction induced anisotropy of the plasmon spectrum — •Samvel Badalyan[1,2], Alex Matos-Abiague[2], Giovanni Vignale[3], and Jaroslav Fabian[2] — [1]Department of Radiophysics, Yerevan State University, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Department of Physics and Astronomy, University of Missouri - Columbia, Missouri 65211, USA

We have investigated the combined effect of the Rashba and Dresselhaus spin-orbit interaction on the many-body Coulomb interaction in a two-dimensional electron system (2DES). It is shown that the many-body polarization function is strongly anisotropic both in the static and dynamic limits. The dielectric function of a 2DES has been calculated within the random phase approximation and the plasmon energy as a function of the momentum magnitude for its different orientations has been obtained. We have also calculated the dynamical structure factor and have shown its peaked behavior as a function of the polar angle of plasmon momentum. This peak corresponds to the plasmon with finite damping due to the spin-orbit interaction. Thus, we have demonstrated clearly that due to the anisotropy of the spin-orbit interaction, the plasmons with the definite values of energy and momentum can be excited only in the certain direction corresponding to the polar angle, determined from the plasmon spectrum.

This work is supported by the Volkswagen Foundation, the DFG Grant Sonderforschungsbereich 689, and NSF Grant No. DMR-0313681.

HL 35.12 Wed 17:15 ER 164

Efficient optical spin detection in the absence of magnetic fields at room temperature — •Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2],

Andreas D. Wieck[2], Ellen Schuster[3], and Werner Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-University Bochum, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-University Bochum, Germany — [3]Laboratorium für Angewandte Physik, University Duisburg-Essen, Germany

GaAs/AlGaAs-diodes have been used in a Faraday-geometry to transfer a circular optical excitation into a spin current at room temperature. The optical information is transferred into a current density which is dependent on the magnetization of the deposited Fe/MgO/n-AlGaAs-tunneling barrier. Detection is possible for a remanent state of magnetization and the current shows a strong proportionality to the circular state of polarization irradiating the diode. Furthermore, the current signal reproduces the remanent behaviour of the Fe. A comparison with a pure Schottky tunnel contact at a Fe/n-AlGaAs-interface diode shows strong current fluctuations for the latter which indicates a worse interface quality than for the case of an oxide-barrier. Few percent of polarization degree difference are measureable without significant temperature dependence up to room temperature and the sensitivity even rises for higher excitation intensities. This work has been supported by the DFG within the SFB491.

HL 35.13 Wed 17:30 ER 164

Spin Coulomb drag in a quasi-two-dimensional electron system beyond RPA — •Samvel Badalyan[1,2], Chang Sub Kim[3], and Giovanni Vignale[4] — [1]Department of Radiophysics, Yerevan State University, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Department of Physics, Chonnam National University, 500-757 Gwangju, Korea — [4]Department of Physics and Astronomy, University of Missouri - Columbia, Missouri 65211, USA

We study the spin Coulomb drag in a quasi-two-dimensional electron gas of finite transverse width, including local field corrections beyond the random phase approximation (RPA). We find that the finite transverse width of the electron gas causes a significant reduction of the spin Coulomb drag. This reduction, however, is largely compensated by the enhancement coming from the inclusion of many-body local field effects beyond the RPA. Our calculations are in very good agreement with the experimental observations of the spin Coulomb drag by C. P. Weber et al., Nature, 437, 1330 (2005).

This work is supported by the Volkswagen Foundation, the DFG Grant Sonderforschungsbereich 689, and NSF Grant No. DMR-0313681.

HL 36: Poster III

Time: Wednesday 16:30–19:00 Location: Poster D

HL 36.1 Wed 16:30 Poster D

Theory of the low temperature phase of succinonitrile — •Imad Belabbas, Johan Carlsson, and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck Gesellschaft, Faradayweg 4-6, D-14 195 Berlin-Dahlem (Germany)

Recently, succinonitrile has emerged as a promising solid electrolyte for lithium batteries [1]. Succinonitrile is a molecular crystal that crystallizes into two different phases. Below 233 K, succinonitrile has a perfectly ordered structure that only contains gauche isomers. Between, 233 K and 331 K, succinonitrile is a plastic crystal that contains a mixture of molecules with gauche and trans conformations. As a first step toward studying the full properties of succinonitrile, we have investigated the crystal structure of the low temperature phase. For the latter, only the lattice parameters are known, but not the position of the molecules in the unit cell. We have adopted a two steps approach, where force field and density-functional theory (DFT) calculations were applied. Initially, an extended scan of the configurational space was performed where the structures were ordered according to their non-bonded molecular interaction energy. This provided a set of potential candidates that were used as input for a global minimum energy search procedure based on genetic algorithms. The obtained configuration of the unit cell was further refined by means of DFT calculations. This procedure led to a theoretical structural model for the low temperature phase of succinonitrile.

[1]- J. P. Alarco, Y. Abu-Lebdeh, A. Abouimrane and M. Armand, Nature Materials, 3, 476 (2004).

HL 36.2 Wed 16:30 Poster D

Determination of electrochemical potentials of organic semiconductors via cyclic voltammetry and their relevance for organic photovoltaic devices — •Clemens Feser[1], Carsten Daibel[2], and Vladimir Dyakonov[1,2] — [1]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Wuerzburg — [2]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Wuerzburg, Am Hubland, D-97074 Wuerzburg

An important key parameter of organic bulk heterojunction solar cells is the open circuit voltage (VOC), which maximum is predominantly determined by the energy gap between the HOMO-level of the electron donor and the LUMO-level of the acceptor material. These electrochemical potentials (ECP) can be determined via cyclic voltammetry (CV). The ECP-values sensitively depend on the sample's state of aggregation (solid/liquid), variation of the solution and/or the electrolyte as well as on the choice of the conduction salt. A home-built CV-technique has been set up and was modified to evaluate the optimal conditions for accurate determination of the ECPs of a series of organic semiconductors, e.g. electron donors and acceptors like conjugated polymers and fullerenes, respectively. Further, we prepared organic bulk heterojunction solar cells based on different semiconductor combinations and evaluate the experimentally determined VOC in respect of the electrochemically determined HOMO- and LUMO-energies.

HL 36.3 Wed 16:30 Poster D

Charge carrier injection studies into wide band gap organic semiconductors — •Maximilian Nothaft, Fedor Jelezko, Jens Pflaum, and Jörg Wrachtrup — 3. Phys. Ins., Univ. Stuttgart, 70550 Stuttgart, Germany

Charge carrier injection into the LUMO of wide band-gap organic single crystals of small molecules, like naphthalene or anthracene, is difficult to realize because of the request for air-stable contact materials providing low work functions in the range of 2.0eV. E.g. to explore the transport in these molecular semiconductors by FET or SCLC measurements, a stable carrier injection at the respective contact interfaces has to be guaranteed. In this contribution we will present two different approaches on the injection of charge carriers into crystals of the organic semiconductors p-terphenyl and anthracene. At first, free electron injection was performed via a scanning electron microscope at voltages between 5kV to 30kV and, at second, by use of evaporated Al/Au contacts. From space charge limited current measurements up to 200V, we conclude on the transport parameters in these materials. Furthermore, it will be shown that simultaneous injection of holes and electrons yields to recombination electroluminescence from the wide band-gap host crystals, which resembles that of the optically excited fluorescence spectra. As an outlook, the effect of intentional doping of these organic crystals by certain guest molecules such as pentacene and dibenzoterrylene will be discussed.

HL 36.4 Wed 16:30 Poster D

Electronic Structure and Charge Transport in Durene Crystals — •Christoph Arndt[1], Frank Ortmann[2], Karsten Hannewald[2], Friedhelm Bechstedt[2], and Jens Pflaum[1] — [1]3. Phys. Institut, Univ. Stuttgart — [2]European Theoretical Spectroscopy Facility and IFTO, Friedrich-Schiller-Univ. Jena

The intrinsic charge-carrier mobility defines an important material parameter and allows an understanding of the microscopic transport processes in organic semiconductors. Durene has shown one of the best transport performances in single crystals with room-temperature mobilities up to 5 cm^2/Vs [1]. The bandlike transport behavior in combination with the small conjugated pi-electron system makes durene also attractive for theoretical descriptions by ab-initio DFT calculations [2].

In this contribution we present experimental data on the mobility tensor of durene crystals accompanied by a theoretical analysis including the influence of fundamental vibrational modes. Bridgman

crystals were grown from purified material and electronically characterized by the time-of-flight technique. To access the anisotropy of the mobility, durene slabs along different crystallographic orientations were prepared and the charge-carrier mobility was determined in the temperature range between 5K and 300K. The measurements showed a significant increase of the hole mobilities towards lower temperatures reaching values as high as 100 cm^2/Vs.

[1] Z. Burshtein and D.F. Williams, Phys. Rev. B **15**, 5769 (1977).
[2] F. Ortmann, K. Hannewald, and F. Bechstedt, Phys. Rev. B **75**, 195219 (2007).

HL 36.5 Wed 16:30 Poster D

Impedance spectroscopy on polymer solar cells — •Roland Rösch[1], Ingo Hörselmann[2], Andrei Herasimovic[2], Susanne Scheinert[2], Gerhard Gobsch[1], and Harald Hoppe[1] — [1]Institute of Physics, Ilmenau University of Technology, Weimarer Straße 32, 98693 Ilmenau, Germany — [2]Institute of Solid State Electronics, Ilmenau University of Technology, Gustav-Kirchhoff-Str. 1, 98693 Ilmenau, Germany

Impedance spectroscopy is a powerful tool to investigate internal electrical properties of an electronic device. We use this non-invasive technique to study polymer solar cells based on P3HT:PCBM blends and measure the admittance in dependence on the frequency of the applied voltage and fit the results with an equivalent circuit (EC). The elements of the EC reflect the internal electrical properties as contact behaviour, dielectric constants, depletion layers or charge transport. We varied the hole- and electron extracting contacts by modification layers or different metals. The different interlayers show an influence on charge transport and contact behaviour, which results in different device properties.

HL 36.6 Wed 16:30 Poster D

Electron spin resonance studies of sol–gel-processed anatase-TiO_2-nanocrystals and charge transfer in blends with P3HT — •Andreas Sperlich[1], Jan Friedman[1,2], Ingo Riedel[1,2], 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]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg

Light-induced electron spin resonance (L)ESR studies of photogenerated charge carriers in mesoporous films of TiO_2 blended with poly(3-hexylthiophene) (P3HT) were performed. The TiO_2-films were produced by sol-gel processes. XRD–measurements confirm anatase-structure. In pure films of TiO_2, several distinct lines are observed under illumination. These excited states are known as "photodoping" and lead to enhanced electrical conductivity. With ESR, they can be assigned to Ti_3^+ and O_2^- crystal and surface states which form paramagnetic electron and hole traps. Blended with P3HT the spectrum is dominated by one symmetrical line that originates from polarons on the polymer backbone. With different illumination conditions (UV vs. white light) it can be shown that both, electron transfer from the polymer to the TiO_2 and hole transfer in the other direction, are possible processes for the generation of free charge carriers. The charge transfer efficiency is important for applications in organic–inorganic hybrid solar cells.

HL 36.7 Wed 16:30 Poster D

Transport Gap and exciton binding energy determination in organic semiconductors — •Stefan Krause[1], Benedetta Casu[2], Achim Schöll[1], Friedrich Reinert[1], and Eberhard Umbach[1] — [1]University of Würzburg, Experimental Physics II, Am Hubland, 97074 Würzburg, Germany — [2]Inst. f. Physik. u. Theor. Chemie, Auf der Morgenstelle 8 , 72076 Tübingen , Germany

The transport gap of an organic semiconductor is defined as the energy difference between the HOMO and LUMO levels in the presence of a hole or electron, respectively, after relaxation has occurred. Its knowledge is mandatory for the optimisation of electronic devices based on these materials. UV photoelectron spectroscopy (UPS) and inverse photoelectron spectroscopy (IPES) are routinely applied to measure these molecular levels. However, the precise determination of the transport gap on the basis of the respective data is not an easy task. It involves fundamental questions about the properties of organic molecules and their condensates, about their reaction on the experimental probe, and on the evaluation of the spectroscopic data. In particular electronic relaxation processes, which occur on the time scale of the photo excitation, have to be considered adequately. We determined the transport gap for the organic semiconductors PTCDA, Alq3, DIP, CuPc, and PBI-H4. After careful data analysis and comparison to the respective values for the optical gap we obtain values for the exciton binding energies between 0.1 - 0.5 eV. This is considerably smaller than commonly believed and indicates a significant delocalisation of the excitonic charge over various molecular units.

HL 36.8 Wed 16:30 Poster D

Characterization of organic photovoltaic cells in comparison with analytic simulations — •Christian Körner[1,2], Florian Holch[2], Achim Schöll[2], Carsten Deibel[1], Friedrich Reinert[2], and Vladimir Dyakonov[1] — [1]Universität Würzburg, Experimentelle Physik VI, 97074 Würzburg — [2]Universität Würzburg, Experimentelle Physik II, 97074 Würzburg

Electronic devices based on organic semiconductors receive a growing interest in fundamental and application related research. One reason is that organic thin film photovoltaic cells promise to offer a cost– and resource–efficient fabrication. In order to achieve higher efficiencies it is indispensable to better understand the fundamental processes within the solar cell and at the interfaces, such as charge–carrier generation, separation and transport.

The samples, composed of Copper–Phthalocyanine (CuPc) and C_{60} layers and sandwiched between an ITO–coated glass substrate and metal electrodes, are prepared via organic molecular beam deposition under clean and well defined conditions in ultra high vacuum. By *in-situ* measurements of the current–voltage characteristics, the influence of incident light power, temperature, and cathode material can be investigated in detail.

The experimental results will be discussed in comparison to an analytical simulation of the open–circuit voltage, in view of different models for the charge carrier injection at the electrodes.

HL 36.9 Wed 16:30 Poster D

Investigation of electronic traps in disordered organic semiconductors via thermally stimulated current measurements — •Julia Schafferhans, Carsten Deibel, and Vladimir Dyakonov — Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg

Charge transport in disordered organic semiconductors is generally described as thermally activated hopping in a gaussian distribution of localized states. The presence of charge traps is critical to the performance of organic electronic devices, since trapped charge carriers do no longer contribute to the current flow. The trap distribution in the polymer poly(3-hexylthiophene) (P3HT) is investigated by applying the fractional thermally stimulated current technique. Thereby, a low temperatur double-peak distribution has been revealed. One of the peaks is believed to belong to the tail of the intrinsic density of states, whereas the other trap is strongly affected by exposure to oxygen. We discuss the influence of oxygen exposure time on the trap distribution.

HL 36.10 Wed 16:30 Poster D

Influence of metal structures on the optical properties of organic microcavities — •Maik Langner[1], Thomas Weimann[2], Hartmut Fröb[1], Vadim G. Lyssenko[1], and Karl Leo[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany, www.iapp.de — [2]Physikalisch-Technische Bundesanstalt AG 2.44, 38116 Braunschweig, Germany, www.ptb.de

Organic semiconductor microcavities combine the advantages of widely tunable light emission with a high gain and comparatively simple processing. For various reasons it is desirable to introduce metal structures into the standard OVCSEL design, e.g. current injection or additional lateral optical structuring due to the high index contrast. We show results of samples containing silver gratings on the micrometer and nanometer scale manufactured by means of shadow mask evaporation and electron beam lithography. They are embedded in a microcavity consisting of two highly reflective SiO_2 / TiO_2 - DBRs and a $\lambda/2$ -layer of the dye system Alq_3:DCM. To minimize absorption losses the metal is positioned near to the vertical field minimum at the interface DBR – cavity layer. For the optical investigations we use a microscope setup coupled to a spectrometer which allows for a sub-micron resolution. Changes of the optical properties are compared to FDTD simulations of the electric field distribution.

HL 36.11 Wed 16:30 Poster D

Monte Carlo simulated charge carrier transport in disordered semiconducting organic devices — •Jens Lorrmann[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]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D–97074 Würzburg

The charge carrier transport in disordered organic semiconductors plays an important role in understanding and optimizing the behavior of organic electronic devices. It can be described as thermally activated hopping in a gaussian distribution of localized states and is characterized by the charge carrier mobility. In order to investigate this hopping, kinetic Monte Carlo simulations are very helpful, as they allow to gain insight into charge carrier transport properties in such complex systems.
A Monte Carlo program to simulate the charge carrier mobility in disordered organic semiconductors was implemented, taking into consideration the Coulomb interaction. We discuss the influence of charge carrier density, energetic disorder as well as Coulomb repulsion on the mobility.

HL 36.12 Wed 16:30 Poster D

Investigations of concentration dependent photoluminescense quenching in a P3HT : PCBM bulk heterojunction — •Johannes Krantz[1], Moritz Liedtke[1,2], Andreas Sperlich[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D–97074 Würzburg — [2]The Bavarian Center for Applied Energy Research (ZAE Bayern), Am Hubland, D–97074 Würzburg

The photoluminescence (PL) quenching effect is a strong indicator for charge or energy transfer in photovoltaic polymer - fullerene bulk heterojunctions solar cells. In order to achieve a high photocurrent, an efficient generation of charge carriers is a necessary prerequiste. We present our investigations on the PL-quenching efficiency in P3HT (poly(3-hexylthiophene)) and PCBM ([6,6]-phenyl-C61-butyric acid methyl ester) blends with respect to the donor - acceptor ratio. In order to verify that charge transfer is the dominant process, we conducted electron spin resonance measurements. For a more detailed understanding of the underlying mechanisms of PL quenching, we discuss our data in view of a model by Arkhipov et al.[1] as well as a volume-based model.

HL 36.13 Wed 16:30 Poster D

Micro-Analysis of fullerene crystals in annealed P3HT-PCBM blends — •Maik Bärenklau, Gerhard Gobsch, and Harald Hoppe — Institute of Physics, Ilmenau University of Technology, Weimarer Straße 32, 98693 Ilmenau, Germany

We observe micron-sized needles and other structures of the fullerene derivative PCBM in thin film blends with P3HT upon heat treatment using optical microscopy. Depending on the annealing temperature more and more elongated structures are observed. For lower fullerene contents smaller crystallites are grown. Particular grown fullerene structures and the corresponding structure-property-relationships are discussed in view of solar cell application.

HL 36.14 Wed 16:30 Poster D

Numerical simulation of organic bulk heterojunction solar cells — •Alexander Wagenpfahl[1], Carsten Deibel[1], Andreas Baumann[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D–97074 Würzburg — [2]The Bavarian Center for Applied Energy Research (ZAE Bayern), Am Hubland, D–97074 Würzburg

By implementing a numerical solver for differential equations, we are able to calculate the current–voltage characteristics of organic bulk heterojunction solar cells. Under illumination, Fermilevel splitting can be observed. By considering different models for polaron dissociation in the active layer as well as charge carrier injection at the interfaces, we are able to compare our simulations to experimental data. In particular, we will discuss the influence of illumination on the solar cell characteristics.

HL 36.15 Wed 16:30 Poster D

Photophysics of charge transfer in polymer–C_{70}-fullerene composites — •Björn Titze[1], Andreas Sperlich[1], Carsten Deibel[1], Vladimir Dyakonov[1,2], and Oleg Poluektov[3] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D–97074 Würzburg — [2]The Bavarian Center for Applied Energy Research (ZAE Bayern), Am Hubland, D–97074 Würzburg — [3]Chemistry Division Argonne National Laboratory, 9700 S. Cass Avenue Argonne, IL 60439 USA

Charge polarons in thin films of polymer and polymer–C_{70}-fullerene composites are investigated by light induced electron spin resonance at 9,5GHz (X-Band). The materials studied were poly(3-hexylthiophene) (P3HT), [6,6] phenyl-C61-butyric acid methyl ester (PCBM) and a soluble C_{70}-derivate. The composites show two distinct polaron signals under illumination and a temperature below 150K, which can be assigned to photogenerated polarons (P^+, P^-) in the blends. Furthermore, lineshapes and relaxation times have been studied by 130GHz (D-Band) electron spin echo below 30K. The g-tensors of positive polarons (P^+) on P3HT and negative polarons (P^-) on C_{70} have been determined. The T_1-relaxation time for both spectra is followed by the interaction of the polarons. We discuss the results with regard to applications such as organic bulk heterojunction solar cells.

HL 36.16 Wed 16:30 Poster D

Characterisation of different hole transport materials as used in organic p-i-n solar cells — •Steffen Pfützner[1], Annette Petrich[1], Christine Malbrich[3], Dirk Hildebrandt[2], Maik Koch[1], Moritz Riede[1], Karl Leo[1], and Martin Pfeiffer[2] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, 01069 Dresden, Germany, http://www.iapp.de — [2]Heliatek GmbH, Liebigstr. 26, 01187 Dresden, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

This work focuses on the replacement of hole transport material MeO-TPD, which has been used so far in organic p-i-n- solar cells despite its has unfavourable behaviour at elevated temperatures. For this reason, different characterisation and investigations of the hole transport materials PV-TPD, PV-TPDoM, Di-NPB and MeO-Spiro-TPD were done, i.e. dopability, hole mobility, absorption, reflection, cyclic voltametry and glass transition temperature were measured. With simplified structures, e.g. m-i-p diodes, and simplified solar cells, consisting of the blue absorbing fullerene C60 as acceptor and the transparent donor material 4P-TPD, further specific material properties were determined.

HL 36.17 Wed 16:30 Poster D

Effect of vacuum pressure during metal electrode sublimation on polymer solar cell performance — •Florian Kühnlenz, Gerhard Gobsch, and Harald Hoppe — Institute of Physics, Ilmenau University of Technology, Weimarer Str. 32, 98693 Ilmenau, Germany

Polymer solar cells based on P3HT/PCBM were prepared identically * except for a variation in the production parameter of the aluminium electrode sublimation. By increasing the pump-down time of the evaporation chamber the pressure for the aluminium sublimation could be decreased over several decades to different final processing values. We found a clear dependence of the chamber pressure during electrode deposition on the overall solar cell performance. We suggest this pressure dependence to be connected with the slow desorption of O2 and H2O from the spin cast layers, because the production of the active layer of the solar cell took place at environmental conditions in air and the underlying PEDOT:PSS layer was processed from aqueous solution.

HL 36.18 Wed 16:30 Poster D

Effect of polymer solar cell geometry on photovoltaic performance — •Burhan Muhsin[1], Joachim Renz[1], Karl-Heinz Drüe[2], Gerhard Gobsch[1], and Harald Hoppe[1] — [1]Institute of Physics, Ilmenau University of Technology, Weimarer Str. 32, 98693 Ilmenau, Germany — [2]Electronic Technology, Institute of Micro- and Nanotechnologies, Ilmenau University of Technology, Gustav-Kirchhoff-Str. 7, 98693 Ilmenau, Germany

We prepared polymer solar cells using different geometries and active areas to study its effect on energy dissipation during operation. On the one side we have determined experimentally series resistances and performance parameters, on the other side we calculated these values theoretically by making simple assumptions based on the knowledge of solar cell geometry and ITO sheet resistance. Differences occurring between experiment and calculation are discussed. As a result, strategies for optimizing polymer solar cell modules are estimated.

HL 36.19 Wed 16:30 Poster D

The Local Electronic Structure of planar versus non planar Phthalocyanines (ZnPc, SnPc and PbPc) studied byResonant Soft X-ray Emission Spectroscopies — •nikolaos peltekis[1], brendan holland[1], louis piper[2], alex demasi[2], kevin smith[2], ignatius mcgovern[1], and cormac mcguinness[1] — [1]School of Physics,

Trinity College Dublin, Dublin 2,Ireland. — [2]Department of Physics, Boston University, 590 Commonwealth Avenue, Boston, MA 02215, USA

The electronic structure of thin films of the organic molecular semiconductors: zinc phthalocyanine (ZnPc), tin phthalocyanine (SnPc) and lead phthalocyanine (PbPc) have been investigated by soft x-ray spectroscopy. Near edge x-ray absorption fine structure (NEXAFS) spectra, together with resonant & non-resonant soft x-ray emission (RSXE and SXE) spectra have been measured at the carbon and nitrogen K edges. The resultant spectra measure the unoccupied and occupied carbon and nitrogen 2p projected density of states respectively. In particular, resonant soft x-ray emission spectroscopy results in the site-specific C 2p and N 2p local partial density of states(LPDOS) being measured. An angular dependence of the C 2p and N 2p RSXE spectra of ZnPc, SnPc and PbPc has been observed. The observed angular dependence,the measured LPDOS and their correspondence to the results of density functional calculations will be discussed. Comparison between planar (ZnPc) and non planar (SnPc, PbPc) phthalocyanine along with the differing stacking arrangement of molecules within ZnPc (planar) and SnPc-PbPc (non-planar) crystalline films will be discussed.

HL 36.20 Wed 16:30 Poster D

Transport in Organic Solar Cells studied with Pulsed Electrically Detected Magnetic Resonance — Jan Behrends[1], •Alexander Schnegg[1], Elizabeth A. Thomsen[2], Ifor D.W. Samuel[2], David J. Keeble[3], and Klaus Lips[1] — [1]Abt. Silizium-Photovoltaik, Hahn-Meitner-Institut Berlin, Berlin, Germany — [2]Organic Semiconductor Centre, School of Physics & Astronomy, University of St Andrews, St Andrews, UK — [3]Carnegie Laboratory of Physics, School of Engineering, Physics, and Mathematics, University of Dundee, Dundee, UK

We report about first pulsed electrically detected magnetic resonance (pEDMR) measurements on organic solar cells at room temperature. Samples containing a blend of MEH-PPV and PCBM were investigated by pEDMR both in spectral as well as in time domain in order to extract information about the electron spin states influencing the current through the device. The pEDMR spectrum gave rise to a single resonance line centered at g = 2.0028(5) which coincides with a polaron signal recently assigned by continuous wave EDMR. By measuring Rabi oscillations as a function of the spectral position in the pEDMR spectrum, we were able to exploit the unique capabilities of pEDMR to assign current determining spin states not only by their spectral position, but also by their interspin couplings. Plotting the Rabi frequencies as a function of the resonance field, two frequencies could be clearly separated, which resembles the case of two coupled electron spins.

HL 36.21 Wed 16:30 Poster D

Refined transmission measurement setup for 2D-terahertz photonic crystals — •Thomas Kissinger and Andrei Pimenov — Physikalisches Institut, Universität Würzburg, Germany

We examine transmission spectra of 2D-photonic crystals in the terahertz frequency region quantitatively. We show that the reasons for deviations between calculated (employing FDTD-simulations) and experimental spectra are often not due to sample manufacturing, but due to the optical measuring setup. Issues like high diffraction of terahertz waves, spatial frequency (k-vector) selection of output radiation, deviations from incoming plane-wave illumination and finite size effects of the sample or simulation cell are all important to understand the transmittance of such highly anisotropic objects like photonic crystals. We compare and optimize different experimental and simulation setups in order to obtain stable and mutually consistent results, while keeping the optical system and the models used as simple and straightforward as possible.

HL 36.22 Wed 16:30 Poster D

Propagation of electromagnetic waves in waveguides based on photonic/plasmonic structures in nanocomposite glass — •Oleksiy Kiriyeko, Moritz Beleites, Stefan Wackerow, Wolfram Hergert, and Heinrich Graener — Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Seckendorff-Platz 1, 06120 Halle

Nanocomposite glass containing metallic nanoparticles is a basis material of plasmonic structures with particular optical properties. Periodic structures are experimentally produced in such a material using an electric field assisted dissolution method. Laser assisted dissolution or modification of nanoparticle containing areas is an elegant way to form waveguides in the twodimensional periodic structures. The finite element method (FEM) implemented in COMSOL/Multiphysics is used to calculate the complex effective permittivity of a two-component material in which equally-sized silver nanoparticles are randomly distributed in a homogeneous dielectric, which is the glass matrix in our case. The properties of different waveguides in triangular lattices in such a nanocomposite glass are investigated. Special attention is devoted to the influence of changes of the geometric structure or of the nanoparticle filling fraction on the waveguide properties. The theoretical investigations are compared with experimental results.

HL 36.23 Wed 16:30 Poster D

Design of photonic structures: Combination of FDTD methods with genetic algorithms — •Christian Matyssek[1], Stefan Meyer[2], Wolfram Hergert[1], Rüdiger Weiner[2], and Martin Arnold[2] — [1]Institute of Physics, MLU Halle-Wittenberg, Von-Seckendorff-Platz 1, 06120 Halle — [2]Institute of Mathematics, MLU Halle-Wittenberg, Theodor-Lieser-Straße 5, 06120 Halle

The optimal design of properties of photonic crystals and coherent control approaches to light guidance in nanostructures are two application areas where methods to calculate electromagnetic fields in complicated structures have to be combined with optimization methods. To that purpose we construct a compact FDTD algorithm based on a spatial Yee-grid combined with higher-order accurate time integration schemes. In time integration the solver performance is optimized combining an integrator based on well approved Krylov subspace methods (VODPK, ROWMAP) with preconditioning techniques that take into account the specific structure of the model equations. As an effective global optimization method a genetic algorithm is used. As a first example for the application of the method the optimization of band gaps is demonstrated. The application to the optimization of waveguide structures and metallic nanoparticle arrays is discussed.

HL 36.24 Wed 16:30 Poster D

Thermal emission properties of 2D and 3D Photonic Crystals with and without functionalized surfaces — •Benjamin Gesemann, Stefan L. Schweizer, and Ralf B. Wehrspohn — MLU Halle-Wittenberg, Inst. for physics - AG microMD, Halle, Germany

We present measurements and simulations of the thermal emission properties inside and out of 2D and 3D photonic Crystals using localized integrated emission sources as well as out of plane emission of entirely heated crystals. The photonic crystals were fabricated using a photo-electrochemical etching process allowing us to fabricate deep 2D-structures with aspect ratios (depth/diameter) exceeding 100. By modulating the pore diameter during the etching also 3D-periodic structures can be prepared. Additional functionalized coatings can be used to modify the emission properties and create selective thermal emitter. We will discuss the influence of plasmonic and dielectric effects on selective thermal emission.

HL 36.25 Wed 16:30 Poster D

Simulation of light propagation in photonic crystal structures using advanced finite element methods — •Sven Burger, Jan Pomplun, Frank Schmidt, and Lin Zschiedrich — Zuse Institute Berlin, Takustraße 7, D - 14195 Berlin, Germany

Finite element methods allow for accurate and fast simulations of light propagation in micro- and nanostructures. We are developing a programme package for the simulation of time-harmonic light scattering problems and eigenvalue problems based on the finite element method. The package contains higher order finite elements for 1D, 2D and 3D problems, adaptive refinement strategies, and domain decomposition algorithms. We report on the status of the software, and we discuss recent applications of the methods to simulations of photonic crystal fibers [1] and other periodically assembled nanostructures (metamaterials) [2].

[1] G. J. Pearce, G. S. Wiederhecker, C. G. Poulton, S. Burger, and P. St. J. Russell. Opt. Express **15**, 12680 (2007).

[2] G. Dolling, M. W. Klein, M. Wegener, A. Schädle, B. Kettner, S. Burger, and S. Linden. Opt. Express **15**, 14219 (2007).

HL 36.26 Wed 16:30 Poster D

Quasiperiodic structures in metallic photonic crystals — •Christina Bauer[1], Dietmar Nau[1,2], Sergei Zhukovsky[3], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, 70550 Stuttgart, Germany — [2]Institute of Applied Physics, Univer-

sity of Bonn, 53115 Bonn, Germany — [3]Physics Institute, University of Bonn, 53115 Bonn, Germany

Quasicrystals are aperiodic structures which possess long-range order but no translational symmetry. We fabricated one-dimensional metallic photonic crystals with quasiperiodic lateral spacing. Gold nanowires were arranged on top of an Indium-Tin-Oxide (ITO) waveguide in a Fibonacci sequence or in Cantor sets. Examining the extinction spectra and comparing them to a purely periodic structure, additional peaks arise. The modelling of the extinction spectra both in TE as well as in TM polarization works well using the model of Nau et al. [1], which takes the spatial Fourier transform of the structure together with the waveguide dispersion into account. Angle-dependent measurements also reveal the photonic bandstructure of such quasiperiodic metallic photonic crystal samples.

[1] D. Nau et al., Phys. Rev. Lett. 98, 133902 (2007).

HL 36.27 Wed 16:30 Poster D

Nonlinear Coordinate Transformation as an Extension of the Fourier Modal Method to Finite-Sized Structures — •Thomas Zebrowski[1], Sabine Essig[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

The Fourier Modal Method (FMM) can be extended to solve electromagnetic wave propagation problems associated with finite-sized structures. Since the basic algorithm is handling systems which are infinitely periodic in the lateral plane, non-periodic structure simulations via FMM have to introduce an artificial periodicity. In this case, however, interactions between the unit cells are unavoidable unless special measures are taken. Such an isolation of the unit cells may be facilitated through nonlinear conformal mappings. This means that we map the infinitely extended space surrounding the finite-sized structure onto a finite edge layer surrounding the unit cell. The resulting coordinate transformation is easily introduced into the algorithm. On our poster we show that this extended FMM algorithm can treat three-dimensional wave propagation problems that are difficult to solve with other frequency-domain methods such as the finite element approach.

HL 36.28 Wed 16:30 Poster D

Time-Domain Simulations using Discontinuous Galerkin methods — •Kai Stannigel[1], Michael König[1,3], Jens Niegemann[1,2,3], Lasha Tkeshlashvili[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

The accurate numerical treatment of complex nano-photonic structures requires a flexible spatial discretization scheme. Standard finite elements are of limited use for time-domain calculations, since they usually require the inversion of large matrices in each time-step and are thus computationally expensive. This problem can be overcome by the use of Galerkin discontinuous elements. We demonstrate the superior accuracy and performance of this method by applying it to typical problems in the field of nano-photonics. The results are compared to standard methods such as FDTD.

HL 36.29 Wed 16:30 Poster D

Numerical Treatment of Nonlinearities in Higher-Order Time-Domain Methods — •Jan Gieseler[1], Jens Niegemann[1,2,3], Lasha Tkeshlashvili[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

The accurate numerical treatment of field propagation in complex nano-structures often requires the use of higher-order methods. In nonlinear systems, advanced discretization schemes are particularly important to deliver reliable results. In this poster, we demonstrate how to calculate numerical fluxes for the nonlinear Maxwell equations. These fluxes are then used to construct a higher-order discontinuous Galerkin scheme for solving Maxwells equations with a Kerr nonlinearity. Our approach is further compared to standard methods such as FDTD.

HL 36.30 Wed 16:30 Poster D

Component Analysis and Optimization of Photonic Crystal Based Semiconductor Laser Diodes — •Helmut Zarschizky[1], Lin Zschiedrich[1,2], Jan Pomplun[1,2], and Sven Burger[1,2] — [1]JCMwave GmbH, Haarer Straße 14a, 85640 Putzbrunn, Germany — [2]Zuse Institute Berlin, Takustraße 7, 14195 Berlin, Germany

Due to the reasonably large photonic bandgap in semiconductor based photonic crystals widely tunable laser diodes seem to be an attractive application. Design and optimization of layer thicknesses, lateral laser channel width, dimension of the unit cell and orientation of the crystal lattice for wave guiding and resonator facets are carried out using FEM-based simulation software. 2D- and 3D-results give detailed suggestions on appropriate resonator designs for wavelength tuning ranges over 100 nanometers in the telecommunication band (1550 nm) and for gas sensing (about 1850 nm).

HL 36.31 Wed 16:30 Poster D

Defocused Imaging of Fluorescent Beads in Photonic Crystals — •Sven Zimmermann, Frank Cichos, and Rebecca Wagner — Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

Photonic crystals are materials with a periodically varying dielectric constant. Multiple scattering of light on this spatially modulated refractive index causes a photonic band structure and photonic band gaps. We show that the fluorescence of emitters embedded into the photonic crystals is spectrally and spatially redistributed. Thus they can be used for studying the angular dependence of the photonic stop band. The photonic crystals are produced by self organisation of polystyrene beads using a vertical deposition technique. A small amount of beads is replaced by dye doped beads. They are detected using defocused fluorescence microscopy. Since the photonic crystal introduces an anisotropy to their emission the defocused imaging patterns are modified compared to a homogeneous medium (which is a medium without band structure). The diffraction patterns show a threefold symmetry which is clearly caused by the photonic crystal since it does not exist for emitters outside of it. This modification of the patterns is compared to simulations of the band structure and defocused images.

HL 36.32 Wed 16:30 Poster D

Wannier function based numerical analyses of Photonic-Crystal functional elements incorporating optically anisotropic materials — •Patrick Mack[1,2], Daniel Hermann[2,3], Christoph Kölper[2], and Kurt Busch[2,3,4] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe — [2]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [3]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [4]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

Actively tunable properties of photonic crystals (PCs) may yield the key to integrated all-optical circuitry, allowing for new devices in optical telecommunication. We present numerical investigations of tunable functional elements in macroporous silicon PC structures based on infiltrating optically anisotropic materials into individual PC pores.

The numerical data has been obtained with the photonic Wannier function approach which is very well suited for computing the optical properties of PC-based optical devices. Recent advances in the experimental realization of such structures indicate that corresponding designs may be realized in the near future.

HL 36.33 Wed 16:30 Poster D

Chirp dependent Emission of a fs-pumped Semiconductor Disc Laser — •Eckhard Kühn[1], Angela Thränhardt[1], Stephan W. Koch[1], Wolfgang Stolz[1], Sangam Chatterjee[1], Christoph Lange[1], Wolfgang Rühle[1], Wendel Wohlleben[2], and Marcus Motzkus[3] — [1]Fachbereich Physik, Philipps Universität Marburg, Deutschland — [2]Polymer Research, BASF AG Ludwigshafen, Deutschland — [3]Fachbereich Chemie, Philipps Universität Marburg, Deutschland

We present an experimental study and theoretical analysis of a semiconductor disc-laser system (VCSEL) under coherently controlled, phase sensitive excitation conditions. We show that the sign and the amplitude of the quadratical chirp modifies the total number and the average energy of the injected carriers. This strongly influences the laser gain and therefore the overall VCSEL emission. For the theoretical analysis of this effect, we use nonequilibrium simulations based on the microscopic carrier treatment of coupled Maxwell-multiband

semiconductior Bloch Equations. This reveals the physical origin of the experimental findings as the change of the 1s exciton-resonance absorption of the quantum-well barriers due to excitation induced dephasing. The numerical simulations show good qualitative agreement with the experimental data.

HL 36.34 Wed 16:30 Poster D

Dephasing processes in quantum dot microcavity systems: a microscopic description — •Sandra Ritter, Christopher Gies, Jan Seebeck, Jan Wiersig, and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen

Due to various applications the system of quantum dots placed in three-dimentional optical resonators receives great attention. Starting from a fully quantum mechanical description of the carrier-photon interaction for quantum dots in microcavities, we study the influence of carrier scattering and dephasing on the emission properties. A consistent inclusion of scattering processes in various carrier and photon correlation functions is realized by coupling to acoustic phonons. The interplay of scattering and dephasing is of particular importance in the ‚good cavity regime', where the cavity loss rate is smaller than the spontaneous emission rate of the quantum dots into the cavity.

HL 36.35 Wed 16:30 Poster D

Highly spatial resolved PL spectroscopy of single dislocations in InGaN/GaN quantum well structures — •Julia Danhof[1], Matthias Eder[1], Clemens Vierheilig[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Nikolaus Gmeinwieser[2], Ansgar Laubsch[2], and Berthold Hahn[2] — [1]NWF II - Physik, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg — [2]Osram Opto Semiconductors, Leibnizstraße 4, 93055 Regensburg

GaN based heterostructures normally show quite high dislocation densities. The impact of the dislocations on the performance of optoelectronic devices is still unclear. With our confocal microscope, we study single threading dislocations for samples with a dislocation density below 10^7 cm^{-2}. The impact of threading dislocations on the optical properties of GaN bulk crystals is well known: The dislocations act as nonradiative recombination centers, and the shift of the near band edge emission due to the stress dipole around the dislocation core can be detected by highly spectral resolved photoluminescence (PL) spectroscopy. We now study the impact of single dislocations on the optical properties of InGaN/GaN quantum well structures. By simultaneous detection of the PL signal of both the InGaN quantum well and the GaN barriers, the variation of the quantum well signal can explicitly be attributed to single dislocations which are identified by the GaN emission. The effects in the quantum well are studied in dependency of temperature and excitation density.

HL 36.36 Wed 16:30 Poster D

Influence of Optical Gain on the Spectral and Temporal Characteristics of 405 nm (Al,In)GaN Laser Diodes Grown on Different Substrates — •Bernd Schmidtke[1], Tobias Meyer[1], Harald Braun[1], Ulrich T. Schwarz[1], Désirée Queren[2], Marc Schillgalies[2], Stephan Lutgen[2], and Uwe Strauss[2] — [1]NWF II - Physik, Universität Regensburg — [2]Osram Opto Semiconductors GmbH

We investigate the spectral and temporal behaviour of violet (Al,In)GaN laser diodes (LDs) emitting at wavelengths of about 405 nm, grown on low dislocation density GaN substrate and on SiC substrate, respectively. LDs on GaN substrate show a broad spectrum with several longitudinal modes above threshold, whereas LDs on SiC substrate partially are lasing on a single longitudinal mode, depending on the driving current. With a high spectral resolution setup we measure the gain below threshold of each longitudinal mode, employing the Hakki-Paoli method. Measurements show a slightly fluctuation of gain for the modes of GaN substrate LDs, but a much higher fluctuation for LDs on SiC substrate. We carry out simulations of the longitudinal mode spectrum of (Al, In)GaN laser diodes using a rate equation model with nonlinear gain effects. Additionally the gain of each longitudinal mode was modified to take the fluctuations of the measured gain into account. With the respective amplitude of these gain fluctuations, the simulated spectra resemble the GaN or SiC substrate LD spectra.

HL 36.37 Wed 16:30 Poster D

Lateral Mode Behaviour of Broad Ridge 405 nm (Al,In)GaN Laser Diodes: Experiment and Simulation — •Stephan Rogowsky[1], Dominik Scholz[1], Harald Braun[1], Ulrich T. Schwarz[1], Ansgar Laubsch[2], Georg Brüderl[2], and Uwe Strauss[2] — [1]NWF II - Physik, Universität Regensburg — [2]Osram Opto Semiconductors GmbH

In the (Al,In)GaN material system lateral ground mode operation of ridge waveguide laser diodes (LDs) is limited to narrow ridge widths up to a few micrometers. For broader ridge LDs, which are inevitable for high output power applications, filaments or higher order lateral modes appear, which influence the far-field beam quality. We investigate the lateral profile of the optical laser mode in the waveguide experimentally and theoretically. We get our experimental results from time resolved scanning near-field optical microscopy (SNOM) measurements on pulsed electrically driven LDs. We measure the number and the width of filaments as a function of ridge width and current density. We compare these experimental data with one-dimensional simulations of the lateral laser mode profile. In these simulations we include the carrier- and thermal-induced modifications of the ridge waveguide refractive index profile. Therefore the spatial resolved rate equations for carriers and photons are solved in a self-consistent loop, including the interaction with the optical mode in the modified refractive index profile. By this method we can simulate the shape of typical measured lateral mode profiles for different ridge widths and current densities with a consistent set of parameters for broad ridge (Al,In)GaN LDs.

HL 36.38 Wed 16:30 Poster D

Hall effect measurements on AlInN layers with high In-content and low Hall mobility — •Kay-Michael Günther, Hartmut Witte, Christoph Hums, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Magdeburg

At AlInN/GaN interfaces grown with strained AlInN on GaN and with Indium concentrations above 32 % a p-channel is expected. For such material, a precise characterization of the electrical and transport properties by Hall-effect measurements is fundamental. In the case of low mobility and/or high resistance such measurements are very difficult: the Hall voltage is about 100-1000 times smaller than the voltage drop without the magnetic field. The apparent Hall coefficient is not caused by a free carrier concentration but rather by dynamic persistent or storage processes due to inhomogeneities within the AlInN layers. However, even in the case of extremely noisy signals useful information, e.g. on the type of carriers can be extracted by comparing the average values of many Hall-effect measurements with and without a magnetic field. Furthermore, the noise can be reduced by lock-in measurements.

HL 36.39 Wed 16:30 Poster D

Structural and magnetic properties of Eu-, Ho- and Sm-implanted GaN — •Fang-Yuh Lo[1], Verena Ney[2], Andreas Ney[2], Alexander Melnikov[1], Dirk Reuter[1], Sébastien Pezzagna[3], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum — [2]Experimentalphysik, Universität Duisburg-Essen, Lotharstr. 1, D-47057 Duisburg — [3]RUBION, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum

GaN is a wide band gap semiconductor, which has many applications in high-power electronics as well as optoelectronics. Recently, GaN-based diluted magnetic semiconductors have attracted great interest because theoretical work predicted Curie temperatures above 300K. However, the experimental results are quite different and depend strongly on the fabrication methods. In our studies, the rare-earth elements, Eu, Ho and Sm, are introduced into GaN-based heterostructures by focused ion beam implantation. The structural and magnetic properties of the implanted material are studied.

HL 36.40 Wed 16:30 Poster D

Near infrared absorption in nonpolar cubic AlN/GaN superlattices — •Jörg Schörmann[1], Elena Tschumak[1], Donat J. As[1], Klaus Lischka[1], Eric A. DeCuir[2], and Omar Manasreh[2] — [1]Department of Physics, University of Paderborn, Warburger Str. 100, 33095 Paderborn — [2]Department of Electrical Engineering, University of Arkansas, 3217 Bell Engineering Center, Fayetteville, Arkansas 72701

Nonpolar cubic GaN/AlN superlattices were grown at 720°C by plasma-assisted molecular beam epitaxy on free standing 3C-SiC substrates. 20 periods of AlN/GaN quantum wells were deposited on a 100 nm thick GaN buffer layer. The thickness of the AlN barrier is 1.35 nm for all samples, while the thickness of the GaN well varies between 1.6 nm - 2.10 nm depending on the samples. The periodicity

of the GaN/AlN active regions was confirmed by the presence of several peaks in the high resolution x-ray diffraction (HRXRD) spectra. The thickness of the total period was estimated by fitting the HRXRD data using a dynamic scattering theory. Room temperature optical absorption spectra of the intersubband transitions were obtained using a Bruker IFS-125HR spectrometer. Optical absorption was observed in the spectral range of 1.5 μm - 2.0 μm and confirmed theoretically using a square well self-consistent Poisson-Schrödinger model.

HL 36.41 Wed 16:30 Poster D

Untersuchung von relaxierten und nicht-relaxierten InGaN Quantenfilmen mit Photolumineszenz und Röntgenbeugung — •Torsten Langer, Holger Jönen, Lars Hoffmann, Daniel Dräger, Heiko Bremers, Daniel Fuhrmann, Uwe Rossow und Andreas Hangleiter — Technische Universität Braunschweig, Institut für Angewandte Physik, Mendelssohnstrasse 2, 38106 Braunschweig

Für optoelektronische Anwendungen im langwelligen Bereich werden InGaN-Quantenfilme mit hohem Indium-Gehalt von grösser 30% benötigt. Da bei so hohem Indium-Gehalt sehr grosse Piezofelder aufgrund der Verspannung zum GaN vorhanden sind, müssen die Schichtdicken fuer eine gute Quanteneffizienz deutlich kleiner als im blauvioletten Bereich sein. Für eine gute Homogenität in der Schichtdicke und der Indium-Konzentration sowie einer guten Injektion der Ladungsträger ist dagegen eine möglichst grosse Schichtdicke vorteilhaft. Für eine Indium-Konzentration von etwa 30% sehen wir eine Relaxation in Röntgenbeugung für Schichten von ca. 2.5nm. Wir stellen vergleichende Messungen von Photolumineszenz und Röntengenbeugung vor zur Frage der Homogenität der Indium-Konzentration an der Schwelle zur Relaxation der InGaN-Quantenfilme.

HL 36.42 Wed 16:30 Poster D

Oxidation of GaN(0001)-2×2 surfaces by oxygen and water — •Pierre Lorenz, Richard Gutt, Juergen A. Schaefer, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany

Experimental and theoretical studies show a high reactivity of GaN surfaces, which is of importance for various applications [1]. We have performed an in-situ analysis of the interaction of oxygen and water with clean and stoichiometric 2×2 reconstructed GaN(0001) surfaces grown on 6H-SiC(0001) by plasma assisted molecular beam epitaxy, with an RMS roughness well below 1 nm measured by atomic force microscopy. For the as-grown samples, two surface states at 2 eV and 3 eV below E_F can be found in the ultraviolet photoelectron valence band spectra. Upon oxygen exposure, drastic changes are observed. Within the first 4 Langmuir of oxygen, the state at 2 eV as well as the 2×2 superstructure vanishes. Additionally, the work function ϕ increases by 0.3 eV and a downward bend bending of 0.4 eV is observed. For higher exposures, ϕ remains constant and the valence band spectra merge into curves with two distinct oxygen related states at 6 eV and 11 eV in agreement with earlier works [2,3]. The reaction to water shows a comparable behaviour, with a disappearence of the 2 eV surface state after an exposure of 0.2 L.
[1] C.-L. Hu et al. , Chem. Phys. Lett. 424 (2006) 273 [2] V.M. Bermudez, J.Appl. Phys. 80 (1996) 1190 [3] V.M. Bermudez and J.P. Long, Surf. Sci. 450 (2000) 98

HL 36.43 Wed 16:30 Poster D

Ortsaufgelöste Mikro-EL- und Mikro-PL-Spektroskopie an blauen InGaN/GaN LEDs auf Si(001) und Si(111) — •T. Fey[1], L. Reissmann[1], F. Schulze[1], A. Dadgar[1,2], J. Christen[1] und A. Krost[1,2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität, 39016 Magdeburg — [2]AZZURRO Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg

Es wurden MOCVD-gewachsene blaue InGaN/GaN-MQW LEDs auf Si(001)- und Si(111)-Substrat mittels ortsaufgelöster μ-EL- und μ-PL Spektroskopie untersucht. Die Anregung erfolgte mit der 324 nm Linie eines He-Cd-Lasers, bzw. durch Injektionsströme von bis zu 200 mA. Bei beiden Meßmethoden wurden jeweils die identischen Probenausschnitte von 80x200 μm2 abgerastert. Beide Proben zeigen Fabry-Perot-Moden in ihrem Spektrum. Die LED auf Si(001) zeigt eine Blauverschiebung der PL- zur EL-Peakwellenlänge von 15-20 nm. Die Position des Fabry-Perot-Interferenzmusters verschiebt sich mit zunehmenden Strömen im Vergleich zur optischen Anregung. Dies kann nur mit einem veränderten Brechungsindex aufgrund sich ändernder Ladungsträgerdichten erklärt werden. Die einsetzende Rotverschiebung des EL-Peaks deutet auf ein Aufheizen der LED hin. Während die PL-Peakwellenlänge zufällig auf einer lateralen Skala <3 μm fluktuiert, treten Domänen von identischen EL-Peakwellenlängen mit 30-50 μm Ausdehnung bereits bei Strömen ab 50 mA auf. Offenbar werden lokale Potentialfluktuationen durch die hohe injizierte Ladungsträgerdichte ausgeglichen. Eine auf Si(111) gewachsene Vergleichs-LED zeigt ebenfalls eine blauverschobene PL-Peakwellenlänge.

HL 36.44 Wed 16:30 Poster D

Carbon doping of cubic GaN by CBr_4 — •Elena Tschumak[1], Hartwig Pöttgen[1], Olga Kasdorf[1], Jörg Schörmann[1], Jürgen W. Gerlach[2], Donat J. As[1], and Klaus Lischka[1] — [1]Universität Paderborn, Department Physik, Warburger Strasse 100, 33095 Paderborn, Germany — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, 04318 Leipzig

Carbon-doped cubic GaN (c-GaN:C) films were grown by plasma-assisted molecular beam epitaxy using carbon tetrabromide (CBr_4) as a carbon source. The growth was in situ moni-tored by reflection high-energy electron diffraction (RHEED). To detect the atomic carbon, the quadrupol mass spectrometer was used. Secondary ion mass spectroscopy (SIMS) was used to quantify the carbon incorporation behavior. The electrical properties of carbon doped c-GaN samples were studied by capacitance-voltage (CV) measurements and Hall-effect measurements between 10-400K. The optical properties of the epilayers were stud-ied by photoluminescence (PL) measurements at room temperature and at 4K.

HL 36.45 Wed 16:30 Poster D

TEM Investigations on defect terminating SiN interlayers in (Al, In)GaN layer systems on sapphire substrate — •Martin Beer[1], Josef Zweck[1], Joachim Hertkorn[2], Frank Lipski[2], Peter Brückner[2], Stephan Schwaiger[2], and Ferdinand Scholz[2] — [1]Universität Ulm, Albert-Einstein-Allee 45, D-89081 Ulm, Germany — [2]Universität Regensburg, Universitätsstr. 31, D-93051 Regensburg, Germany

To decrease the dislocation density in (Al,In)GaN layer systems for LEDs grown on sapphire substrates a defect terminating SiN interlayer was deposited at two different positions in the epitaxial layer grown by MOVPE. In the first series of samples the SiN layer was deposited directly on the AlN Buffer layer, in the second series it was inserted into the GaN layer about 350 nm above the substrate - film interface. The deposition time of the SiN layers was varied between 3 min and 7 min yielding to a fractional coverage of about 60 % to 90 %, respectively. Cross-sectioned samples of the differently grown structures were prepared and afterwards analysed in the TEM, e.g. by means of weak beam dark field imaging and HRTEM. The obtained results will be compared to etch pit density measurements.

HL 37: Invited Talk Chatterjee

Time: Thursday 9:30–10:15 Location: ER 270

Invited Talk HL 37.1 Thu 9:30 ER 270

Terahertz detection of many-body signatures in semiconductor heterostructures — •Sangam Chatterjee, Torben Grunwald, David Köhler, Tilmann G. Jung, Daniel Golde, Mackillo Kira, and Stephan W. Koch — Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, 35032 Marburg, Germany

The collective response of many-body systems in semiconductor heterostructures is studied by means of THz time-domain spectroscopy. This makes it possible to unambiguously identify correlated states in semiconductors such as plasmons or excitons.

As examples of our results we present investigations of a two-dimensional electron gas in a high electron-mobility transistor-like structure. While it is commonly accepted that the plasma frequency in two dimensions vanishes with vanishing momentum, we measure a plasmon pole in the transmission spectra of our system. Furthermore,

the observed density dependence is similar to the 3D system (Nature 414, 286 (2001)).

As another example, experimental evidence of different excitonic behavior in GaAs/AlGaAs and (GaIn)As/GaAs quantum wells is presented. The dynamics of the induced absorption of the 1s-2p transition is monitored after optical excitation at the 1s resonance. A microscopic many-body analysis is used to explain the measured results.

HL 38: Invited Talk Korn

Time: Thursday 10:15–11:00 Location: ER 270

Invited Talk HL 38.1 Thu 10:15 ER 270

Spin dynamics in high-mobility 2D electron systems: effects of electron-electron interaction and anisotropy — •Tobias Korn[1], Dominik Stich[1], Natalie Steffek[1], Dieter Schuh[1], Werner Wegscheider[1], Ming-Wei Wu[2], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg — [2]University of Science and Technology of China, Hefei

Understanding the spin dynamics in semiconductor heterostructures is highly important for future semiconductor spintronic devices. In high-mobility 2D electron systems (2DES), the spin lifetime strongly depends on the initial degree of spin polarization due to the electron-electron interaction. By time-resolved Faraday rotation (TRFR) techniques, we demonstrate that the spin lifetime is increased by an order of magnitude as the initial spin polarization degree is raised from the low-polarization limit to several percent[1,2]. Additionally, the spin lifetime in 2DES is strongly anisotropic if the Rashba and Dresselhaus spin-orbit fields are of the same order of magnitude. By comparing TRFR measurements in an in-plane magnetic field to numerical simulations, we are able to determine both, the Rashba and the Dresselhaus terms with high accuracy. Using these values, we can infer an in-plane anisotropy of the spin lifetime of about 60 to 1, with a maximum in-plane spin lifetime of several nanoseconds [3].

[1] Stich et al., Phys. Rev. Lett. **98**, 176401 (2007).
[2] Stich et al., Phys. Rev. B **76**, 205301 (2007).
[3] Stich et al., Phys. Rev. B **76**, 073309 (2007).

HL 39: Ultra fast phenomena

Time: Thursday 11:15–13:00 Location: ER 270

HL 39.1 Thu 11:15 ER 270

Intensity dependence of charge and spin currents generated by ultrafast two-color photoexcitation*of semiconductor quantum wells — Bernhard Pasenow[1], Huynh Thanh Duc[2,1], •Torsten Meier[3,1], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg, Germany — [2]Ho Chi Minh City Institute of Physics, Viet Nam Center for Natural Science and Technology,*1 Mac Dinh Chi, Ho Chi Minh City, Vietnam — [3]Department Physik, Fakultät für Naturwissenschaften, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Charge and spin currents that are generated on ultrafast time scales by two-color laser excitation of semiconductor quantum wells are computed using Bloch equations that formulated in the basis of $\mathbf{k}\cdot\mathbf{p}$ wave functions [1,2]. The optically induced inter- and intraband excitations are both treated nonperturbatively providing a consistent description of phototransport effects in the high-excitation regime. The analysis shows that the photoexcited charge and spin currents depend on the amplitudes of the incident ω and 2ω beams in a highly nonlinear fashion. It is predicted that Rabi flopping leads to intensity-dependent changes of the current directions [3].

[1] B. Pasenow, Dissertation, Philipps-University Marburg, 2006.
[2] T. Meier, B. Pasenow, H.T. Duc, Q.T. Vu, H. Haug, and S.W. Koch, Proc. of SPIE **6471**, 647108 (2007).
[3] B. Pasenow, H.T. Duc, T. Meier, and S.W. Koch, Solid State Communications, in press.

HL 39.2 Thu 11:30 ER 270

Two-color pump-probe spectroscopy of electron dynamics in doped superlattices — •Martin Wagner[1], Dominik Stehr[1], Harald Schneider[1], Stephan Winnerl[1], Manfred Helm[1], Aaron Andrews[2], Tomas Roch[2] und Gottfried Strasser[2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden-Rossendorf, Postfach 51 01 19, 01314 Dresden — [2]Institut für Festkörperelektronik, TU Wien, Floragasse 7, 1040 Wien, Österreich

We report on two-color pump-probe measurements to investigate the intraminiband dynamics of doped GaAs/AlGaAs SLs with different miniband widths smaller or larger than the optical phonon energy. We have analyzed the cooling behavior at low temperature. We employed infrared pulses from a free-electron laser to excite electrons to the upper miniband at the center of the SL mini-Brillouin zone and the interminiband transition was probed at the zone edge with broadband THz pulses. After relaxation to the ground miniband the electronic distribution is heated up which results in more absorption at the zone edge. When the distribution cools down this induced absorption signal decays, leading to decay times of 40-50 ps for a miniband width smaller and 3.5 ps for a width larger than the optical phonon energy. This difference in time constants can be explained by the new relaxation channel through polar optical phonons. Additionally we performed measurements at room temperature where the lower miniband is already occupied at the zone edge. Thus no induced absorption and fast decay times are observed.

HL 39.3 Thu 11:45 ER 270

Picosecond acoustic pulse altering the emission dynamics of a semiconductor planar microcavity — •Thorsten Berstermann[1], Dmitri R. Yakovlev[1,2], Manfred Bayer[1], Alexey V. Scherbakov[2], Andrey V. Akimov[2], Jacqueline Bloch[3], and Isabelle Sagnes[3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44227 Dortmund, Deutschland — [2]A.F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia 2 — [3]Laboratoire de Photonique et de Nanostructures, LPN/CNRS, Route de Nozay, 91460 Marcoussis , France

In the present work we report the first experiments where the propagating strain wave packets, which contain GHz frequency components, effect the intensity and the wavelength of the photoluminescence in a semiconductor microcavity strongly coupled to the exciton resonance in a quantum well. The studied microcavity was grown on GaAs substrate and contains a 8nm wide $In_{0.04}Ga_{0.96}As$/GaAs quantum well in a λ-cavity, surrounded by Bragg mirrors built up from 20 and 24 pairs of GaAs/AlAs layers. The strain pulses are induced via 100fs short laser pulses obtained from a pulsed laser with a regenerative optical amplifier. The strain amplitude is $\sim 10^{-4}$, yielding a shift of the exciton resonance in the quantum well of $\sim$1 meV [1]. This results in the detuning of the coupled microcavity and exciton resonances causing the modulation of the photoluminescence intensity and its wavelength on a picosecond time scale. The observed effects inroduce new methods for ultrafast control of the emission from optical microcavities and photonic crystals. [1] Akimov et al. PRL 97, 037401 (2006)

HL 39.4 Thu 12:00 ER 270

THz detection with scalable photoconductive antennas — •Falk Peter[1], Stephan Winnerl[1], Sven Nitsche[1], André Dreyhaupt[1], Harald Schneider[1], Manfred Helm[1], and Klaus Köhler[2] — [1]Forschungszentrum Dresden Rossendorf — [2]Fraunhofer Institut für Angewandte Festkörperphysik

We present studies on nonresonant photoconductive THz detectors and emitters. Our system consists of a large-area terahertz detector based on an interdigitated electrode structure and an emitter with similar electrode geometry [1]. Emitters based on this concept stand out due

to their high efficiency for conversion of near-infrared radiation into far-infrared radiation. The main advantage of the scalable antennas as compared to conventional photoconductive antennas is that they do not require tight focusing of the THz and gating beams. While the emitter is fabricated on semi-insulating GaAs, we compare different detection antennas based on ion-implanted and low temperature grown (LT) GaAs, respectively. We discuss which material properties affect the performance and noise level of our system and discuss the role of the carrier lifetime upon the measured THz signal. The best signal-to-noise ratios are found for N+ dual energy implantations (0.4 MeV and 0.9 MeV) with doses in the 10^{13} cm^{-2} range and for (LT) GaAs.

[1] F.Peter, S.Winnerl, S. Nitsche, A. Dreyhaupt, H. Schneider, and M.Helm, Appl. Phys. Lett. 91, 081109 (2007)

HL 39.5 Thu 12:15 ER 270

THz Lyman spectroscopy and coherent THz control of dark excitons in Cu_2O — •Silvan Leinss[1], Tobias Kampfrath[2], Konrad v. Volkmann[2], Martin Wolf[2], Dietmar Fröhlich[3], Alfred Leitenstorfer[1], and Rupert Huber[1] — [1]Department of Physics, University of Konstanz, 78464 Konstanz — [2]Department of Physics, Free University Berlin, Arnimallee 14, 14195 Berlin — [3]Department of Physics, University of Dortmund, 44221 Dortmund

We employ ultrabroadband THz pulses to resonantly couple to the internal exchange-split 1s-2p Lyman doublet of yellow excitons in Cu_20 (T_L = 4 K). A line shape analysis provides absolute values of density and temperature of the optically dark exciton gas forming after two-photon photogeneration of unbound electron-hole pairs. At a delay time of 100 ps, 1s-para states are observed with a density of 2×10^{16} cm^{-3} and a temperature of 12 K. Intense THz transients with peak electric fields of 0.5 MV/cm allow us to coherently control the internal quantum state of this ensemble via a partial intra-excitonic Rabi flop. Up to 70% of the quasiparticles are promoted from the 1s into the 2p state. Electro-optic sampling directly monitors the Larmor precession of the Bloch vector in real time. The results suggest a promising new route for preparing ultracold and dense exciton gases.

HL 39.6 Thu 12:30 ER 270

Influence of heavy-hole light-hole band mixing on the strength of optically generated spin-currents in III-V semiconductor quantum wells — •Bernhard Pasenow[1], Torsten Meier[2], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg, Germany — [2]Department Physik, Fakultät für Naturwissenschaften, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

The coherent optical injection and temporal decay of spin and charge currents in semiconductor heterostructures has been investigated on a microscopic level including Coulomb and phononic effects up to second Born scattering contributions [1,2].
In this talk the previously used two-band effective mass approach is extended to a realistic bandstructure model using microscopic 8x8 kp matrix elements focussing on heavy-hole light-hole band-mixing effects. It will be shown how this band-mixing influences the strength of the optically generated spin-currents in different semiconductor quantum wells leading to rules for optimal structure composition [3].

[1] H.T. Duc, T. Meier, and S.W. Koch, PRL 95, 086606 (2005).
[2] H.T. Duc, Q.T. Vu, T. Meier, H. Haug, and S.W. Koch, PRB 74, 165328 (2006)
[3] B. Pasenow, T. Meier, and S.W. Koch, unpublished

HL 39.7 Thu 12:45 ER 270

Ultrafast dynamics of coherent optical phonons in α-quartz — •Konrad von Volkmann[1], Tobias Kampfrath[1], Marcel Krenz[1], Alexander Grujic[2], Christian Frischkorn[1], and Martin Wolf[1] — [1]Freie Universität Berlin, Berlin, Germany — [2]Femtolasers GmbH, Fernkorngasse 10, 1100 Vienna, Austria

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 absorption (yielding k) or ellipsometry (leading to n).

We present temperature and pump-polarization dependent data for both probe methods. The polarization dependence will be discussed in terms of impulsive stimulated Raman scattering as excitation mechanism and a detailed analysis of the corresponding Raman tensors will be given. Previous measurements have shown a pump-fluence *in*dependent lifetime which indicates that the decay mechanism of the lattice vibrations is phonon-phonon scattering. The temperature dependence of the phonons confirms this finding and enables a discussion of the scattering rates and the involved phonons.

HL 40: Invited Talk Hannewald

Time: Thursday 14:00–14:45 Location: ER 270

Invited Talk HL 40.1 Thu 14:00 ER 270

Charge transport in organic molecular crystals — •Karsten Hannewald — European Theoretical Spectroscopy Facility and Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Germany

An important class of organic semiconductors are molecular crystals of high purity. Besides the overall technological potential (OFETs, OLEDs), these crystals are interesting model systems for fundamental studies of the intrinsic excitations and charge-carrier transport mechanisms. We present a theoretical and numerical description of charge transport in such organic crystals. Our approach is based upon the Kubo formula for electrical conductivity within the framework of a mixed Holstein-Peierls model. Special attention is paid to polaronic effects that arise due to the strong electron-phonon interaction in organic materials. Explicit formulas for the polaron bandwidths and mobilities as a function of temperature are derived. The theory is supplemented by *ab initio* calculations of the relevant material parameters (transfer integrals, electron-phonon coupling, phonons) for various materials (oligo acenes, durene, guanine). Our predictions for the temperature dependence and anisotropy of the electron and hole mobilities agree well with experimental data and provide new insight into several hitherto poorly understood transport phenomena.

HL 41: Organic semiconductors

Time: Thursday 15:00–17:30 Location: ER 270

HL 41.1 Thu 15:00 ER 270

Charge transport in guanine crystals — •Frank Ortmann, Karsten Hannewald, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität, Jena, Germany

Charge-transport processes in organic molecular crystals exhibit similarities and differences to those in π-conjugated polymers. For both types of condensed matter the polaronic effects are of outstanding importance. These effects can cause a transition from band-like transport to thermally activated hopping.[1] While the hopping regime is prevalent for DNA polymers, it is not clear if the same holds also for crystaline guanine or if band transport dominates. Also the influence of the temperature is rarely discussed in literature. In our approach to the problem of charge-carrier transport in these systems [2,3], we discuss the temperature dependence of the polaron bandwidth and the mobility in guanine crystals [4].

[1] Hulea et al. Nat. Mater **5** , 982 (2006)
[2] Hannewald et al. PRB **69** , 075211 (2004)

[3] Hannewald et al. PRB **69** , 075212 (2004)
[4] Ortmann et al. J. Phys. Chem. B (to be published)

HL 41.2 Thu 15:15 ER 270

Charge carrier mobility in organic bulk P3HT:PCBM solar cells with varied donor–acceptor ratio — •Andreas Baumann[1], Carsten Deibel[1], Jens Lorrmann[1], Maria Hammer[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg, Germany

The efficiency of organic solar cells has been increased to above 5 % in the last decade, promissing an interesting potential as a renewable energy source. For P3HT: PCBM heterojunction solar cells a ratio of 1:1 was found to yield the highest efficiencies. Concerning the donor–acceptor ratio, both an efficient charge transfer as well as a balanced mobility of the charge carriers are necessary to reach such high solar cell performances. We investigated the electron and hole mobilities in P3HT:PCBM heterojunction solar cells with different donor (P3HT)–acceptor (PCBM) ratio experimentally. For a deeper understanding, experimental results are discussed by comparing them with Monte Carlo simulations of hopping transport in a Gaussian density of states distribution.

HL 41.3 Thu 15:30 ER 270

Polymer solar cell modules: first experimental results and their optimization — •Harald Hoppe[1], Burhan Mushin[1], Joachim Renz[1], Karl Heinz Drüe[2], Jonas Bachmann[3], Claudia Buerhop-Lutz[3], Ingo Riedel[4], Vladimir Dyakonov[4], and Gerhard Gobsch[1] — [1]Institute of Physics, Ilmenau University of Technology, Weimarer Str. 32, 98693 Ilmenau, Germany — [2]Electronic Technology, Institute of Micro- and Nanotechnologies, Ilmenau University of Technology, Gustav-Kirchhoff-Str. 7, 98693 Ilmenau, Germany — [3]ZAE BAYERN, Thermosensorik und Photovoltaik, Am Weichselgarten 7, 91058 Erlangen, Germany — [4]ZAE BAYERN, Funktionsmaterialien der Energietechnik, Am Hubland, 97074 Würzburg, Germany

Polymer solar cell modules based on the standard polymer-fullerene system of to-date, P3HT-PCBM, have been prepared and characterized. We have observed only a loss of ca. 20% when up scaling the active area of the solar cell by a factor somewhat larger than 10. A solar cell efficiency of 3% and a module efficiency of 1.9%, relating to the total area, are reported. The route for further optimization of module performance is discussed based on analysing the existing loss factors within this material system. We made thermographic measurements on the modules and identified parasitic shunts.

HL 41.4 Thu 15:45 ER 270

Investigation of novel organic n-type semiconductors with respect to absorption, charge carrier generation and mobility — •Moritz Liedtke[1,2], Johannes Krantz[1], Andreas Sperrlich[1], Björn Titze[1], Maria Hammer[1], Carsten Deibel[1], Vladimir Dyakonov[1,2], and Martin Baumgarten[3] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]The Bavarian Center for Applied Energy Research (ZAE Bayern), Am Hubland, D-97074 Würzburg — [3]Max Planck Institute for Polymer Research, D-55128 Mainz

Novel organic n-type semiconductors as acceptors for applications in organic semiconducting devices such as solar cells are investigated. As reference materials, we used the donor poly(3-hexylthiophene) (P3HT) and the commonly used [6,6] phenyl-C61-butyric acid methyl ester (PCBM) as acceptor. We studied the materials and their composites in view of light absorption, photoluminescence quenching, electron spin resonance and field-effect mobillity measurements. Thus we obtained information on charge carrier generation, the spin state of excitations and the charge carrier mobility.

HL 41.5 Thu 16:00 ER 270

How strain controls the exciton linewidth in single polyfluorene nanowires — •Enrico Da Como, Klaus Becker, and Jochen Feldmann — Photonics and Optoelectronics Group, Dep. of Phys. and CeNS, LMU, Munich

In this contribution, by low temperature single molecule fluorescence spectroscopy, we show a correlation between intramolecular order and the exciton linewidth in single chains of poly(9,9-dioctylfluorene) (PFO). According to the degree of planarization in the adjacent fluorene repeat units, PFO single chains can be distinguished between beta- (planar) or glassy (twisted) phase. By single molecule polarization anisotropy in excitation we have compared the overall shape of the chain in both phases. The results demonstrate that beta-phase chains are characterized by higher polarization values than the glassy ones, reflecting a structure comparable to a one-dimensional (1D) crystalline nanowire [1]. A detailed investigation of beta-phase chains shows a strong correlation between the exciton zero-phonon-linewidth and the polarization anisotropy of the emitting chromophore. While linewidth provides a lower limit for the exciton dephasing time, which reaches remarkable values up to 3 ps for straight chromophores, low anisotropy is symptomatic of the degree of strain which acts on the 1D structure. Bent chromophores show systematically larger linewidths suggesting an accelerated dephasing in the exciton wavefunction or an increased spectral diffusion. The results give a picture on how structure in a 1D organic semiconductor correlates with the electronic properties. [1] E. Da Como et al. Nano Lett. 7, 2993 (2007).

15 min. break

HL 41.6 Thu 16:30 ER 270

Electron and hole transport in evaporated layers of copper-phthalocyanine — •Michael Kraus, Andreas Opitz, and Wolfgang Brütting — Institute of Physics, University of Augsburg, Germany

The realisation of electron and hole transport in the same material will extend the probabilities of organic electronic circuits. An example is the field of complimentary logics where separated p- and n-type field-effect transistors are necessary. In this study copper(II)-phthalocyanine (CuPc) is investigated which is commonly used in organic field-effect transistors (OFETs) due to its stability in ambient air or in organic photovoltaic cells as a light absorber.

We fabricated bottom-gate top-contact OFETs with evaporated CuPc layers as active layer. The Si/SiO_2 substrates were treated with a thin layer of PMMA to achieve a trap free interface. It is possible to control the type of carrier transport by using various electrode materials differing in their work function. So both types of unipolar transport and also ambipolar transport are realised. The transfer-length-method is applied to calculate mobility and contact resistance separately. The field-effect mobility was found as an intrinsic property of the material which depends on the carrier type but not on the electrode material. Our results show an asymmetry between electron and hole transport since the hole mobility is one order of magnitude higher than the electron mobility.

HL 41.7 Thu 16:45 ER 270

Influence of Dissociation and Recombination on the Photocurrent of Organic Bulk Heterojunction Solar Cells — •Carsten Deibel, Andreas Baumann, Thomas Strobel, and Vladimir Dyakonov — Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg

Despite the significant increase of performance of organic bulk heterojunction solar cells in recent years, the detailed knowledge of the relevant elementary processes remains under debate. Concerning charge carrier recombination, literature so far reports different mechanisms: monomolecular recombination or a combination of bimolecular recombination with thermalisation, or what is called dispersive recombination. In order to contribute to this discussion, we present investigations of the photocurrent of polymer:fullerene solar cells. We apply time-resolved as well as steady-state techniques such as photo-CELIV — charge carriers generated by a short laser pulse are extracted after a variable delay time — and current–voltage measurements, in dependence of temperature. In order to complement these experiments, we perform Monte Carlo simulations of polaron pair dissociation in disordered donor–acceptor systems, considering monomolecular and bimolecular recombination. Comparing the simulations to the experimental results, we discuss the impact of recombination mechanisms on the photocurrent.

HL 41.8 Thu 17:00 ER 270

Optical Pumped Electrical Functional Organic Laser Device — •Bodo Wallikewitz, Matthias de la Rosa, Jonas Kremer, Dirk Hertel, and Klaus Meerholz — Universität zu Köln, Chemie Department, Luxemburgerstr. 116, 50939 Köln

The performance of organic light-emitting diodes (OLEDs) has made tremendous progress over the past decade, nevertheless, the realization of organic laser diodes remains a challenge. To achieve lasing

optical gain manifested by amplified spontaneous emission (ASE) is mandatory. We have obtained low ASE thresholds (5 uJ/cm2) and high gain (50 cm-1) in oxetane-based photo-crosslinkable conjugated copolymers. Due to their photoresist properties, these materials can be structured by second-order DFB resonator through holographic exposure. Optically pumped single layer polymer lasers with the emitter and resonator made of the same material are investigated and the coupling mechanism is discussed. To realize an organic laser diode it is necessary to confine the waveguided mode in the active layer (gain medium) and to prevent losses induced by the metal contacts in the device. An electrical functional laser device and an ASE device with a threshold of 4.5 and 9 uJ/cm2 was enabled by using thick crosslinked hole transport layer (X-HTL) and non-crosslinked electron transport layer (ETL) cladding the functional emitter layer. OLEDs are characterized and the influence of thick multilayers on OLEDs performance is discussed. The efficiency decreases from 9 Cd/A for a standard 100nm "thin" OLED to 5 Cd/A for a 1 um "thick" multilayer OLED.

HL 41.9 Thu 17:15 ER 270

Magnetoresistance effects in a PTCDI based ferromagnet/organic semiconductor hybrid structure — •Matthias Grünewald[1], Markus Michelfeit[1], Georg Schmidt[1], Rüdiger Schmidt[2], Frank Würthner[2], and Laurens W. Molenkamp[1] — [1]Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Organische Chemie 2, Universität Würzburg, Am Hubland, 97074 Würzburg

Organic semiconductors (OSC) are promising materials for spintronic devices because of their very long spin relaxation times. Already in 2004 a first OSC based spin valve has been demonstrated [Xiong et al, Nature 427, 2004]. Most of the experiments on OSC based spin valve like structures were carried out using low mobility OSC like Alq3. The low mobility, however, results in either low currents or high bias voltages, making the difference between true diffusive spin transport or tunnelling barely discernable. Here we present a spin valve structure based on LSMO (lanthanum strontium manganese oxide) and Co as electrode materials and a novel UHV deposited PTCDI based OSC. The Co contacts are deposited in-situ after OSC deposition. The device shows high field magnetoresistance (HFMR) at 4K superimposed by a spin valve like switching behaviour when a magnetic field is applied in plane of the sample. No magnetoresistance can be observed for fields perpendicular to the plane, excluding any influence of organic magnetoresistance (OMAR). The magnitude of the HFMR depends on the applied bias voltage with a maximum at about 1.5 V. This work is funded by the EU within the FP6 project OFSPIN.

HL 42: Optical Properties of Quantum dots: Theory and Simulation

Time: Thursday 9:30–13:00 Location: EW 201

HL 42.1 Thu 9:30 EW 201

Gauge invariant k.p envelope function theory and g-factors in quantum dots — •Till Andlauer, Richard Morschl, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

We present a gauge invariant real space discretization scheme that includes magnetic fields nonperturbatively in the framework of the multiband k.p envelope function theory. Our procedure is based on Wilson's formulation of gauge theories [1]. The magnetic field couples to the envelope functions via phase factors that result from spatial discretization of the gauge covariant derivative. These phase factors contain a discretized curve integral over the vector potential. In addition, the carrier's spin couples to the magnetic field via a Zeeman-term. In the case of infinitesimal grid spacings, our method becomes equivalent to the minimal substitution method. Applying our procedure, we calculate effective electron and hole g-factors of InAs/InP nanowire dots as a function of dot size and magnetic field direction. We obtain excellent agreement with experimental data [2] and show that the changes in g-factors correlate well with the spatial extent of the wave functions. Furthermore, we investigate the influence of strain and high magnetic fields on the g-factors. In the latter case, we find nonlinear Zeeman splittings and strongly deformed eigenstates. [1] K. G. Wilson, Phys. Rev. D 10, 2445 (1974). [2] M. T. Björk et al., Phys. Rev. B 72, 201307(R) (2005).

HL 42.2 Thu 9:45 EW 201

Gain reduction in semiconductor Quantum Dot systems — •Michael Lorke[1], Jan Seebeck[1], Paul Gartner[1], Frank Jahnke[1], and Weng Chow[2] — [1]Institute for Theoretical Physics, University of Bremen — [2]Sandia National Laboratories, Albuquerque, New Mexico

For practical application of quantum dots (QDs) in light emitters as well as for fundamental studies of their emission properties, dephasing processes due to carrier-carrier and carrier-phonon interaction play a critical role. They determine the homogeneous linewidth of the QD resonances, limit the coherence properties of QD lasers and their ultrafast emission dynamics, and have a strong influence on coherent optical nonlinearities. A microscopic theory is used to study the optical properties of semiconductor quantum dots. The dephasing of a coherent excitation and line-shifts of the interband transitions due to carrier-carrier Coulomb interaction and carrier-phonon interaction are determined from a quantum kinetic treatment of correlation processes which includes non-Markovian effects.

Our quantum kinetic theory predicts a new effect, not found in other gain materials. For large carrier densities, the maximum gain can decrease with increasing carrier density. This behavior arises from a interplay of state filling and dephasing, so that a appropriate treatment of the carrier density dependence of dephasing is necessary. Results for the α-factor for QD systems and a comparison of the peak gain between QDs and quantum wells are will be shown. The presented theory will also be used to determine gain spectra in nitride material systems.

HL 42.3 Thu 10:00 EW 201

Theoretical investigation of optical properties of semiconductor nanostructures — •Gudny Gudmundsdottir and Frank Grosse — Institut für Physik der Humboldt Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Near band edge optical properties of compound semiconductors are determined by excitons. The two particle problem is numerically challenging in semiconductor nanostructures due to their inhomogeneous nature. The one-particle potentials for electron and hole contain the spatially varying band edge potentials given by the local chemical composition and are additionally modified by intrinsic static strain fields and acoustic phonons through deformation potential coupling.

We present calculations of optical properties by solving the time dependent Schrödinger equation for the full three dimensional exciton problem (6 coordinates) in embedded semiconductor quantum dots varying in shape and composition including disorder (alloys). The parallel implementation (MPI) of the computer code allows to treat these complex nanostructures efficiently. Input strain fields are generated from molecular dynamics simulations enabling us to study the influence of phonon wave packets on the optical response of quantum dots.

HL 42.4 Thu 10:15 EW 201

Atomistic Theory of Excitonic Effects in Nanostructures — •Gabriel Bester — Max Planck Institute for Solid State Research, Stuttgart, Germany

The confinement in all three space dimensions given in nanostructures leads to several new phenomena of fundamental interest that can be handled by different levels of theory. For nanostructures of small size, the atomistic nature and ensuing symmetry is most relevant and the system should be viewed as a large assembly of atoms. The adequate description is then atomistic in nature, such as in tight binding or pseudopotential approaches. For larger structures, the atomistic nature tends to become less important while particle-particle correlations become more relevant. In this size regime descriptions such as effective mass in the single band or in the multiband approach (k.p) followed by configuration interaction have established themselves. I will present a theoretical framework, based on empirical pseudoptentials and configuration interaction calculations that enables us to address the intermediate length scale where both, the atomistic nature and correlations are retained. I will illustrate the method by showing recent applications in the realm of quantum dot physics where properties such as

quantum entanglement [1], piezoelectricity [2] or Coulomb blockade [3] have been investigated.

[1] Bester et al., Phys. Rev. Lett. 93 047401 (2004). [2] Bester et al. Phys. Rev. Lett. 96, 187602 (2006). [3] Ediger, Bester, et al., Nature Physics 3, 774 - 779 (2007).

15 min. break

HL 42.5 Thu 10:45 EW 201

The phonon bottleneck revisited at low temperatures — •Jan Seebeck[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute for Materials Physics, Bucharest-Magurele, Romania

The application of semiconductor quantum dots in optoelectronic devices requires efficient carrier-scattering processes. For low carrier densities the interaction with LO phonons provides fast scattering channels, which can be understood by describing carriers as polarons.

Within a quantum kinetic many-body theory we revisit the phonon bottleneck problem. For low temperatures, an asymptotic phonon bottleneck is observed, where after an initial redistribution of carriers the carrier kinetics freezes, not reaching a thermal distribution in terms of the Kubo-Martin-Schwinger condition. Also non-Markovian effects in the dephasing properties as well as intermediate polar coupling nitride materials are discussed.

HL 42.6 Thu 11:00 EW 201

Plane-Wave-implementation of the $\mathbf{k}\cdot\mathbf{p}$-formalism including strain and piezoelectricity to study the optoelectronic properties of semiconductor nanostructures — •Oliver Marquardt, Tilmann Hickel, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung

Optical properties of semiconductor nanostructures such as quantum dots and wires are a direct consequence of their shape, size and material composition. The $\mathbf{k}\cdot\mathbf{p}$ formalism provides a real space approach to compute relevant parameters of nanostructures as e.g. needed to simulate optoelectronic devices such as light and laser emitting diodes. Contributions like strain and piezoelectric potentials entering the $\mathbf{k}\cdot\mathbf{p}$ formalism are typically calculated using continuum elasticity theory.
We have reformulated this approach into a mixed real / reciprocal space formalism and implemented it into our plane-wave DFT-package S/Phi/nX. This allowed us to make efficient use of the existing highly optimized minimization routines as well as the efficient preconditioner techniques in a plane-wave basis set.
We investigate different nanostructures with a focus on the III-nitride materials in the zincblende and wurtzite phase. A detailed comparison to approaches resolving fully the atomistic structure will be shown in order to verify the validity of our approach. Further the influence of the spin-orbital coupling which has been commonly neglected is shown to lift the artificial degeneracy of the hole ground state.

HL 42.7 Thu 11:15 EW 201

Input/Output Characteristics of Semiconductor Quantum Dot Lasers — •Christopher Gies, Jan Wiersig, and Frank Jahnke — Institute for Theoretical Physics, University Bremen, 28334 Bremen, Germany

The field of quantum dot- (QD) microcavity lasers is vividly developing. Initial uncertainties in the definition of a laser threshold and discrepancies in the physics of QDs and two-level atoms have lead us to the development of a microscopic semiconductor laser theory. Effects like Pauli blocking, modifications to the source term of spontaneous emission, and the absence of complete inversion in the carrier system can strongly influence the emission characteristics in QD-based systems. Consequently, we find deviations from predictions of atomic laser models and extracted parameters. With respect to the jump in the input/output curve that is dependent on the spontaneous emission factor β, we discuss various effects that lead to differences between the atomic and the semiconductor model. Our applications focus on the influence of pulsed and continuous wave excitation, which is of great relevance for current experiments.

HL 42.8 Thu 11:30 EW 201

Optical Spin Switching in a Quantum Dot with a Single Mn Atom — •Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str.10,48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

Spins in semiconductor quantum dots are promising candidates as basic ingredients for new quantum hardware, e.g. magnetic bits. In a single quantum dot with a single Mn atom as has been fabricated recently the spin of the Mn instead of the exciton spin can be used as new basis for spintronics. The Mn spin has six possible orientations. In contrast to the carrier spins however it is not directly accessible by laser light. Instead, it can be controlled via the exciton, which can be driven by the optical excitation with ultra short laser pulses. Exciton and Mn spin couple to each other via direct exchange interaction. Though stronger coupled, the heavy holes can hardly induce spin flips, but electrons and light holes have great impact on the dynamics of the Mn spin. Starting from an initial state, we show that the Mn spin states can be selectively accessed via flips on ultrashort times scales induced by a sequence of laser pulses.

15 min. break

HL 42.9 Thu 12:00 EW 201

Study of combined decoherence channels of optically controlled spin rotations in quantum dot systems — •Anna Grodecka[1,2], Paweł Machnikowski[2], Carsten Weber[3], Andreas Knorr[3], and Jens Förstner[1] — [1]Computational Nanophotonics Group, University Paderborn, Germany — [2]Institute of Physics, Wrocław University of Technology, Poland — [3]Nonlinear Optics and Quantum Electronics, Technical University Berlin, Germany

It has been recently proposed [1] that coupling to a trion state may lead to a Raman transition between the two Zeeman-split spin states in a quantum dot, which allows for optical coherent control of a spin. However, the question arises whether the intrinsic features of the system may lead to decoherence which counteracts the ideal coherent control.

In this work, we study the combined decoherence channels resulting from the influence of phonon and photon reservoirs, as well as from the imperfections of the evolution of an optical spin control based on an off-resonant coupling of the spin states to a trion state in a doped semiconductor quantum dot. Using a perturbative theory describing the open system evolution we calculate the total error of the spin-based quantum gate. The optimal conditions for coherent operations are indicated and possible ways of reducing the decoherence are discussed [2].

1. P. Chen, C. Piermarocchi, L. J. Sham, D. Gammon, and D. G. Steel, Phys. Rev. B 69, 075320 (2004).
2. A. Grodecka, C. Weber, P. Machnikowski, and A. Knorr, Phys. Rev. B 76, 205305 (2007).

HL 42.10 Thu 12:15 EW 201

The impact of travelling phonon wave packets on quantum dot spectra — •Jan Huneke[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie , WWU Münster, Wilhelm-Klemm-Str.10,48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

The influence of phonon wave packets travelling across a semiconductor quantum dot on the optical spectra of the lowest quantum dot transition is analysed. Two situations are compared: (i) a phonon wave packet is generated by the optical excitation of a single quantum dot near a surface, which after reflection at the surface reenters the quantum dot; (ii) a phonon wave packet is generated by the excitation of a nearby second dot and then travels across the quantum dot. The analysis accounts for pure dephasing interactions between electronic and phononic degrees of freedom in quantum dot systems driven by ultrafast laser pulses. For this situation a generating function formalism provides exact analytical results. We find that although the displacement fields crossing the dot are almost identical in these two situations, the real time responses as well as the corresponding spectra exhibit qualitative differences and thus allow for a discrimination of phonon wave packets from different origins. By looking at the analytical results it is possible to trace back the physical origin of the differences in the above considered spectra to the fact that the phonons that cross the dot travel in different quantum mechanical subspaces namely: reflected phonon wave packets propagate in the single pair subspace while wave packets generated by a second dot travel in the two-pair manifold.

HL 42.11 Thu 12:30 EW 201

Coherence properties, photon statistics, and mode properties of quantum-dot based microcavity lasers — •Jan Wiersig[1],

Christopher Gies[1], Michael Lorke[1], Frank Jahnke[1], and Martina Hentschel[2] — [1]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen — [2]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden

Semiconductor quantum dots as active material offer several advantages for laser applications. In combination with optical microcavities these systems promise ultra-low thresholds and genuine single-mode lasing [1,2]. This talk reviews our recent progress in developing a microscopic theory for the photon correlation functions $g^{(1)}(\tau)$ and $g^{(2)}(\tau)$ describing the first-order coherence and the photon statistics of quantum-dot-based microcavity lasers. In the transition region from spontaneous to dominantly stimulated emission our theory predicts a qualitative change of $g^{(1)}(\tau)$ from a Gaussian-like to an exponential behaviour in agreement with recent experiments. Moreover, we demonstrate two different approaches to achieve unidirectional laser light emission from deformed microdisk cavities. One scheme is based on avoided resonance crossings [3], the other one on chaotic ray dynamics.

[1] S.M. Ulrich, C. Gies *et al.*, Phys. Rev. Lett. **98**, 043906 (2007).
[2] C. Gies, J. Wiersig, M. Lorke, and F. Jahnke, Phys. Rev. A **75**, 013803 (2007).
[3] J. Wiersig and M. Hentschel, Phys. Rev. A **73**, 031802(R) (2006).

HL 42.12 Thu 12:45 EW 201

Annealing of overgrown InAs/GaAs Quantum Dots: A Tight-Binding Study — •Alexander Kleinsorge[1], Thomas Hammerschmidt[1], and Peter Kratzer[2,1] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, D-47048 Duisburg, Germany

The electronic and optical properties of quantum dots (QDs) are determined by their atomic structure. A better understanding of this relationship requires input from electronic structure theory. We employ the empirical sp^3s^* tight-binding approach, including 2nd-nearest-neighbor interactions and spin-orbit coupling, preceded by structural relaxation using a potential of the Abell-Tersoff type. Large systems with up to 10^6 atoms can be treated using the folded-spectrum method.

To simulate the intermixing during annealing of InAs QDs in GaAs, we implemented a strain-driven kinetic Monte-Carlo (kMC) method, where the hopping rate of the cation vacancies depends on the differences of the relaxation energy (calculated with the Tersoff potential). Using strain-dependent rates in the kMC-Simulation leads to faster dissolving of the wetting layer. Because of the different shape of the electron and hole wavefunctions, the exciton is associated with a dipole moment which causes the experimentally observed Stark shift. We investigate how the dipole moment of the ground state exciton in a QD depends on the concentration profiles after annealing.

HL 43: Quantum dots and wires: Optical properties II

Time: Thursday 14:00–16:30 Location: EW 201

HL 43.1 Thu 14:00 EW 201

Influence of growth parameters on the photoluminescence linewidth of InGaAs/GaAs quantum dots — •Lewis Lingys, Aleksandar Gushterov, and Johann-Peter Reithmaier — Technische Physik, Institut für Nanostrukturtechnolgie u. Analytik, Universität Kassel

InGaAs/GaAs quantum dots are of great interest for studying light-matter interactions on a basic level also leading to new device applications like quantum dot (QD) lasers or single-photon sources. A problem still under investigation is to produce ensembles of QDs with a small size fluctuation in order to achieve a small photoluminescence (PL) linewidth. We present studies on how the PL linewidth is affected by variation of growth parameters for QDs structures grown by MBE. Dot density, dot size and optical properties are not easily tailored in a desired way as several mechanisms are in effect during epitaxial growth. III-V ratio, substrate temperature, nominal thickness of InGaAs layers and content of In have to be chosen correctly to produce a desired QDs structure. We present the influence of different growth parameters on the optical properties of the resulting QD structures with emphasis on the line width which is an indicator for the size dispersion. The results are compared with morphology data gained by atomic force microscopy.

HL 43.2 Thu 14:15 EW 201

Optical QD properties as quantitative fingerprints of structural and chemical properties — •Andrei Schliwa[1], Robert Seguin[2], Sven Rodt[2], Momme Winkelnkemper[2], Dieter Bimberg[2], Thomas Hammerschmidt[3], and Peter Kratzer[4] — [1]WIAS Berlin — [2]TU-Berlin, Institut für Festkörperphysik — [3]University of Oxford — [4]Universität Duisburg-Essen

The detailed shape and composition of capped quantum dots (QD), which present the decisive input parameters for all device modeling, are difficult to determine directly. Spectroscopic data can, however, serve as fingerprints for a specific QD structure. Thus, addressing the inverse problem of fitting spectroscopic data to a detailed theoretical model leads to the determination of size, shape and composition as adjustable parameters.

Single-particle states were obtained by eight-band k*p theory, taking into account arbitrary QD-shapes, strain (using atomistic- as well as continuum mechanical models), piezoelectricity (first- and second order). The energies of few-particle states (exciton, biexciton, charged excitons) are calculated using the configuration interaction approach, thus, accounting for direct Coulomb effects, exchange and correlation. We will present systematic calculations of many types of QDs, varying size, shape, and composition.

To demonstrate the power of our approach, results of modeling are compared to single QD cathodoluminescence spectra tracing the evolution of one and the same QD over several steps of annealing.

HL 43.3 Thu 14:30 EW 201

Ultrafast Spin Dynamics in Colloidal ZnO Quantum Dots — •Nils Janssen[1], Tobias Hanke[1], Florian Sotier[1], Tim Thomay[1], Kelly Whitaker[2], Daniel Gamelin[2], and Rudolf Bratschitsch[1] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz, Germany — [2]Department of Chemistry, University of Washington, Seattle, WA 98195, USA

We have performed time-resolved Faraday rotation measurements in the Ultraviolet (UV) to reveal the ultrafast spin dynamics of electrons in colloidal ZnO quantum dots. A biexponential decay in the ensemble spin dephasing time T_2^* is observed. The fast decay component on the order of 200 ps is dominated by the recombination of UV excitons. In a competing process, optically excited holes are trapped in dot surface states, which results in negatively charged quantum dots and a long decay component on the order of nanoseconds in the Faraday rotation signal. Time-resolved differential transmission measurements show a biexponential decay with comparable timescales, and photoluminescence emission measurements confirm this interpretation. The spin dephasing dynamics measured by time-resolved Faraday rotation will be compared to those estimated from electron paramagnetic resonance lineshape analysis for charged colloidal ZnO quantum dots.

HL 43.4 Thu 14:45 EW 201

Decay dynamics of neutral and charged excitonic complexes in single InAs/GaAs QDs — •Max Feucker, Robert Seguin, Sven Rodt, Konstantin Pötschke, and Dieter Bimberg — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

Across the inhomogeneously broadened lineshape of a quantum dot (QD) ensemble the decay times are expected to vary since the wavefunctions and the oscillator strengths are sensitive to the actual geometry of the QD. We performed time-resolved cathodoluminescence spectroscopy of 26 different single InAs/GaAs QDs to investigate the decay dynamics of neutral and charged excitonic complexes. The largest decay rate was found for the XX+, followed by XX, X+ and finally the X. We will show that the ratios of lifetimes of the different excitonic complexes are mainly governed by the number of involved recombination channels. There is excellent agreement between the measured and predicted values for the lifetime ratios of the neutral (X/XX) and the positively charged (X+/XX+) complexes. Surprisingly the lifetime of the exciton (X) shows a much larger yet unexplained scatter than that of all the other complexes.

HL 43.5 Thu 15:00 EW 201

Replica of confined acoustic phonons in the photoluminescence of single CdSe/CdS/ZnS core/shell/shell nanocrystals — •Tobias Kipp[1], Gerwin Chilla[1], Marija Nikolic[2], Andreas Frömsdorf[2], Torben Menke[1], Andreas Kornowski[2], Detlef Heitmann[1], Stephan Förster[2], and Horst Weller[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg — [2]Institut für Physikalische Chemie, Universität Hamburg

We investigate the photoluminescence (PL) of single CdSe/CdS/ZnS core/shell/shell NCs whose ligands were exchanged to poly(ethylen oxide) (PEO) before they were embedded in a PEO matrix. We find NCs exhibiting a strong and durable PL even under high excitation power. By averaging PL spectra of a single NC, a set of peaks with distinct distance to the zero-phonon line (ZPL) of the NC can be observed. These peaks are attribute to phonon replicas. Most interestingly, by modeling the NC as an elastic sphere and calculating its vibrational modes, we can identify three peaks close to the ZPL as confined acoustic phonon modes: the breathing mode and its two radial harmonics. Other peaks can be assigned to LA and LO phonons of the CdSe core and LO phonons of both the CdS and ZnS shells.

We acknowledge financial support by the Deutsche Forschungsgemeinschaft via the SFB 508.

15 min. break

HL 43.6 Thu 15:30 EW 201

Ultrafast electro-optical spin control in charged quantum dot molecules — •Jose M. Villas-Boas[1], Sergio E. Ulloa[2], Jonathan J. Finley[1], and Gerhard Abstreiter[1] — [1]Walter Schottky Institut, Technische Universität München, Germany — [2]Department of Physics and Astronomy, Ohio University, Athens, USA.

In this work we model the dynamics of a semiconductor quantum dot (QD) molecule using a density matrix formalism and we show that it is possible to coherently manipulate its final state by applying a laser pulse with appropriate intensity, polarization and detuning. We focus our attention on the case where we have one electron loaded in the QD molecule, which can be achieved either using a gate voltage or doping. By applying a laser pulse with different frequencies we show that we can selectively induce Rabi oscillations between several possible state configurations, as for example trion (charged exciton) in one dot or an indirect trion (electron in one dot and exciton in the other). These changes are induced by the coherent coupling between dots and fully controlled by external electro-optical means. Our model takes into account possible sources of decoherence, which allow us to discuss the potential and limitations of using such system for quantum information processing. We will also discuss the possibility of using pulsed gate voltages to control the final state, where we can bring adiabatically the levels in resonance and transfer the electron (hole) population to the other dot. JVB is supported by the Alexander von Humboldt Foundation and QD-molecule research is supported by DFG via SFB631 and Nanosystems Initiative Munich (NIM).

HL 43.7 Thu 15:45 EW 201

Quantum Dot Superluminescent Light Emitting Diodes: Ideal Blackbody radiators? — •Martin Blazek[1], Wolfgang Elsässer[1], Mark Hopkinson[2], and Michel Krakowski[3] — [1]Institute of Applied Physics, Darmstadt University of Technology, Germany — [2]Dept. E&E.E, University of Sheffield, United Kingdom — [3]Alcatel Thales, III-V Lab, France

Quantum Dot (QD) Superluminescent Light Emitting Diodes (SLEDs) provide large optical bandwidths at desired wavelengths and are therefore promising devices for incoherent light application. The intensity noise behavior of QD SLEDs is of fundamental physical interest as it provides insight into the photon emission process. We performed high precision intensity noise measurements over several decades of optical output power. For low driving currents spontaneous emission leads to Shot Noise. For high currents we find Excess Noise behavior with Amplified Spontaneous Emission acting as the dominant source of noise. The QD SLEDs' noise can be described as blackbody radiation noise with a limited number of optical modes. It is therefore possible to identify the SLEDs' relevant intensity noise parameters.

HL 43.8 Thu 16:00 EW 201

Measuring the Correlated Photon Emission of Single Semiconductor Quantum Dots Using a Compact Femtosecond Fiber Laser — •Florian Sotier[1], Matthias Kahl[1], Tobias Hanke[1], Tim Thomay[1], Katja Beha[1], Suddhasatta Mahapatra[2], Alexander Frey[2], Karl Brunner[2], Alfred Leitenstorfer[1], and Rudolf Bratschitsch[1] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78464 Konstanz, Germany — [2]Experimental Physics III, University of Würzburg, D-97074 Würzburg, Germany

We report on time-resolved microphotoluminescence and photon correlation measurements of single epitaxially-grown self-assembled CdSe/ZnSe quantum dots. The structures are excited with a modelocked Er:fiber laser which is tunable between 500 nm and 700 nm. In contrast to previous works, which used ultraviolet light for excitation, we are able to resonantly pump low-lying excited states in individual quantum dots. We present time-resolved photoluminescence measurements on single dots revealing the spontaneous emission decay from the different finestructure split states. With a Hanbury-Brown and Twiss setup we are able to demonstrate photon antibunching of these nanoemitters. We will compare the time-resolved data with cw measurements of the photon statistics.

HL 43.9 Thu 16:15 EW 201

Time-resolved optical spectroscopy on epitaxially tailored quantum dots in the GaAs/AlGaAs material system — •Johanna Simon, Max Bichler, Jonathan Finley, and Gerhard Abstreiter — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany

We report on spatially resolved optical spectroscopy of coupled quantum dots (QD) grown by 2-fold cleaved edge overgrowth (2-CEO). 2-CEO QDs are formed at the intersection of two perpendicular quantum wires and typically have weak confinement energies in the range of 7-15 meV. 2-CEO allows precise control over dot shape and location, thus making it particularly suitable for fundamental studies on coupled QD systems with precisely defined structural properties and inter-dot coupling.

Using spatially resolved μ-photoluminescence (μPL) we clearly identify emission from coupled QDs in a sample containing 22 identical QDs in a chain, with an inter-dot spacing of 30 nm. Time-resolved spectroscopy is used to probe their spontaneous emission dynamics and reveals multi-exponential decay transients. Most surprisingly, the longer time constant extends beyond 10 ns, a finding that is attributed to carrier delocalization, where the electron wave function is distributed over several dots, while the hole remains localized due to its higher effective mass. Systematic studies of the spontaneous emission dynamics as a function of inter-dot separation and the number of QDs in the array will be presented. In addition, perspectives for electrically tunable coupled QD systems are discussed.

HL 44: Quantum dots and wires: preparation and characterization II

Time: Thursday 16:45–18:30 Location: EW 201

HL 44.1 Thu 16:45 EW 201

Investigation of MOVPE InN quantum dot growth by variation of temperature , V/III ratio and ammonia stabilisation flow — •Simon Ploch, Christian Meissner, Markus Pristovsek, and Michael Kneissl — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, EW6-1, D-10623 Berlin, Germany

Despite their unique electronic and optical properties very little attention has been devoted to the growth of InN- nanostructures. Because of its bandgap in the range of 0.7 eV InN is an interesting candidate for lasers and LED emitting in the infrared spectral range. So far most InN quantum dots are grown in MBE. To prevent the formation of metalic Indium, very high V/III ratios in the range of 300,000 were used in the InN growth. We present our growth studies of InN quantum dots on GaN investigated by in-situ spectroscopic ellipsometry. As allready shown, we were abel to realize 8-10 ML high 3D structures

with a mean hight of 1.7 nm, a mean diameter of 16.5 nm and a density of 2.1011 /cm* . The InN QDs were grown in a N2 atmosphere at 100 mbar, with a V/III ratio of 15,000, the time was 60s. By increasing the V/III ratio from 5,000 to 20,000 we observed a decrease of the growth rate, which can be explained by layer desorption due to reactive hydrogen from ammonia. It should be noted that we were able to obtain high cristaline quality InN QD at low V/III ratios in the range of 5,000 which corespondes with a short growth time compareable to InAs QD growth conditions. An ammonia stabilisation flow shows benefit effects on the InN quantum dot composition due

HL 44.2 Thu 17:00 EW 201

InN Nanocolumns - Electrical Properties and Site-Selective Growth — •Christian Denker, Friederich Limbach, Soenke Huels, Florian Werner, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

The possible applications of Indium Nitride semiconductor nanocolumns in novel optoelectronic and photovoltaic devices as well as the fundamental material properties are better assessed on single nano-objects. In addition, selective growth of nanocolumns in a regular array is pursued with the aim of reducing ensemble masking effects in the measurements and facilitating further processing.

In the past we fabricated self-organised InN nanowires with a length of up to 2 μm and an aspect ratio up to 1:40 by molecular beam epitaxy (MBE). Single nanocolumns are contacted by e-beam lithography for measurements in a 4-point configuration. The resulting U-I curves will be presented.

For catalyst-free selective nucleation of the nanocolumns patterning of the natively oxidized Si(111) substrate is needed. As the standard process of SiN or SiO masking has not yet been successfully used in the MBE of InN, a new technique was applied. We show that the nucleation of InN can be inhibited by depositing a thin carbon layer, e.g. through e-beam exposure in a scanning electron microscope. This method will be optimised to grow arrays of well separated InN nanocolumns.

This work was supported, within the EU FP6, by the ERANET project "NanoSci-ERA: NanoScience in the European Research Area"

HL 44.3 Thu 17:15 EW 201

Catalyst-free and catalyst-induced growth of GaN nanowires by molecular beam epitaxy — •Caroline Chèze[1], Lutz Geelhaar[1], Walter Weber[1], Henning Riechert[1], Philomela Komninou[2], Thomas Kehagias[2], and Theodoros Karakostas[2] — [1]Qimonda and NaMLaB, Dresden, Germany — [2]Aristotle University of Thessaloniki, Thessaloniki, Greece

GaN nanowires (NWs) were grown by molecular beam epitaxy with and without catalyst under very similar conditions, enabling a direct comparison of their growth mechanisms. The type of substrate determines whether a catalyst is necessary to induce the formation of NWs. On sapphire, NWs grow only when Ni seeds are deposited on the substrate before GaN-growth. Particles found at the NW-tips suggest that NWs form in a way similar to the vapour-liquid-solid mechanism. In contrast, on Si NWs form in a self-induced way without any catalyst. To elucidate the growth mechanisms, the incorporation rate of Ga was monitored in situ by line-of-sight quadrupole mass spectrometry. In all cases, growth starts with a reduced incorporation rate, i.e. nucleation is delayed. However, the growth rate saturates after different delays for the two different ways of NW-formation. At a growth temperature of 780°C, the nucleation phase is on Si at least five times longer than on sapphire (>3000 s vs. about 600 s). Thus, the external catalyst Ni strongly facilitates the formation of NWs. Based on these observations, we will discuss the possible growth mechanisms leading to the formation of NWs either by the catalyst-free (on Si) or by the catalyst-induced (on sapphire) approach.

HL 44.4 Thu 17:30 EW 201

Transmission Electron Microscopy investigation of self-organized InN nanocolumns — •Henning Schuhmann[1], Christian Denker[1], Tore Niermann[2], Jörg Malindretos[1], Angela Rizzi[1], and Michael Seibt[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Now at: Institut für Optik und Atomare Physik, Technische Universität Berlin, D-10623 Berlin, Germany

Semiconductor InN Nanocolumns have electronic properties which makes them a promising candidate for novel photovoltaic devices.

Molecular-beam epitaxy (MBE) grown InN on Si(111) forming self organized InN nanocolumns with diameters down to 20 nm and lengths of up to 2 μm. These structures have been investigated by using energy dispersive X-Ray (EDX) scanning transmission electron microscopy showing an oxygen-rich layer coating the InN nanocolumns. High-resolution TEM of the interface between the nanocolumns and the Si substrate indicates the existing of an amorphous interlayer. Conventional techniques have been applied for cross-section TEM specimen preparation, in addition a Dual Beam Focused Ion Beam (FIB) has been used to prepare cross-section and plan-view specimens. The latter allows us to study single nanocolumns along the rod axis projection. This work was supported, within the EU FP6, by the ERANET project "NanoSci-ERA: NanoScience in the Eropean Research Area"

HL 44.5 Thu 17:45 EW 201

Dependence of InGaN quantum dot formation on two-step growth parameters — •Christian Tessarek, Stephan Figge, Detlef Hommel, Joachim Kalden, Kathrin Sebald, and Jürgen Gutowski — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

InGaN is a potential candidate for the application in LED and lasers with emission in the blue-green spectral region. Compared to quantum wells (QWs) it is expected to have an improvement in the optical and electrical characteristics of a device by implementing InGaN quantum dots (QDs).
The overgrowth of Stranski-Krastanov-type QDs with a GaN-capping layer leads to the dissolution of the QD structures. Utilizing a two-step-growth-mode we succeeded to grow capped QDs. The first step in this growth is the deposition of a few monolayer thin $In_xGa_{1-x}N$ nucleation layer (NL) which is stabilized in a second step by growing a $In_yGa_{1-y}N$ formation layer (FL) with y<x. The resulting structure shows both QW as well as QD related luminescence as we proved by micro-photoluminescence (PL) measurements. To achieve sole QD luminescence the QW contribution has to be suppressed while not dissolving the QDs. For this reason we have investigated the effect of different gas fluxes during the growth of NL and FL on the QD and QW PL. Furthermore, we will present the impact of growth interruptions and growth temperatures on the PL-spectra. Finally, the growth on different AlGaN templates and the influence of strain is investigated.

HL 44.6 Thu 18:00 EW 201

Influence of growth time and NH_3 stabilisation flow on InN quantum dot formation by MOVPE — •S. Ploch[1], C. Meissner[1,2], M. Pristovsek[1], and M. Kneissl[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

Despite their unique electronic and optical properties very little attention has so far been devoted to the growth of InN quantum dots (QDs). In the present study we have investigated the metalorganic vapour phase epitaxy (MOVPE) of InN QDs on GaN/sapphire by in-situ spectroscopic ellipsometry. Three-dimensional nanostructures with a mean hight of 1.7 nm (corresponding to 6 monolayers of InN), a mean diameter of 16.5 nm and a density of $2{\cdot}10^{11}$ cm^{-2} have been realized. In this case the InN QDs were grown for 60 s at a total reactor pressure of 100 mbar and a V/III ratio of 15,000. By decreasing the V/III ratio from 20,000 to the relatively low value of 5,000 we observed an increase of the total growth rate, which can be explained by reduced layer desorption due to the reaction of InN with atomic hydrogen from the ammonia pyrolysis. It should be noted that we were able to obtain high crystalline quality InN QDs even at low V/III ratios around 5,000 using an ammonia stabilisation flow. These growth conditions and times between 5 s and 60 s are very similar to growth of InAs QDs.

HL 44.7 Thu 18:15 EW 201

Charge Sensing in Carbon Nanotube Double Quantum Dots — H. O. H. Churchill[1], •D. Marcos[2], F. Kuemmeth[1], S. K. Watson[1,3], and C. Marcus[1] — [1]Department of Physics. Harvard University. Cambridge 02138. Massachusetts, USA — [2]Departamento de Teoría de la Materia Condensada. Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco 28049. Madrid, Spain — [3]Department of Physics. Middlebury College. Middlebury 05753. Vermont, USA

Recent advances in fabrication techniques have made it possible tocreate tunable quantum dots on semiconducting nanowires and carbon nanotubes. In particular, double-dots formed on carbon nanotubes [1-3], are interesting candidates for the implementation of qubits based on their unique electronic structure as well as the weakness of nuclear

and spin-orbit coupling in the predominantly C12 host. Here we report measurements obtained from an integrated double dot and charge sensor [4,5] fabricated from a single carbon nanotube. The conductance through the single dot allows us to monitor the charge state of the double dot even if it is decoupled from the leads. We also demonstrate fast manipulation of the double dot using pulsed-gates techniques.

[1] M. J. Biercuk et al., Nano Letters 5, 1267 (2005).
[2] S. Sapmaz et al., Semiconductor science and technology, 21(11), S52 (2006).
[3] M. R. Graeber et al., Phys. Rev. B 74, 075427 (2006).
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The NSF-NIRT (EIA-0210736) and the Harvard Center for Nanoscale Systems are acknowledged.

HL 45: GaN devices

Time: Thursday 9:30–11:45 Location: EW 202

HL 45.1 Thu 9:30 EW 202

Dünnschicht-LEDs auf der Basis von InGaN/GaN MQW auf Si(111) — •Stephanie Fritze[1], Oliver Schulz[2], Annette Diez[1], Jürgen Bläsing[1], Lars Reissmann[1], Thomas Hempel[1], Armin Dadgar[1,2], Jürgen Christen[1] und Alois Krost[1,2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Deutschland — [2]AZZURRO Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg

Gegenüber den bereits etablierten GaN-basierten LEDs auf Saphir oder SiC bieten Strukturen auf Silizium einen deutlichen Preisvorteil. Da Silizium jedoch über 94% des generierten Lichts absorbiert, müssen für Anwendungen in der Beleuchtungstechnik solche LEDs als verlustarme Dünnschicht-LEDs hergestellt werden. Dazu wurde nach dem Verlöten der LED auf einen leitfähigen Träger das Substrat mittels Dünnen und nasschemischem Ätzen entfernt. Kontaktwiderstände verschiedener p-Kontakte wurden mittels Transmissions-Linien-Modell (TLM)-Strukturen bestimmt und verglichen. Die Reflektivität der p-Kontakte, die gleichzeitig als Reflektor dienen, wurde für verschiedene Metallisierungen untersucht. Für eine Maximierung der Effizienz wurden verschiedene LED-Designs bezüglich einer homogenen Ladungsträgerinjektion analysiert. Die Dünnschicht-LEDs werden konventionell prozessierten Bauelementen gegenübergestellt, die aus den selben Halbleiterstrukturen hergestellt wurden. Hierzu werden diese bezüglich ihrer Emissionseigenschaften optisch und elektrisch charakterisiert.

HL 45.2 Thu 9:45 EW 202

External field dependent spatial resolved PL spectroscopy on InGaN/GaN heterostructures — •Clemens Vierheilig[1], Harald Braun[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Nikolaus Gmeinwieser[2], Ansgar Laubsch[2], and Berthold Hahn[2] — [1]NWF II - Physik, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg — [2]Osram Opto Semiconductors, Leibnizstraße 4, 93055 Regensburg

The optical properties of InGaN based quantum well structures are strongly affected by internal electric fields and fluctuations of the indium content. By micro-photoluminescence of InGaN LEDs with applied bias and micro-electroluminescence we study the correlation between QW emission intensity and energy, both of which fluctuate on a micrometer length scale. Particularly interesting is the characteristic dependency of this energy-intensity correlation on the applied external electric field. For a spatially resolved measurement of the tunnel barrier we also measure the laser induced photocurrent under reverse bias. Purpose of this study is to separate QW composition or width fluctuation from fluctuations of the internal fields.

HL 45.3 Thu 10:00 EW 202

Semipolar {1$\bar{1}$01} GaInN quantum wells for green light emitting diodes — •Martin Feneberg[1], Thomas Wunderer[2], Frank Lipski[2], Peter Brückner[2], Ferdinand Scholz[2], Rolf Sauer[1], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm — [2]Institut für Optoelektronik, Universität Ulm

Semipolar GaInN/GaN light emitting devices are a heavily discussed topic in current research. These devices are supposed to help filling the so-called "green gap"of wavelengths between 500nm and 600nm where no efficient emitters exist.

Semipolar {1$\bar{1}$01} quantum wells were grown, processed and finally analyzed by electric-field-dependent photoluminescence and electroluminescence. From the PL emission energy as a function of the externally applied voltage which modifies the built-in polarization field we have determined the remaining polarization field. For this purpose, model calculations were carried out which self-consistently take full account of the tilted band structure, charge accumulation, fields in the depletion region and other relevant parameters. With these results we are able to calculate the internal quantum efficiencies of semipolar quantum wells. After carefully adjusting growth and process parameters while maintaining material quality we demonstrate first semipolar light emitting diodes operating at about 500nm.

HL 45.4 Thu 10:15 EW 202

Spectral Identification of Filaments in Broad Ridge 405 nm (Al,In)GaN Laser Diodes — •Harald Braun[1], Hans-Michael Solowan[1], Dominik Scholz[1], Tobias Meyer[1], Ulrich Theodor Schwarz[1], Stefanie Brüninghoff[2], Alfred Lell[2], and Uwe Strauss[2] — [1]NWF II - Physik, Universität Regensburg — [2]Osram Opto Semiconductors GmbH, Regensburg

In broad area (Al,In)GaN laser diodes (LDs) with ridge widths larger than a few micrometer the laser mode in the waveguide builds up filaments, which influence the far field of the LD. Employing temporal and spectral resolved scanning near-field optical microscopy (SNOM) on pulsed electrically driven LDs we analyse the lateral mode profile on a nanosecond to microsecond timescale. Furthermore we are able to resolve the single Fabry-Perot modes of the laser mode correlated to the lateral position in the ridge waveguide. Different filaments have slightly different effective refractive indices and thus show up as separate longitudinal mode combs. In this way we can reconstruct the optical mode in the waveguide as a superposition of filaments, identified by their spectral fingerprint. Different samples, grown on SiC and GaN substrates, respectively, were investigated. The measurements show similar results for all samples concerning the lateral mode profile, whereas the samples grown on GaN substrate exhibit a less chaotic behaviour in the temporal and spectral regime compared to the LDs grown on SiC substrate.

HL 45.5 Thu 10:30 EW 202

GaInN/GaN quantum well laser structures emitting in the blue-green spectral range — •Daniel Dräger[1], Uwe Rossow[1], Holger Jönen[1], David Schenk[2], Jean-Yves Duboz[2], and Andreas Hangleiter[1] — [1]Institute of Applied Physics, Technical University of Braunschweig, Germany — [2]CRHEA-CNRS, Valbonne, France

Presently, GaN-based laser diodes are limited to the violet-blue region of the spectrum. Our aim is to obtain laser emission in the blue-green spectral range. In order to study GaInN-based laser structures, low pressure MOVPE was used to grow such structures on a variety of substrates (freestanding GaN, GaN templates, and SiC). This allows investigations of the influence of the substrate related dislocation densities on gain, losses and carrier recombination. Our samples were investigated by optical gain spectroscopy using the variable stripe length method.

In order to reach wavelengths longer than 450 nm an increase of the indium concentration to more than 25 % is needed. Such high In content requires careful optimization of the growth conditions in order to avoid damaging of the quantum wells by thermal stress. Combining the results of the gain measurement with a theoretical calculation of the gain spectra we determine the threshold power, carrier density and the carrier recombination times of the sample. On bulk GaN substrates we find threshold power levels as low as 20 kW/cm^2. Up to now we obtain optical gain up to a peak wavelength of 465 nm with losses of about 30 cm^{-1}. Our next targets are a wavelength of 480 nm as well as a further reduction of the threshold power.

HL 45.6 Thu 10:45 EW 202

Characteristics of (Al,In,Ga)N multiple quantum well structures for blue-green laser diodes — •Veit Hoffmann[1], Arne

Knauer[1], Frank Brunner[1], Carsten Netzel[1], Markus Weyers[1], Günther Tränkle[1], Tim Kolbe[2], Jan Robert van Look[2], and Michael Kneissl[1,2] — [1]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

(Al,In,Ga)N based laser diodes (LD) emitting in the violet spectral region are already commercially available with excellent lifetimes and high efficiencies. In order to extend the emission wavelength of these devices towards the blue and green high quality InGaN quantum well structures have to be realized. However, multiple quantum well (MQW) structures with high indium content exhibit low efficiencies, due to the large piezoelectric fields (F_{PZ}) as well as the deterioration in crystal quality. We have investigated the growth of InGaN MQW structures emitting in the blue-green wavelength region with photoluminescence and high resolution X-Ray diffraction. In our studies we were able to determine F_{PZ} quantitatively and show how F_{PZ} is influenced by the barrier composition, e.g. by adding indium to the barriers and by partially doping the barriers with silicon. By increasing the growth temperature $_G$ during the barrier growth, we were able to improve the ratio of radiative to non-radiative recombination. Finally, we will discuss the effects of barrier composition and optimized growth conditions on light output and threshold current densities for LDs.

HL 45.7 Thu 11:00 EW 202

Temperature and current dependent electroluminescence measurements on colour-coded Multiple Quantum Well Light Emitting Diodes — •Werner Bergbauer[1,2], Ansgar Laubsch[1], Matthias Peter[1], Tobias Mayer[1], Stefan Bader[1], Günther Benstetter[2], Raimund Oberschmid[1], and Berthold Hahn[1] — [1]OSRAM Opto Semiconductors GmbH, 93055 Regensburg, Germany — [2]FH Deggendorf, 94469 Deggendorf, Germany

As the efficiency and the luminous flux have been increased enormously in the last few years, today Light Emitting Diodes (LEDs) are even pushed to applications like general lighting and Home Cinema Projection. Still, InGaN / GaN heterostructure based LEDs suffer from loss-mechanisms like non-radiative defect and Auger recombination, carrier leakage and piezo-field induced carrier separation. To optimize the high current efficiency we evaluated the benefit of Multiple Quantum Well (MQW) compared to Single Quantum Well (SQW) LEDs. Temperature dependent electroluminescence of colour-coded structures with different Indium content in certain Quantum Wells was measured. The experiments demonstrated a strong temperature and current dependence of the MQW operation. The comparison between different LED structures showed effectively the increased LED performance of those structures which operate with a well adjusted MQW active area. Due to the enhanced carrier distribution in the high current range, these LEDs show a higher light output and additionally a reduced wavelength shift.

HL 45.8 Thu 11:15 EW 202

Effect of the barrier composition on the efficiency and emission spectra of GaN-based near ultraviolet light emitting diodes — •T. Kolbe[1], A. Knauer[2], V. Küller[2], S. Einfeldt[2], J. R. van Look[1], 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

Light Emitting Diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. Carrier confinement, piezoelectric fields and a low external quantum efficencies are particularly problematic for ultraviolet LEDs.
Here we present continuous wave and pulsed electroluminescense measurements of GaN-based multi quantum well LEDs with different barrier compositions. These devices were grown by metalorganic vapour phase epitaxy on (0001) sapphire substrates. The emission wavelength is approximately 375nm for an active region comprised of $In_{0.03}Ga_{0.97}N$ quantum wells (QWs) and surrounded by GaN, $Al_{0.16}Ga_{0.84}N$ or $In_xAl_{0.16}GaN$ barrier layers. We found that the blue-shift of the emission wavelength related to the piezoelectric field in the QWs and the resulting quantum confined Stark effect (QCSE) clearly depends on the barrier composition and is zero for samples with lattice matched $In_{0.04}Al_{0.16}Ga_{0.80}N$ barrier. An InAlGaN barrier with 3.3% indium resulted in a 50-fold increase of output power compared to LEDs with GaN barriers.

HL 45.9 Thu 11:30 EW 202

Enabling factors for the improvement of nitride-based LED efficiency — •Ansgar Laubsch[1], Werner Bergbauer[1], Matthias Sabathil[1], Matthias Peter[1], Tobias Meyer[1], Georg Brüderl[1], Joachim Wagner[2], Norbert Linder[1], Klaus Streubel[1], Raimund Oberschmid[1], and Berthold Hahn[1] — [1]OSRAM Opto Semiconductors GmbH, Regensburg, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Freiburg, Germany

Recent progress in the epitaxial growth of LEDs with InGaN/GaN quantum-well heterostructures has led to a significant enhancement of output power. In this talk, we will discuss the mechanisms limiting the devices' internal efficiency and identify enabling factors for further improvements. We compare samples with different Indium content as well as different design of the active layer.

Although heteroepitaxial growth of GaN on sapphire generates high defect densities, non-radiative defect-related Shockley-Read-Hall recombination does not seem to substantially limit the efficiency of standard InGaN/GaN LED structures. We rather discuss a supplemental Auger-like non-radiative path for carrier recombination that becomes dominant at quantum-well carrier densities typical for LED operation. Additionally, the piezo-field induced reduced overlap of electron and hole wavefunction in standard c-plane grown InGaN quantum wells reduces the radiative recombination rate.

HL 46: Transport in high magnetic field/quantum-Hall-effect

Time: Thursday 11:45–12:45 Location: EW 202

HL 46.1 Thu 11:45 EW 202

The role of the electric Hall field in the QHE — •Tobias Kramer — Institut I: Theoretische Physik, Universität Regensburg, Germany

I present a model of the quantum Hall effect, which incorporates the electric Hall field non-pertubatively. The presence of crossed electric and magnetic fields causes a quantization of the electronic drift current and leads to a non-linear transport theory, which explains the breakdown of the QHE at high currents.

For low temperatures (or high currents), the electric field splits higher Landau levels into non-integer sublevels. The appearance of the substructure and the non-integer plateaus in the resistivity is NOT linked to electron-electron interactions, but caused by the presence of a (linear) electric field. Some of the resulting fractions correspond exactly to half-integer plateaus.

References:

T. Kramer A heuristic quantum theory of the integer quantum Hall effect International Journal of Modern Physics B, 20, 1243-1260 (2006) http://arxiv.org/abs/cond-mat/0509451

HL 46.2 Thu 12:00 EW 202

quantum hall ferromagnetism in graphene: SU(4) bosonization approach — •ricardo doretto[1,2] and cristiane morais smith[2] — [1]Institut feur Theoretische Physik, Universitaet zu Koeln, Koeln, Germany — [2]Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands

We study the quantum Hall effect in graphene at filling factors $\nu = 0$ and $\nu = \pm 1$, concentrating on the quantum Hall ferromagnetic regime, within a non-perturbative bosonization formalism. We start by developing a bosonization scheme for electrons with two discrete degrees of freedom (spin-1/2 and pseudospin-1/2) restricted to the lowest Landau level. Three distinct phases are considered, namely, the spin-pseudospin, spin, and pseudospin phases. The first corresponds to a quarter-filled ($\nu = -1$) while the others to a half-filled ($\nu = 0$) lowest Landau level. In each case, we show that the elementary neutral excitations can be treated approximately as a set of n-independent kinds of boson excitations. We then apply the formalism to an effective continuous model proposed by Alicea and Fisher. For each quantum Hall state, an effective interacting boson model is derived and the disper-

sion relations of the elementary excitations are analytically calculated. We propose that the charged excitations (skyrmions) can be described as a coherent state of bosons. We calculate the semiclassical limit of the boson model derived from the SU(4) invariant part of the original fermionic model and show that it agrees with the results of Arovas et-al. for SU(N) quantum Hall skyrmions. We briefly discuss the influence of the SU(4) symmetry breaking terms in the skyrmion energy.

HL 46.3 Thu 12:15 EW 202

Fibre optical interferometer for analysis of microelectromechanicalsystems — •Tjark Windisch, Martin Borowski, Marc A. Wilde, and Dirk Grundler — Physik Department E10, Technische UniversitätMünchen, James-Franck-Strase 1, D-85748 Garching

We realize a system for measurements on microelectromechanicalsystems (MEMS) based on a fibre optical interferometer. Our system is designed for low-temperature($<$ 300 mK) and high-field ($>$ 15 T) measurements and includes a piezoelectrical positioning system (x, y, z and θ) with spatial resolution up to 200 nm. To minimize the external mechanical noise the system is embedded in an active piezoelectric vibration isolation system. The positioning system allows us to position in situ the fibre in relation to the micron sized samples. The goniometer enables us to adjust the tiltangle between the fibre and the sample which reduces the scattering losses and thus increases the signal-to-noise ratio.

By this, we can detect the static deflection of a MEMS device with spatial resolution up to 200 nm as well as detect the shift in the eigenfrequencies. The system is in particular designed to perform de Haas-van Alphen-effect measurements on miniaturized cantilever magnetometers (MCMs). First results are shown.

We thank Jan-Ivo Springborn and Niels Ruhe for technical assistance and the German Excellence Initiative for financial support via "Nanosystems Initiative Munich (NIM)".

HL 46.4 Thu 12:30 EW 202

Topological Hall Effect studied in simple models — •Georgo Metalidis[1] and Patrick Bruno[2] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe, D-76128 Karlsruhe — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

Recently, a contribution to the Hall effect in ferromagnets has been found that is induced by the Berry phase, and does not involve a magnetic flux nor spin-orbit coupling. We have investigated this effect in a two-dimensional electron gas subject to a simple magnetic texture. Both the adiabatic regime, where the electron spin follows the magnetic texture exactly, and its nonadiabatic counterpart are studied, including the effect of disorder. In doing so, an ongoing discussion about the correct adiabaticity criterion in the diffusive limit is clarified.

HL 47: GaN: preparation and characterization I

Time: Thursday 14:00–17:30 Location: EW 202

HL 47.1 Thu 14:00 EW 202

Wachstum verspannungskompensierter AlGaN/GaN-Bragg-Spiegel mittels MOVPE — •Heiko Dartsch, Stephan Figge, Timo Aschenbrenner und Detlef Hommel — IFP, Universität Bremen, Otto-Hahn-Allee, 28359 Bremen

Zur Herstellung oberflächenemittierender Laserdioden (VCSEL) ist der Einsatz von hochreflektierenden Bragg-Spiegeln (DBRs) nötig. Für auf Galliumnitrid basierende Bauelemente bietet sich die Verwendung von Aluminium zur Herstellung der Niederindexschichten an. Dabei sind grundsätzlich zwei Vorgehensweisen denkbar: Zum einen in Form einer ternären AlGaN-Verbindung und zum anderen die Verwendung eines Übergitters bestehend aus binärem AlN und GaN.

Beide Ansätze wurden mittels metallorganischer Dampfphasenepitaxie (MOVPE) verfolgt. Einen entscheidenden Einfluß auf die Qualität der hergestellten Spiegel hat die Gitterfehlanpassung zwischen den Hoch- und Niederindexschichten, welche bei höheren Aluminiumgehalten zur Relaxation der Schichten führen kann. So weisen auf GaN-Templates gewachsene Strukturen mit ternärem Niederindexmaterial mit einer Aluminiumkonzentration von 20% bereits in hohem Maße Rissbildung auf. Durch die Verwendung einer Pufferschicht mit einem Aluminiumgehalt von 20% gelingt es hingegen vollverspannte DBR-Strukturen herzustellen, deren Niederindexmaterial 40% Aluminium enthält. Mit diesem Ansatz sind Spiegel mit Reflektivitäten von über 90% im Wellenlängenbereich um 500 nm realisiert worden. Auf der gleichen Grundlage ließen sich zudem dazu qualitativ vergleichbare DBRs mit binärer Übergitterstruktur als Niederindexschicht herstellen.

HL 47.2 Thu 14:15 EW 202

Defect structure in m-plane GaN grown on $LiAlO_2$ using metalorganic and hydride vapour phase epitaxy — •Tim Wernicke[1], Anna Mogliatenko[3], Carsten Netzel[1], Eberhard Richter[1], Arne Knauer[1], Frank Brunner[1], Markus Weyers[1], Wolfgang Neumann[3], and Michael Kneissl[1,2] — [1]FBH Berlin, Germany — [2]Institute of Solid State Physics, TU Berlin, Germany — [3]AG Kristallographie, Institut für Physik, HU Berlin, Germany

The FWHM of symmetric $(10\bar{1}0)$ XRD rocking curves of m-plane GaN grown on $LiAlO_2$ is anisotropic. By investigating the microstructure with transmission electron microscopy (TEM) we identifid basal plane stacking faults (BSF) and stacking mismatch boundaries (SMB) in the GaN layers. BSFs are aligned in-plane along the a-direction and therefore cause an anisotropic broadening of the $\mathrm{FWHM}_{(10\bar{1}0)}$ with incidence along [0001]. SMBs have no preferential direction and hence result in an isotropic broadening of the $\mathrm{FWHM}_{(10\bar{1}0)}$. We observed that this anisotropy can be reduced by lowering the MOVPE growth temperature. We propose that the lowering of the growth temperature leads to a reduction of BSFs which is accompanied by an increase in SMBs. The MOVPE grown layers were used as templates for the growth of 200 μm thick m-plane GaN layers by HVPE. During HVPE growth the $LiAlO_2$ substrate thermally decomposed and peeled off after cool-down. On the surface a network of cracks not being aligned to crystallographic directions was found. The layers were not transparent probably due to metallic Ga inclusions and exhibited an asymmetric bow according to the lattice anisotropy of the (100) $LiAlO_2$ surface.

HL 47.3 Thu 14:30 EW 202

Bestimmung der temperaturabhängigen thermischen Ausdehnungskoeffizienten von AlN — •Hanno Kröncke[1], Stephan Figge[1], Boris M. Epelbaum[2] und Detlef Hommel[1] — [1]Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen — [2]Institut für Materialwissenschaften 6, Universität Erlangen, Martensstr. 7, 91058 Erlangen

Auf Grund der großen Bandlücke von 6,2 eV, der Härte und der Temperaturstabilität ist Aluminiumnitrid (AlN) von großem Interesse für optische Anwendungen bis in den UV-Bereich und für Hochleistungselektronik. Die Verwendung für heteroepitaktische Bauelemente scheitert bisher jedoch an der Verfügbarkeit hochqualitativer Substrate. Für eine künftige Anwendung sind daher Verspannungen und thermische Ausdehnung der Materialien von hohem Interesse.

Untersucht wurden in dieser Studie durch PVT (physical vapor transport) auf einem Substrat und auch freistehend gewachsene AlN Kristalle mittels hochauflösender Röntgendiffraktometrie. Für das Volumenmaterial wurden die c- und a- Gitterkonstanten über einen Temperaturbereich von 20 bis 1200 K vermessen. Aus diesen wurden die anisotropen, temperaturabhängigen, thermischen Ausdehnungskoeffizienten bestimmt, die aus früheren Untersuchungen nur richtungsunabhängig bekannt waren. Die Daten wurden mit Hilfe von Debye- und Einsteinmodellen angepasst und mit Werten aus anderen Verfahren verglichen. Weiterhin wurden die auf Substrat mit den freistehend gewachsenen Proben hinsichtlich Mosaizität und Korngröße verglichen.

HL 47.4 Thu 14:45 EW 202

Einfluss einer SiN-Maske auf die Qualität von a-plane GaN auf r-plane Saphir — •M. Wieneke, A. Dadgar, J. Bläsing, H. Witte, A. Krtschil, T. Hempel, P. Veit, J. Christen und A. Krost — Otto-von-Guericke-Universität Magdeburg, Postfach 4120, 39016 Magdeburg

In einer Probenserie wurde unter Variation der Abscheidedauer einer SiN-Zwischenschicht deren Einfluss auf die Beschaffenheit von a-plane GaN-Schichten untersucht, die mittels metallorganischer Gasphasenepitaxie auf r-plane Saphir gewachsen wurden. Bei längeren Beschichtungsdauern zeigen Lichtmikroskop-Aufnahmen eine deutliche Zunahme der Pit-Dichte, während die Charakterisierung der Pro-

ben mittels Röntgenbeugung eine Reduktion der ω-Halbwertsbreiten der GaN(11-20), -(10-10) und -(0002)-Reflexe jeweils von 0.25°, 0.50° und 0.40° auf 0.15°, 0.30° und 0.20° ergab. Mittels Transmissionselektronenmikroskopie konnten lokale Reduktionen der Halbversetzungen und Stapelfehler gezeigt werden. C-V-Messungen ergeben eine Netto-Störstellenkonzentration von (2-3)*10^{15} cm^{-3} auf der Oberfläche, während Halleffektmessungen Ladungsträgerkonzentrationen im Bereich von 10^{17} - 10^{18} cm^{-3} zeigen. Dies deutet auf die Auflösung der SiN-Masken und die damit verbundene Si-Dotierung an der Grenzfläche zum Substrat hin. Temperaturabhängige Halleffektmessungen weisen zwei thermische Aktivierungsenergien des Hallkoeffizienten in den Bereichen von 15-26 meV bei tiefen Temperaturen und 42-60 meV bei hohen Temperaturen auf, was auf die Dotierung mit Si und auf Stickstoffvakanzen zurückgeführt wird.

HL 47.5 Thu 15:00 EW 202

InGaN Pyramids: Towards positioned quantum dots — •Clemens Wächter, Michael Jetter, Gareth Beirne, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany

InGaN quantum dots (QDs) are of high interest for quantum optics due to their large exciton binding energies, even more if the quantity of the QDs is controllable and the position is well known. This can be achieved for example by growing QDs on prepatterned substrates. In the nitride material system this prepattering can be reached by selective epitaxy of hexagonal pyramids on a SiO_2-masked GaN-template. The InGaN material is then deposited on these substrates, forming low dimensional structures on these pyramids. However, the research regarding these structures is still in progress. In this talk the recent efforts and results will be presented. Samples were prepared with varying InGaN growth temperature, growth pressure, cap structures and pyramid sizes. These samples were characterized using optical microscopy, scanning electron microscopy, time resolved (micro-)photoluminescense spectroscopy and cathodoluminescense spectroscopy. Using all these informations the current status and future developments will be presented.

HL 47.6 Thu 15:15 EW 202

Optical and magnetic properties of different Mn centers in GaMnN — •Enno Malguth, Axel Hoffmann, and Wolfgang Gehlhoff — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

The potential realization of a ferromagnetic spin-coupling in dilute magnetic semiconductors requires a wide band gap material doped with magnetic ions and with a high concentration of free carriers. Against this background, optical and magnetic experiments were performed on GaMnN samples co-doped with Mg and Si. We observed Mn in the charge states 2+, 3+ and 4+. In detail, we studied the stability of these charge states as a function of the concentration of Mn and of p- or n- co-doping. Our observations can be explained coherently by a shift of the Fermi level. A number of different Mn^{4+} centers were observed in photo luminescence spectra. We give a tentative identification of Mn^{4+} related complexes on the basis of temperature, excitation and magnetic field dependent measurements as well as electron spin resonance. Excitation mechanisms of Mn^{4+} were investigated by means of photo luminescence excitation spectroscopy indicating that the internal excitation of Mn^{3+} may be part of an efficient excitation process.

HL 47.7 Thu 15:30 EW 202

Herstellung und Implantation von ^{172}Lu(^{172}Yb) in GaN und Messung bei tiefen Temperaturen — •Riccardo Valentini und Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik, Nußallee 14-16, 53115 Bonn

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 Herstellung des Mutterisotops ^{172}Lu erfolgt durch Bestrahlung einer Thulium-Folie mit ^{4}He, ^{169}Tm(α,n)^{172}Lu, am Bonner Isochron-Zyklotron und die Implantation in GaN am Bonner Isotopenseparator, d.h. Herstellung und Implantation finden vor Ort statt.

Es soll die Temperaturabhängigkeit der Hyperfeinfelder für ^{172}Lu(^{172}Yb) in GaN untersucht werden. Wir führen Messungen bei tiefen Temperaturen zwischen 75 K und 295 K in einem Displex durch. Zu erwarten ist generell eine Zunahme der Wechselwirkungsfrequenz. Der Verlauf bei Temperaturen um 100 K konnte bisher noch nicht eindeutig geklärt werden. Die Messungen werden auf einer PAC-Anlage durchgeführt, die das Material LSO als Szintillator benutzt. Dadurch kann eine bessere Energieauflösung, eine höhere Anisotropie und eine kürzere Messzeit als mit anderen Szintillatormaterialien erzielt werden.

15 min. break

HL 47.8 Thu 16:00 EW 202

Recombination dynamics in coalesced a-plane GaN ELO structures investigated by high spatially and ps-time-resolved cathodoluminescence microscopy — •B. Bastek[1], F. Bertram[1], J. Christen[1], T. Wernicke[2], M. Weyers[2], and M. Kneissl[3] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin — [3]Institute of Solid State Physics, Technical University Berlin

The characteristic epitaxial lateral overgrowth (ELO) domains of fully coalesced a-plane GaN layers were directly imaged by highly spatially and spectrally resolved cathodoluminescence microscopy (CL) at 5 K. The patterned layers were grown by MOVPE on r-plane sapphire substrate and stripe masks oriented in the [01$\bar{1}$0] direction. In the area of coherent growth (I) the broad basal plane stacking fault (BSF) emission centered at 3.41 eV dominates the spectra. Also in the region (II) of coalescence the BSF luminescence dominates, however, the intensity increases by one order of magnitude compared to area (I). In complete contrast, in the stripes associated with the laterally grown domains (III) in [0001] direction, exclusively an intense and sharp (D^0,X) emission at 3.475 eV is observed. ps-time-resolved CL of the free excitons (FX) recorded from this domains (III) decays bi-exponentially. The initial lifetime of 180 ps is primarily given by the capture of FX by impurities to form bound excitons (BE). With rising temperature this capture time constant decreases as $T^{-1/4}$ and reaches a minimum of 104 ps at T = 60 K. Above 60 K, i.e. when FX starts to dominate the BEs, the lifetime increases rapidly to a value of 240 ps for 300 K.

HL 47.9 Thu 16:15 EW 202

Influence of strain on the growth of thick InGaN layers — •J. Stellmach, M. Leyer, M. Pristovsek, and M. Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

The growth of high quality InGaN alloys is critical for a number of various optoelectronic device applications like LEDs and laser diodes. Nevertheless, the exact growth mechanisms of InGaN with high indium content is still not fully understood.

In the present study the growth of thick InGaN layers was systematically investigated. InGaN films with thicknesses between ∼35 nm and ∼200 nm were grown on GaN templates with metal-organic vapour phase epitaxy (MOVPE). The group III partial pressures of 1.1 Pa for TMGa, 0.45 Pa for TMIn and the V/III-ratio of 1600 were kept constant. The growth temperature was varied between 750 °C and 800 °C. The growth of InGaN layer was characterized by in-situ spectroscopic ellipsometry (SE). Up to temperatures of 790 °C structural analysis by XRD showed two strained layers with different indium content. The formation of the layer structure was investigated by varying the growth times at 770 °C. In the first 500 s (35 nm) a rough (rms=9 nm) and pseudomorphically strained InGaN layer with low indium content (4 %) is formed. Between 500 s and 1000 s this strained layer becomes smoother (rms=3.4 nm). For thicknesses beyond the In content increases (8 % at 84 nm) and reaches 11 % at 200 nm. We propose that the transition from a first layer with a low indium content to a second layer with an higer indium content is due to a gradual release of strain.

HL 47.10 Thu 16:30 EW 202

Spatially and spectrally resolved cathodoluminescence of hexagonal GaN pyramids covered by InGaN single quantum wells — •S. Metzner[1], B. Bastek[1], F. Bertram[1], T. Hempel[1], J. Christen[1], M. Jetter[2], T. Tsifotidis[2], and P. Michler[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Institut fuer Halbleiteroptik und Funktionelle Grenzflaechen, Stuttgart University, Germany

Masking with polystyrene micro spheres, self organized hexagonal GaN pyramids terminated by the six {1$\bar{1}$01} facets were selectively grown by metal-organic vapor phase epitaxy. An InGaN single quantum well (SQW) capped with a GaN layer was deposited on top. The spatially averaged cathodoluminescence (CL) spectrum shows an intense (D^0,X) line from GaN and a broad emission band between 2.0 - 2.6 eV origi-

nating from the InGaN SQW. The CL from the masked area reveals a blue-shifted (D^0,X) GaN emission at 3.4925 eV (FWHM = 5.8 meV) corresponding to a compressive stress of 0.8 GPa. In contrast, the (D^0,X) GaN emission of the pyramid facets is more intense, broadened, and red-shifted with respect to fully relaxed GaN. This red-shift decreases from base (3.4398 eV) to top of the pyramids by about 20 meV, indicating strain relaxation and strong local impurity incorporation at the slower growing facets. The InGaN luminescence exclusively emitted on the pyramids shows a monotonous blue-shift of about 100 meV from base (2.3542 eV) to top of the facets. Smaller SQW thickness and/or lower In content can explain the observed blue-shift towards the tip. The impact of polarization fields further enhances this effect.

HL 47.11 Thu 16:45 EW 202

MOVPE of m-plane InGaN/GaN buffer and LED structures on $LiAlO_2$ — Hannes Behmenburg[1], Tzu-Chi Wen[2], Yilmaz Dikme[1], Christof Mauder[2], Lars Khoshroo[2], Mitch Chou[3], Mikalai Rzheutskii[4], Evgenii Lutsenko[4], Gennadii Yablonskii[4], Joachim Woitok[5], Holger Kalisch[2], Rolf Jansen[2], and •Michael Heuken[1,2] — [1]AIXTRON AG, Aachen, Germany — [2]Electrom. Theory, RWTH Aachen, Germany — [3]Mat. Sci. & Opto-Elect. Eng., Sun Yat-Sen Univ., Taiwan — [4]Inst. of Phys., NASB, Minsk, Belarus — [5]PANalytical B.V., Almelo, The Netherlands

M-plane GaN growth on $LiAlO_2$(100) is one possibility to deposit non-polar material and leads to a more efficient recombination in MQW structure. A short in-situ nitridation in a nitrogen/ammonia atmosphere as the first step is essential for the deposition of GaN in the m-plane mode. The surface was sealed with a thin Mg-doped InGaN layer. A 220 nm thick GaN:Mg and a 500 nm thick GaN layer to protect the sensitive substrate grown under H2 atmosphere complete the investigated buffer. In 2Theta/Omega scans only m-plane GaN was detected, and rocking curves of the symmetric (1-100) reflex revealed an improvement in quality with increasing thickness of the InGaN:Mg layer up to 100 nm. Above this critical thickness, the line width deteriorated. The same trend was observed by AFM measurements which showed a minimum surface roughness of 11.4 nm root mean square. Blue InGaN LED structures on such buffers showed photoluminescence wavelengths which were independent of excitation intensity and exhibited a high degree of polarization.

HL 47.12 Thu 17:00 EW 202

Cathodoluminescence Microscopy of GaN Nanopyramids grown on Si(111) — •F. Bertram[1], S. Metzner[1], J. Christen[1], H. Tang[2], J. Lapointe[2], and J.A. Bardwell[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]nstitute for Microstructural Sciences, National Research Council Canada, Ottawa, Canada

A 10 nm thick AlN buffer MBE grown on Si(111) was patterned into an array of hexagonal pads with openings from 0.5 to 1.5 um. The subsequent GaN overgrowth was carried out in both, the vertical and the lateral direction forming distinct GaN nanopyramids terminated by {10-12} side facets. The GaN pyramids were covered with an InGaN quantum well for the purpose to form an InGaN quantum dot at the very top. A lateral pyramid size of about 1 um and a height of about 800 nm is obtained independent from the mask size. The spatially integrated cathodoluminescence (CL) spectrum of a single pyramid at 5 K exhibits multiple sharp emission lines over a wide spectral range from 357 to 500nm. No CL emission was observed outside the pyramids. Intensity mappings across the pyramids show clear 6 fold symmetry. The intensity drops significantly at the edges of the pyramid. The top region of the pyramids exhibit a bright hexagonally shaped contrast dominated by GaN emission. On the contrary, the InGaN luminescence is very intense at the base of the pyramids. The InGaN intensity decreases and the emission blue-shifts from 405 to 375nm, from the base to the top of the pyramid.

HL 47.13 Thu 17:15 EW 202

Thermodynamics and adatom kinetics of non-polar GaN surfaces. — •Liverios Lymperakis and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Max-Planck-Strasse 1, 40237, Düsseldorf, Germany

III-Nitride based nanowires have recently attracted considerable interest due to their potential applications for novel nano-optoelectronic devices. The shape and size of the nanostructure as well as the quality of the grown material depends strongly on the atomistic mechanisms taking place on the facets of the nanowires during growth. GaN nanowires usually grow having the c-axis as axial direction while the side facets are expected to exhibit non-polar surfaces. While extensive and detailed theoretical studies on the thermodynamics and kinetics of the polar c-plane GaN surfaces exist, a detailed analysis which will combine thermodynamics and kinetics of the non-polar α- and m-plane surfaces is still lacking. We have therefore performed planewave pseudopotential calculations within the density functional theory in order to study the thermodynamics and the adatom kinetics on α- and m-plane GaN surfaces. The mapping of the potential energy surface for the Ga adatoms (minority species for N rich growth) reveals a strong anisotropy for the diffusion barriers for both a- and m-plane surfaces. For N adatoms (minority species for Ga rich growth) our results show a subsurface diffusion channel which becomes activated already at low growth temperatures. Based on these results we have been able to explain recent experimental observations on the growth anisotropy of GaN non-polar surfaces as well as on the growth of GaN nanowires.

HL 48: ZnO: Preparation and characterization II

Time: Thursday 9:30–10:30 Location: ER 164

HL 48.1 Thu 9:30 ER 164

Characterization of Mn doped ZnO Nanopowder — •Eva Schlenker[1], Andrey Bakin[1], Herbert Schmid[2], Werner Mader[2], Heiko Bremers[3], Andreas Hangleiter[3], Mohamed Al-Suleiman[1], Hergo-Heinrich Wehmann[1], and Andreas Waag[1] — [1]Institute of Semiconductor Technology, TU Braunschweig, 38106 Braunschweig — [2]Institute for Inorganic Chemistry, University of Bonn, 53117 Bonn — [3]Institute of Applied Physics , TU Braunschweig, 38106 Braunschweig

In the quest of materials for spintronic applications, diluted magnetic semiconductors recently attracted much attention. The main challenge is finding a ferromagnetic material with Curie temperature Tc > 300 K whose magnetic properties can be controlled electrically. The interest was particularly focused on Zn(TM)O since theoretical calculations predict that ZnO containing Mn could exhibit ferromagnetism with Tc above room temperature. In the present study, the structural and magnetic properties of Mn doped ZnO nanopowder are investigated and compared to undoped ZnO crystals. Doping of ZnO with Mn results in increased lattice constants as revealed by XRD. However, an inhomogeneous distribution of the Mn dopants within the nanopowder was revealed by energy-dispersive X-ray and electron energy-loss spectroscopy. Magnetic properties are investigated by means of SQUID measurements on aggregates of powder particles as well as by MFM to study the behavior of single grains. The MFM image differs significantly from the topography as imaged by AFM and suggests the existence of long-ranging magnetic signals emerging from the sample.

HL 48.2 Thu 9:45 ER 164

As-Dotierung von homoepitaktisch abgeschiedenen ZnO-Schichten — •Sören Heinze, Andre Krtschil, Jürgen Bläsing, Hartmut Witte, Armin Dadgar, Frank Bertram, Peter Veit, Jürgen Christen und Alois Krost — Otto-von-Guericke-Universität Magdeburg, Fakultät für Naturwissenschaften, Institut für Experimentelle Physik

Zahlreiche Arbeitsgruppen konnten mittlerweile Erfolge bei der Homoepitaxie von ZnO auf thermisch vorbehandelten Substraten erzielen. Uns gelang dabei erstmals die homoepitaktische Abscheidung in einem 2-dimensionalen Wachstumsmodus, wie in Referenz [1] berichtet. Die Schichten zeigen dabei nicht nur exzellente morphologische sondern auch ausgezeichnete Lumineszenzeigenschaften hinsichtlich Homogenität der Wellenlänge und Intensität des emittierten Lichts, was an Hand von Kathodolumineszenzuntersuchngen gezeigt wurde. Desweiteren wurde mittels TEM-Untersuchungen die mikroskopische Ursache der Oszillationen in θ-2θ-XRD-Messungen welche von verschiedenen Autoren (z.B. in Referenz [2]) berichtet wurden aufgeklärt. Außerdem werden erste Ergebnisse zur As-Dotierung homoepitaktisch gewachsener Schichten präsentiert.

[1] S. Heinze et al. "Homoepitaxial growth of ZnO by metalorganic vapor phase epitaxy in two-dimensional growth mode", Journal of Crystal Growth 308, 170 (2007)

[2] D.J. Rogers et al. "ZnO homoepitaxy on the O polar face of hydrothermal and melt-grown substrates by pulsed laser deposition", Appl. Phys. A 88, (2007)

HL 48.3 Thu 10:00 ER 164

DFT/DFTB simulations of ZnO in bulk, surfaces, and nanostructures — •Christian Fisker — Dept. of Physics and Nanotechnology, Aalborg University, Denmark

As a large band gap semiconductor with the ability to form many different nanostructures, ZnO has gained a lot of interest in the scientific community. Numerical modelling using Density Functional Theory (DFT) has proven more difficult, as the complexity of the Zn d-orbitals greatly limits the size of the modelled system. A much more scalable treatment can be attained using Density Functional based Tight Binding (DFTB).

DFTB parameters for zinc oxide are presented in a manner that both the band gap and crystal structure of bulk ZnO are well reproduced. Surface geometry optimisations are tested against DFT calculations with good results, and the model is applied to calculating geometries and electronic properties of larger systems including nanowires.

HL 48.4 Thu 10:15 ER 164

ZnO:Mn^x valence configuration from the perspective of density functional theory — •Marc Andy Gluba and N. H. Nickel — Hahn-Meitner-Institut Berlin GmbH, Abt. Silizium Photovoltaik (SE1), Kekuléstraße 5, D-12489 Berlin, Germany

Zinc oxide (ZnO) doped with transition metal (TM) ions has attracted considerable interest because of its potential application as a base-material for spintronic devices. According to theoretical predictions by Dietl *et al.* manganese doped into ZnO should preserve its ferromagnetic order up to room temperature[1]. However, the experimental realization of dilute ferromagnetic ZnO is still challenging.

It is widely accepted that TM ions, when incorporated into the ZnO lattice, are isovalent with the zinc ions they substitute for. Thus, Mn in ZnO is commonly present in the divalent charge state for perceptibly high concentrations above 10^{19}cm^{-3}. However, recent electron paramagnetic resonance (EPR) experiments on ZnO with Mn traces of concentrations as low as 10^{14}cm^{-3} suggest that the Mn charge state can deviate from the divalent configuration[2]. In order to elucidate stable valence configurations of Mn and their respective transition levels bandstructure calculations have been performed in the framework of density functional theory (DFT). The impact of additional on-site coulomb interaction within the local spin density approach (LSDA+U) will be discussed.

[1] T. Dietl *et al.*, Science **287**, 1019 (2000)

[2] M. A. Gluba *et al.*, Superlattices and Microstructures (*in press*)

HL 49: ZnO: Optical properties

Time: Thursday 10:45–13:00 Location: ER 164

HL 49.1 Thu 10:45 ER 164

Lasing modes in ZnO microwires — •Christian Czekalla, Jörg Lenzner, Rüdiger Schmidt-Grund, Bingqjang Cao, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

We report lasing from single hexagonally shaped ZnO microwires detected using spatially resolved photoluminescence spectroscopy (PL) under high excitation conditions. The structures were synthesized by a carbothermal evaporation process at ambient pressure and show a efficient excitonic radiative recombination at low excitation intensities. The wires were either dispersed on silicon or sapphire substrates or on carbon gluepads. Under high excitation conditions at low temperature, additional peaks due to inelastic exciton collisions and the formation of an electron hole plasma can be seen. Furthermore, sharp peaks are observed in the spectra growing superlinearly with the excitation intensity, indicating stimulated emission and lasing from Fabry-Perot-modes between the side facets of the microwires with a resonator length between 3 μm and 20 μm. The peaks exhibit a FWHM of only 2 meV and a lasing threshold intensity of about 150 kW/cm^2. Spectra as a function of temperature, wire diameter and polarization will be presented.

HL 49.2 Thu 11:00 ER 164

Influence of dielectric capping on the phololuminescence spectrum of ZnO nanowires nanowires — •Jan Richters, Tobias Voss, Ilja Rückmann, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Due to the large surface-to-volume ratio and the photon confinement, ZnO nanowires are expected to be good candidates for applications in nanoscale optoelectronics in the blue spectral region and for sensors. For many devices, the nanowires need to be embedded in organic or inorganic materials or functionalized with surfactants. It is important to understand the influence of these treatments on the optical and electronic properties of ZnO nanowires to optimize their use in such devices. We report on room-temperature and low-temperature photoluminescence studies of ZnO nanowires embedded in organic and inorganic dielectrics. For this, we investigate ZnO nanowires embedded in various polymers as well as aluminum/ZnO nanowire core-shell structures. The capping in general results in a more pronounced surface exciton band. Additionally, a decreased relative intensity of the green deep-level emission with respect to the near band-edge emission can be observed. These effects scale with the dielectric constants of the amorphous dielectrics. Capping with a dielectric influences the surface states as well as the band bending at the semiconductor surface. We present a model to explain the changes of the relative intensities of the photoluminescence bands.

HL 49.3 Thu 11:15 ER 164

Optical and electrical characterization of acceptors implanted into ZnO — •Joachim Dürr[1], Daniel Stichtenoth[1], Sven Müller[1], Carsten Ronning[1], Amilcar Bedoya Pinto[2], Jörg Malindretos[2], Lars Wischmeier[3], and Tobias Voss[3] — [1]II. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]IV. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Institute for Solid State Physics, University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany

Group I- and V-elements are the most promising candidates for p-type doping of ZnO. We doped ZnO bulk crystals with several of them using ion implantation, because this technique offers several advantages compared to doping during growth, e.g. precise control of the lateral and vertical dopant concentration even beyond solubility limits. After implantation and annealing of the introduced defects, we performed photoluminescence measurements in order to monitor the optical activation of the dopants. We investigated the dependence of acceptor-related features of the spectra on dopant concentration and annealing conditions as well as the temperature dependence. First Hall measurements of acceptor-implanted ZnO will also be presented.

HL 49.4 Thu 11:30 ER 164

Random lasing in ZnO nanopowders — •Roman J.B. Dietz, Johannes Fallert, Felix Stelzl, Huijuan Zhou, Janos Sartor, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany

We investigate the optical properties and random lasing effects of nanocrystalline ZnO powders under high optical excitation. The powders are excited by a pulsed Nd:YAG laser at 355 nm with a pulse duration of 5 ns. The different powders have different average particle sizes which vary from 50 nm to several μm. This gives us the opportunity to measure the threshold of lasing in dependence, among others, on particle size. Furthermore by investigating single pulse spectra we are also able to make statistical evaluations of the lasing probability. We also evaluate the dependence on temperature and size of excited area.

HL 49.5 Thu 11:45 ER 164

DBR und RC-LED Strukturen im ZnSe-basierten Material-

system — •Kai Otte, Carsten Kruse, Jens Dennemarck, Arne Gust und Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

Hochreflektive Bragg-Spiegel (DBRs) sind ein Schlüsselbaustein für Bauelemente wie oberflächenemittierende Laserdioden mit Vertikalresonator (VCSEL) und resonanter Kavitäts-LEDs (RC-LED). Auf Basis eines, in seinen optischen und elektrischen Eigenschaften optimierten, DBRs wurde erstmals eine RC-LED mit Quantenpunkten als aktivem Gebiet für den grünen Spektralbereich realisiert. Dies ist ein wichtiger Schritt in Richtung elektrisch betriebener VCSEL.

Die Bragg-Spiegel, bestehend aus einer ZnSSe Schicht als Hochindexmaterial und einem MgS/ZnSe Übergitter(SL) als Niedrigindexmaterial wurden mittels Molekularstrahlepitaxie auf GaAs Substraten abgeschieden. Mit diesen Bragg-Spiegeln können Reflektivitäten von über 99% erreicht werden. Das ZnSe Materialsystem ermöglicht das Wachstum von DBRs im Wellenlängenbereich von 470 nm bis über 600 nm.

Durch Optimierung des Schichtdickenverhältnisses im MgS/ZnSe SL kann die Leitfähigkeit von n-dotierten DBRs signifikant verbessert werden. Die besten Werte lagen bei 90 $\frac{A}{cm^2}$ bei 3 V für einen 12fach DBR.

HL 49.6 Thu 12:00 ER 164

Gain and dynamics in ZnO nanorod lasers — •Johannes Fallert[1], Roman J. B. Dietz[1], Felix Stelzl[1], Huijuan Zhou[1], Janos Sartor[1], Anton Reiser[2], Klaus Thonke[2], Rolf Sauer[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [2]Institut für Halbleiterphysik, Universität Ulm, Germany

Recent progress in reliable p-doping of ZnO and the realization of ZnO based LEDs foster the hope to achieve ZnO-based short-wavelength laser diodes. In particular, ZnO nanorods which can be grown in ordered, extended arrays offer the possibility to realize nano-scaled lasers. There, ZnO is not only the gain medium, but also acts as a laser resonator. Under lasing conditions the emission wavelength is defined by the guided modes in the nanorod. Here we study the lasing dynamics of individual nanorods by time-resolved μ-photoluminescence. We demonstrate that these modes show gain competition and pronounced shifts with varied pump intensity as well as within their temporal evolution. We find that even at low temperature the gain is exclusively due to an electron-hole plasma. Furthermore the influence of temperature on the available gain is examined and room-temperature lasing is achieved under ns-excitation.

HL 49.7 Thu 12:15 ER 164

Dynamics of charge carrier relaxation and recombination in high quality homoepitaxial-grown and single crystal ZnO — •Markus R. Wagner[1], Ute Haboeck[1], Axel Hoffmann[1], Stefan Lautenschläger[2], Joachim Sann[2], and Bruno K. Meyer[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen

The improvement of growth procedures enables the fabrication of high quality homoepitaxial-grown ZnO layers with negligible amounts of strain near the interface. The optical, electronical and vibrational properties of homoepitaxial grown layers are compared to those of high quality ZnO single crystals. In particular, we report experimental results of time resolved PL and Raman spectroscopy, which provide information on the recombination and relaxation dynamics of charge carriers. The decay times of the observable exciton complexes were studied for different laser energies, resulting in resonant and non-resonant excitation. The dynamics and energy transfer processes were analyzed by probing the free and bound exciton states and phonon replicas, while varying the laser energy. The phonon and carrier dynamics are investigated by time resolved pump and probe spectroscopy. High energy excitation produces hot carriers by two-photon absorption. Their relaxation is accompanied by the emission of phonons, which are studied by time-resolved Raman spectroscopy. The results including resonant and non-resonant Raman measurements are discussed considering electron-phonon and phonon-phonon interactions.

HL 49.8 Thu 12:30 ER 164

Asymmetry in the excitonic recombinations and impurity incorporation of the two polar faces of homoepitaxially grown ZnO films — •Joachim Sann[1], Stefan Lautenschläger[1], Niklas Volbers[1], Bruno K. Meyer[1], Markus R. Wagner[2], Ute Haboeck[2], and Axel Hoffmann[2] — [1]1st Physics Institute, Justus-Liebig University Giessen, Heinrich Buff Ring 16, 35392 Giessen, Germany — [2]Institute of Solid State Physics, TU Berlin, Hardenbergstr. 38, 10623 Berlin, Germany

Homoepitaxial ZnO layers were grown on O-polar and Zn-polar surfaces of ZnO single crystal substrates by chemical vapour deposition. While the structural properties (surface roughness, rocking curve half width) were within experimental error identical, the optical properties as monitored by photoluminescence (PL) were strikingly different. Four excitonic recombination lines are exclusively found on the O-polar surface. In order to understand the defects involved secondary ion mass spectrometry was employed which clearly demonstrated that the impurity incorporation is substantially higher on the O-polar surface. Temperature and power dependent PL measurements provide further insight into the initial-final state recombinations. The newly observed recombinations are caused by excitons bound to a neutral defect complex. In order to account for the thermalisation behaviour found in the temperature dependent measurements splittings in the excited as well as in the ground state must be present. A neutral, isoelectronic Zn vacancy-donor pair is consistent with the experimental data.

HL 49.9 Thu 12:45 ER 164

Stacking fault-related 3.31eV luminescence in zinc oxide — •M. Schirra[1], R. Schneider[1], A. Reiser[1], G.M. Prinz[1], M. Feneberg[1], J. Biskupek[2], U. Kaiser[2], C.E. Krill[3], R. Sauer[1], and K. Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Materialwissenschaftliche Elektronenmikrokopie, Universität Ulm, D-89069 Ulm — [3]Institut für Mikro- und Nanomaterialien, Universität Ulm, D-89069 Ulm

Epitaxial layers, bulk material, and nanostructures of ZnO often exhibit a characteristic luminescence band at ≈3.31eV. The nature and origin of this band has been the subject of some debate, frequently being interpreted in terms of acceptor-related recombination taken as confirmation of successful p-type doping. Our epitaxial ZnO layers, grown nominally undoped on a-plane sapphire substrates, also show the 3.31eV band together with dominant near-band edge emission. A combination of spatially resolved cathodoluminescence (CL) and transmission electron microscopy (TEM) studies performed on the same samples finds that the 3.31eV band appears along distinct lines, which we identify as being related to basal plane stacking faults. Temperature-dependent CL measurements reveal that the 3.31eV band is a free-to-bound $\left(e, A^0\right)$ transition, involving an acceptor state localized at the stacking fault. The acceptor ionization energy is 130meV. Some samples show an additional line ≈13meV below the 3.31eV band. Its properties are consistent with a donor-acceptor-pair transition. The average pair distance is only 4nm. Possible implications of these new results with regard to p-type doping of ZnO are discussed.

HL 50: ZnO: Tansport

Time: Thursday 14:00–15:45 Location: ER 164

HL 50.1 Thu 14:00 ER 164

Conductivity of single ZnO Nanorods after Ga-Implantation in a Focused-Ion-Beam System — •Daniel Weissenberger[1], Michael Dürrschnabel[1], Dagmar Gerthsen[1], Fabián Pérez Willard[1,2], Anton Reiser[3], Günther Prinz[3], Martin Feneberg[3], Klaus Thonke[3], and Rolf Sauer[3] — [1]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe, D-76128 Karlsruhe, Germany — [2]Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76128 Karlsruhe, Germany — [3]Institut für Halbleiterphysik, Universität Ulm, D-89081 Ulm, Germany

Electrical transport measurements on single Ga^+-implanted ZnO nanorods are presented in this contribution. The nanorods were grown by the vapor solid liquid technique and electrically contacted using a procedure based on electron-beam lithography. The implantations were carried out in a combined scanning electron microscope/focused-ion-beam system with doses between 10^{11} and 10^{17} cm^{-2}. At im-

plantation doses of about 10^{14} cm^{-2}, a maximum of the resistance is observed, which we attribute to the decrease of carrier mobility due to lattice defects. High-resolution transmission electron microscopy shows that a high density of stacking faults is generated which consist of inserted (0002) planes perpendicular to the current flow. At high implantation doses, a significant reduction of the resistance is observed. Low specific resistivities of about 3x10^{-3} Ωcm are reached without additional annealing treatment after high-dose implantation [1].
[1] D. Weissenberger et al., Appl. Phys. Lett. 91, 132110 (2007).

HL 50.2 Thu 14:15 ER 164

Magnetotransport and Transport Properties of Compacted ZnO Nanoparticles — •Sonja Hartner[1,2], Moazzam Ali[3], Hartmut Wiggers[2], Axel Lorke[1], and Markus Winterer[3] — [1]Experimental Physics and CeNIDE, Universität of Duisburg-Essen, Duisburg, Germany — [2]Institute for Combustion and Gas Dynamics, Universität of Duisburg-Essen, Duisburg, Germany — [3]Nanoparticle Process Technology, Universität of Duisburg-Essen, Duisburg, Germany

The present study investigates the magnetotransport properties of compacted pellets of nanosized ZnO powders using Hall measurements and impedance spectroscopy (IS). Measurements performed at room temperature show a clear Hall voltage and an ohmic transport behavior. The doped ZnO particles exhibit n-type semiconducting behavior. A charge carrier concentration which is far below the value of bulk material and a mobility of 5 cm^2/Vs, which is half of the value for bulk material are determined. The compacted ZnO nanoparticles show a decreasing mobility with increasing carrier concentration. The IS was performed in air and in hydrogen atmosphere at temperatures ranging from 323K to 673K. By doping the ZnO with 7% aluminum, the conductivity increases by two orders of magnitude in comparison to undoped ZnO. At 523K in hydrogen atmosphere, the conductivity is up to seven orders of magnitude higher than for room temperature and exhibits a positive temperature coefficient as it is known from metallic conductors. The differing properties are attributed to a change in the oxygen vacancy concentration of the sample material.

HL 50.3 Thu 14:30 ER 164

ZnO-based MIS diodes — •Heiko Frenzel, Holger von Wenckstern, Holger Hochmuth, Gisela Biehne, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

Metal-Insulator-Semiconductor(MIS)-diodes with ZnO as the semiconductor and high-k-dielectric oxides as insulator were fabricated using pulsed laser deposition (PLD). Metal contacts were deposited either by thermal evaporation or dc sputtering. Back contacts were realized by a thin degenerated Al-doped ZnO layer [1]. The MIS-diodes were investigated by I-V, quasi-static and dynamic C-V measurements, respectively. For polycrystalline 100 nm thick Al_2O_3 films and Pt-contacts on ZnO, dielectric constants between 9 and 16 have been found. The leakage current for such samples lies in the range of picoamperes for electric fields up to 1.5 MV/cm. C-V measurements reveal a negative shift of the flatband voltage due to positive oxide charges. Annealing experiments have been carried out to improve the dielectric properties of the gate oxide and to reduce parasitic charges. The non-intentionally doped ZnO-MIS-diodes show typical n-type behavior with accumulation and depletion regime and net doping concentrations between 10^{14} and 10^{17} cm^{-3}. Inversion regime should be achieved generating minority charge carriers by irradiating with ultraviolet ($hf > E_g$) light.
[1] H. von Wenckstern *et al.*, Appl. Phys. Lett. **88**, 092102 (2006)

HL 50.4 Thu 14:45 ER 164

Modelling of the frequency and temperature dependence of ZnO Schottky diode capacitance — •Martin Ellguth[1], Matthias Schmidt[2], Alexander Lajn[1], Holger von Wenckstern[1], Rainer Pickenhain[1], and Marius Grundmann[1] — [1]Universität Leipzig, Leipzig, Germany — [2]Forschungszentrum Dresden–Rossendorf e.V., Dresden, Germany

Understanding conduction in semiconductors requires knowledge about incorporated electrically active defects. Commonly, capacitance–spectroscopical methods like capacitance–voltage, deep level transient– and thermal admittance spectroscopy (TAS) are used to characterize these defects. We analyze such measurements by modelling the current–free Schottky diode capacitance. We solve numerically Poisson's equation as well as the donor occupancy time–evolution.

Our model gives exact solutions for the temperature, voltage and probing frequency dependence of the capacitance. In contradiction to classical TAS analysis, our simulation models entire capacitance–temperature/frequency spectra instead of obtaining the defect parameters (energetical depth, concentration, and electron capture cross section) only from the turning points in measured spectra. Additionally, line shape analysis allows the determination of the concentrations of two energetically close–lying levels which cannot be obtained from classical TAS analysis. We applied our simulations on TAS data obtained from ZnO single crystals and thin films and were able to improve the accuracy of the values for the electron capture cross section and to determine the respective concentrations for each defect.

HL 50.5 Thu 15:00 ER 164

Electrical characterisation of oxygen implanted ZnO thin films. — •Matthias Schmidt[1], Gerhard Brauer[1], Wolfgang Skorupa[1], Manfred Helm[1], Holger v. Wenckstern[2], Rainer Pickenhain[2], and Marius Grundmann[2] — [1]Forschungszentrum Dresden – Rossendorf e.V., Dresden, Germany — [2]Universität Leipzig, Leipzig, Germany

Since the achievement of reproducible p–type conduction is a premise for ZnO devices, it is necessary to minimize the donor–like defects causing n–type conduction. Up to now it is under discussion whether intrinsic defects like vacancies or unintentionally incorporated dopants like hydrogen or group three elements are the main source of donors.

In this work we set out to detect donor–like defects which have their origin in oxygen excess or deficiency. In order to generate only intrinsic defects and to minimize oxygen vacancies we implanted oxygen ions into ZnO thin films grown by pulsed laser deposition. After thermal annealing, rectifying palladium contacts were deposited. The rectifying behaviour of the samples has been characterized by current–voltage, and capacitance – voltage measurements. Trap concentrations and energetical depths were obtained from deep level transient–, and thermal – admittance – spectroscopy. In the oxygen implanted samples we found a trap with an energetical depth between 500 meV and 600 meV which was not detectable in virgin samples.

HL 50.6 Thu 15:15 ER 164

Magnetoresistance in n-type conducting Co-doped ZnO — •Qingyu Xu[1], Lars Hartmann[1], Heidemarie Schmidt[1], Holger Hochmuth[2], Michael Lorenz[2], Daniel Spemann[2], and Marius Grundmann[2] — [1]Forschungszentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Bautzner Landstraße 128, 01328 Dresden, Germany — [2]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

Series of Co-doped Al-codoped ZnO films with electron concentration at 5 K ranging from 8.3×10^{17} cm^{-3} to 9.9×10^{19} cm^{-3} were prepared by pulsed laser deposition under different O_2 pressure and substrate temperature. The magnetoresistance (MR) effect was studied between 5 K and 290 K with fields up to 6 T, showing large electron concentration and temperature dependence. A large positive MR of 124 % has been observed in the film with the lowest electron concentration , while only negative MR of -1.9 % was observed in the film with highest electron concentration at 5 K. The positive MR is attributed to the quantum correction on the conductivity due to the s-d exchange interaction induced spin-splitting of the conduction band [1]. The negative MR is attributed to the magnetic field suppressed weak localization [1]. The modelled superimposed positive and negative MR agrees well with the experimentally observed MR and hints towards the physical origin of MR in Co-doped ZnO [2].
[1] P. A. Lee et al. Rev. Mod. Phys. 57, 287 (1985) [2] Q. Xu et al. Phys. Rev. B 76, 134417 (2007)

HL 50.7 Thu 15:30 ER 164

Determination of the free charge carrier profile in ZnO films — •Chris Sturm[1], Holger von Wenckstern[1], Rüdiger Schmidt-Grund[1], Matthias Brandt[1], Tsvetan Chavdarov[1], Bernd Rheinländer[1], Carsten Bundesmann[2], Holger Hochmuth[1], Michael Lorenz[1], Mathias Schubert[3], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., 04318 Leipzig — [3]Department of Electrical Engineering, University of Nebraska-Lincoln, 68588-0511 Lincoln, Nebraska, USA

Non-polar ZnO is a promising material for optoelectronic applications since internal electric fields are avoided. For ZnO based devices such as LEDs, FETS and microcavities ZnO-Al_2O_3 heterostructures are of in-

terest, e.g. as electrical barrier. However it was found that a thin layer in ZnO near to the ZnO-Al_2O_3 interface shows a high free charge carrier concentration. We present investigations of the thickness and the free charge carrier concentration of this layer using two complementary methods: infrared spectroscopic ellipsometry and Hall measurements.

The nominally undoped non-polar ZnO films were grown by pulsed laser deposition r-plane sapphire substrates with different film thicknesses (30 nm − 600 nm). For all ZnO films we have found a remarkably higher free charge carrier concentration at the ZnO-sapphire interface compared to the remaining layer. We obtain an increasing charge sheet density with increasing film thickness. Attempts will be presented to clear up the origin of the experimentally found high concentration.

HL 51: Poster IV

Time: Thursday 16:30–19:00 Location: Poster D

HL 51.1 Thu 16:30 Poster D

Redistribution of excitonic photoluminescence transitions mediated by surface acoustic waves — •Stefan Völk[1,2], Jens Ebbecke[1,2,3], Achim Wixforth[1,2], Dirk Reuter[4], and Andreas Wieck[4] — [1]Institut für Physik der Universität Augsburg, Experimentalphysik I, 86159 Augsburg, Germany — [2]Center for NanoScience (CeNS), 80539 Munich, Germany — [3]School of Engineering and Physical Science, Heriot-Watt University, Edinburgh, EH14 4AS, UK — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Quantum wells in semiconductor heterostructures can be populated optically by electron-hole pairs which form excitons at low temperatures. Recombination of excitons leads to emission of photoluminescence (PL) light. In earlier experiments there was shown that the PL of a single QW can be quenched by a surface acoustic wave (SAW).

We have investigated the excitation spectrum of a system consisting of different wide GaAs quantum wells. As the transition energies depend on two parameters - quantum well depth and width - the PL spectrum of our multi quantum well (MQW) system shows several peaks.

Surprisingly some of these peaks don't reveal the characteristic quenching when a SAW is applied. In some cases even an amplification of PL intensity can be observed. The explanation of this controversy effect is still under debate. Newer experiments on the MQW system suggest excitonic effects.

HL 51.2 Thu 16:30 Poster D

Determination of exciton mass in Cu_20 by two-phonon-spectroscopy — Jan Brandt[1], Dietmar Fröhlich[1], •Christian Sandfort[1], Manfred Bayer[1], and Heinrich Stolz[2] — [1]Institut für Physik, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Fachbereich Physik, Universität Rostock, D-18051 Rostock, Germany

The 1S-paraexciton in Cu_2O is a pure spin-triplet state with Γ_2^+ symmetrie. Therefore it is optically forbidden to all orders. In a magnetic field, however, it mixes with the 1S-orthoexciton and gets quadrupole allowed. From two-phonon excitation spectroscopy involving an optical and acoustical phonon we derive by a purely kinematical analysis a very reliable value for the paraexciton mass ($m_p = 2.61\ m_0$). The resolution of this method is only limited by the linewidth of the exciting laser (< 20 neV). Furthermore we show that the experimental method is suited to test the parameters of the k^2-exchange interaction of the orthoexcitons and determine the sound velocity of acoustic phonons and the refractive index.

HL 51.3 Thu 16:30 Poster D

Optical investigations of hexagonal $Mg_xZn_{1-x}O$ thin layers in UV spectral range — •Alexander Müller, Gabriele Benndorf, Susanne Heitsch, Holger Hochmuth, Christoph Meinecke, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

Ternary alloys of $Mg_xZn_{1-x}O$ have been grown by pulsed laser deposition on a-plane sapphire substrates at different oxygen partial pressures between 1.6×10^{-2} and 5×10^{-5} mbar, using targets with MgO concentrations from 0 to 10 wt-%. The Mg content of the thin films varies between 0 % and 34 %.

The optical properties of the samples were investigated using photoluminescence (PL) measurements and transmission measurements. On selected samples, temperature dependent PL and transmission mesurements were performed.

The refraction index of $Mg_xZn_{1-x}O$ thin films in dependence on the wavelength of the transmitted light is not well known. Therefore, the transmission spectra were modeled using Model Dielectric Functions to obtain information about exciton energies and broadening parameters. Exciton-phonon-complexes are taken into account to describe the equally spaced dips which were found in some transmission spectra.

To support the results of the static measurements, time resolved PL measurements were performed.

HL 51.4 Thu 16:30 Poster D

Generation of a Single-cycle Terahertz Pulse through Shaped Ultrafast Laser Pulses — •Andreas Vaupel, Kapil Kohli, Sangam Chatterjee, and Wolfgang W. Rühle — Faculty of Physics, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

We report the generation of a single-cycle terahertz pulse in a free-space terahertz time domain spectroscopy setup. Terahertz-radiation is generated via optical rectification and detected by utilizing the Pockels effect through electro-optical sampling in ZnTe crystals. A 4-f pulse-shaper setup with a spatial light modulator is used to generate two-colour pulses by manipulating the phase in the Fourier plane. We are able to directly control the timing between and the amplitude ratio of the two pulses. A genetic algorithm is used to obtain the best shaped single-cycle terahertz pulse. A flexible setup is presented which enables the generation of various terahertz pulse shapes.

HL 51.5 Thu 16:30 Poster D

Manipulation von Exitonen in III/V- und II/VI-Heterostrukturen mittels akustischer Oberflächenwellen — •Daniel Fuhrmann[1], Jens Ebbecke[1,2,3], Stefan Völk[1,2] und Achim Wixforth[1,2] — [1]Lehrstuhl für Experimentalphysik 1, Institut für Physik, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg — [2]Center of Nanoscience, Geschwister-Scholl-Platz 1, 80539 München — [3]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, UK

Halbleiter-Heterostrukturen eignen sich ausgezeichnet für die Untersuchung von Exitonen mittels Photolumineszenzmessungen. Epitaktisch gewachsene, dünne Schichtfolgen von Halbleitern unterschiedlicher Bandlücken, ähnlicher Gitterkonstanten lassen zweidimensionale Ladungsträgersysteme entstehen. In diesen Systemen ist die Bindungsenergie der Exitonen um ein Vielfaches größer im Vergleich zum dreidimensionalen Fall.

Vorgestellt werden gezielte Manipulationen der Ladungsträger in III/V- und II/VI-Heterostrukturen, z.B. im lateralen dynamischen Piezopotential akustischer Oberflächenwellen. Beobachtet wird unter anderem die Dissoziation von Elektronen und Löchern in streifenförmige Domänen, sowie der Quantum Confined Stark Effect. Neben GaAs-Strukturen konnten wir weiterhin eine akustisch induzierte Dissoziation von Exitonen in ZnCdSe-Quantentöpfen detektieren. Dies ist dadurch besonders von Interesse, da die hohe Exitonenbindungsenergie von ca. 30 meV in diesem System im Prinzip auch Raumtemperaturanwendungen ermöglicht.

HL 51.6 Thu 16:30 Poster D

Calculations of the optical properties of ZnO microcavities for Bose-Einstein condensation — •Chris Sturm, Rüdiger Schmidt-Grund, Jan Sellmann, Helena Hilmer, Bernd Rheinländer, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Exciton-polaritons in ZnO based resonators are of interest since they are promising candidates for the realization of Bose-Einstein-Condensation (BEC) at room temperature and above. The exciton-polaritons are quasi-particles which are formed due to the coupling between light and excitons in microcavities embedded between two Bragg mirrors. The properties of the active medium of the micro-

cavitiy determine the temperature at which BEC occurs. Due to its large exciton-binding energy of 60 meV and its large exciton oscillator strength ZnO is a promising material for the realization of BEC at temperature up to 560 K [1].

We calculate the reflectivity and the transmitivity of ZnO based resonators. The dielectric function, which is needed for the calculation, is taken from our ZnO films obtained by ellipsometry. The Rabi-splitting and the mode splitting were calculated. Based on these results the occupation of the exciton-polaritons in the momentum space was calculated and the critical exciton-polariton density and the corresponding excitation energy were estimated. These theoretical investigations were used to design the resonators.

[1] M. Zamfirescu *et al.*, Phys. Rev. B **65**, 161205R (2001).

HL 51.7 Thu 16:30 Poster D

Studies of linear absorption in weakly disordered semiconductors - Comparison of various approaches — •Noémi Gögh[1], Walter Hoyer[1], Peter Bozsoki[2], Irina Kuznetsova[1], Mackillo Kira[1], Peter Thomas[1], and Stephan W. Koch[1] — [1]Department of Physics, Philipps Universität, Renthof 5, 35032 Marburg — [2]Department of Physics, Lancaster University, LA14YB Lancaster, UK

A one-dimensional model of a disordered semiconductor is treated in k-space and real space. In the k-space approach the 2nd Born approximation for disorder scattering with and without Markov approximation is applied within a correlation expansion. In real space on the basis of a disordered tight-binding model configurational averaging without any further approximation is performed. Characteristic differences are observed and discussed.

HL 51.8 Thu 16:30 Poster D

Investigation of the optical properties of phase change alloys — •Konstantin Shportko, Stephan Kremers, Michael Woda, Wojciech Wełnic, and Matthias Wuttig — Institute of Physics (IA), RWTH University of Technology Aachen, Aachen, Germany

Phase change materials (PCM) have a unique potential as materials for an emerging non-volatile electronic memory [1]. The aim of this study is to investigate the permittivity dispersion and dispersion of refractive and extinction indexes of the certain alloys of group V and group VI elements. Reflectance spectra have been measured in the UV-VIS/IR range. The spectra have been simulated using SCOUT software. The thickness of the PCM layer has been determined independently. We have analyzed and compared the difference between the spectra of the amorphous and crystalline phases. Our experiments reveal very remarkable findings. Dispersion of the refractive and extinction indexes of both phases show pronounced contrast. The analysis of computations and experimental data reveal the correlation between local structural changes and optical properties as well as the origin of the optical contrast in these materials. The change in optical properties cannot be attributed to a smearing of transition energies as commonly assumed for amorphous semiconductors: the optical contrast between the two phases can only be explained by significant changes in the transition matrix elements [2]. [1] M. Wuttig, N. Yamada, Nature Materials 6, 824 (2007). [2] Welnic W., Botti S., Reining L., Wuttig M. Physical Review Letters 98 (23), 236403, (2007).

HL 51.9 Thu 16:30 Poster D

FTIR and Raman study of AIIBV2 single crystals at low temperatures. — •Konstantin Shportko[1,2], Reinhard Rückamp[1], Matthias Wuttig[1], Yurij Pasechnik[2], Vladimir Trukhan[3], and Tatiana Haliakevich[3] — [1]Institute of Physics (IA), RWTH University of Technology Aachen, Germany — [2]Dragomanov National Pedagogical University, Kyiv, Ukraine — [3]Joint Institute of Solid State and Semiconductor Physics NASB, Minsk, Belarus

AIIBV2 compounds are promising materials for the construction of the new devices for solid state electronics [1]. Presently the data for the dielectric permittivity dispersion of AIIBV2 crystals are still incomplete [2]. FTIR and Raman spectroscopy have been employed to determine the phonon and plasma contribution to the permittivity and to obtain the permittivity model of AIIBV2 single crystals in the far infrared (FIR). IR reflectance and Raman spectra have been measured in the temperature range from 4 to 300 K. The anisotropy of the phonon contribution to the AIIBV2 single crystals dielectric permittivity shows itself in reflection and Raman spectra in the FIR. At low temperature phonon peaks in the both types of the spectra become narrower. Characteristics of the phonon and plasmon modes were obtained in the temperature range from 4 K to 300 K. The temperature dependence of the oscillator parameters has been determined. [1] V.M. Trukhan, A.U. Sheleg, I.V. Fekeshgazi. Photoelectronics. 15 (2004) 13. [2] J. Baran, Yu. A. Pasechnik, K.V. Shportko, M. Trzebitowska-Gusowska, E.F.Venger, Journal of Molecular Structure, 792-793, (2006), 239-242.

HL 51.10 Thu 16:30 Poster D

Über lineare Response-Theorie hinausgehende Behandlung zeitabhängiger Störungen: Anwendung auf HL-Quantenpunkte — •Jakob Ebeling und Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen

Optische Übergänge zwischen Einteilchenzuständen werden üblicherweise mit Hilfe der linearen Response-Theorie berechnet, welche zeitabhängige Störterme lediglich in linearer Ordnung berücksichtigt. Alternativ bietet sich - zumindest im Fall eines endlich-dimensionalen Hilbertraums - eine exakte Aufintegration der von-Neumann-Gleichung an, um auch nicht-lineare Beiträge zu berücksichtigen. Wir benutzen diesen Zugang zur Berechnung optischer Eigenschaften eines Systems mit wenigen Energieniveaus. Konkret berechnen wir die Wechselwirkung der niedrigsten Elektron- und Lochzustände eines Halbleiterquantenpunktes mit einem elektromagnetischen Feld.

HL 51.11 Thu 16:30 Poster D

Electroluminiscence study of site-selective grown self-assembled InAs quantum dots — •Minisha Mehta, Dirk Reuter, Alexander Melnikov, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum, Germany

Self-assembled InAs quantum dots (QDs) are envisioned as building blocks for the realization of novel nanoelectronic devices. For this purpose, the site-selective growth of InAs QDs is highly desirable. We present the results on site-selective growth of self-assembled InAs QDs on GaAs surface patterned by in-situ focused ion beam (FIB) implantation. Under well optimized conditions, a selective growth of single QD in the patterned holes with more than 50 % probability is achieved. Carrier injection and subsequent radiative recombination from site-selective grown InAs/GaAs self-assembled QDs is investigated by embedding the QDs in the narrow intrinsic region of a p-i-n structure. Electroluminescence spectra taken at 77 K show excited state interband transitions up to n=5 from the QDs. Financial support by the BMBF via the NanoQuit program is gratefully acknowledged.

HL 51.12 Thu 16:30 Poster D

Rolled-up Metal Semiconductor Tubes as Building Blocks for Metamaterials — Nils Gerken, •Stephan Schwaiger, Markus Broell, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Materials which are composed of artificially designed building blocks and which can be described by effective parameters i.e. the permeabilitiy μ and the permittivity ϵ are called metamaterials. A lot of research is presently put into tailoring the effective optical parameters of different kinds of metamaterials. Typically, a wide range of values for the permittivity ϵ and permeability μ can be achieved by constructing metamaterials which exhibit resonances in both ϵ and μ [1]. Realising the desired combination of ϵ and μ at a certain wavelength is then basically a task of shifting these two resonances to the corresponding spectral position. By means of finite difference time domain calculations we here investigate the possibility to employ flexible rolled-up metal semiconductor tubes [2] as building blocks for metamaterials with in-situ tuneable permeability and permittivity. We show that the magnetic resonance of a metal semiconductor tube with 1 μm diameter can be shifted between 24 and 32 THz by mechanical deformation. We gratefully acknowledge support by the DFG through SFB 508 and GRK 1286. [1] J.B. Pendry, IEEE Transactions on Microwave Theory and Techniques, Vol. 47, 2075 (1999) [2] O. Schumacher et al., Applied Physics Letters 86, 143109 (2005)

HL 51.13 Thu 16:30 Poster D

Raman scattering on a series of phase-change material ($GeTe$, Sb_2Te_3, $Ge_{15}Sb_{85}$, and $Ge_xSb_yTe_z$) — •Judith Hinterberg[1], Reinhard Rückamp[1], Michael Woda[2], Matthias Wuttig[2], Gernot Güntherodt[1], and Markus Grüninger[3] — [1]2. Physikalisches Institut, RWTH Aachen — [2]1. Physikalisches Institut, RWTH Aachen — [3]2. Physikalisches Institut, Universität zu Köln

The phase-change material $Ge_xSb_yTe_z$ (GST) are widely used for optical data storage, but also their potential for so-called phase-change (PC)-RAMs is promising. However, their local structure – in particular in the amorphous phase – and the ion displacements across the phase transition are not well understood. In order to reveal the local structure we investigate the phonon spectra of various compounds of the pseudo-binary line from Sb_2Te_3 to GeTe as a function of temperature by means of Raman spectroscopy. In particular, we compare Raman spectra of the amorphous, the metastable, and the stable phases of GST 124, GST 224, GST 214, GST 225, GeTe, Sb_2Te_3, and $Ge_{15}Sb_{85}$. Near the phase transition, we find a remarkable similarity between GST and Sb_2Te_3. In contrast to recent claims in the literature [1], the ordering process in GST is not only dominated by the Ge atoms.

[1] A.V. Kolobov *et al.* Nature Mater. **3**, 703-708 (2004)

HL 51.14 Thu 16:30 Poster D

Kinetics of high density excitons in a potential trap — •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]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan — [3]Institut für Physik, Universität Dortmund, D-44221 Dortmund, Germany

At sufficiently high densities and low temperatures excitons are expected to form a BEC. In the past, there have been several claims of observation of excitonic BEC, which, however, could not stand against critical tests. In order to exclude any coherent stimulation by the excitation laser it is necessary to separate the excitation from the detection spatially and spectrally. This criterion is ideally fulfilled by a trap. 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 100 ns. The paraexciton density was deduced via the phonon assisted Γ_5^+ sideband similar to [3]. In the experiments the sample temperature and the excitation power were varied, and the temporal evolution of the exciton population was determined.

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HL 51.15 Thu 16:30 Poster D

Second-Harmonic Generation in Gallium Selenide (GaSe) as Investigated with cw Diode Lasers — •Peter Karich[1], Lothar Kador[1], Kerim R. Allakhverdiev[2,3], Tarik Baykara[2], and Eldar Salaev[3] — [1]Institute of Physics and BIMF, University of Bayreuth, D–95440 Bayreuth, Germany — [2]Marmara Research Centre of TÜBITAK, Materials Institute, P. K. 21, TR–41470 Gebze/Koçaeli, Turkey — [3]Azerbaijan National Academy of Sciences, Insitute of Physics, 370073 Baku, Azerbaijan

A simple custom-built set-up for investigating optical second-harmonic generation in gallium selenide (GaSe) is presented. The high $\chi^{(2)}$ coefficient of the material (86 pm/V) permits the use of small cw diode lasers with output powers in the milliwatt range. The spatial homogeneity of different GaSe crystals is investigated with Maker fringe experiments. Multiple reflections between sample surface and glass substrate and absorption of the second-harmonic wave in the crystal give rise to clearly visible effects in the Maker fringe data [1].

[1] W. N. Herman and L. M. Hayden, J. Opt. Soc. Am. B **12**, 416 (1995).

HL 51.16 Thu 16:30 Poster D

Investigating transport properties of crystalline chalcogenide phase change alloys — •Stephan Kremers, Kostiantyn Shportko, Michael Woda, and Matthias Wuttig — I. Physikalisches Institut (IA), RWTH Aachen, Deutschland

Many chalcogenide alloys show a pronounced optical and electrical contrast between the amorphous and crystalline phase. The origin can be understood refer to W. Welnic (2007). Within this class of materials, phase change alloys stand out by their ability to rapidly and reversibly switch between these two metastable states. Rewritable CDs / DVDs are already taking advantage of these properties and the Phase-Change-Random-Access-Memory (PRAM) is going to enter the market, substituting flash memory in the near future.

We present Ellipsometry measurements of optical properties in the range of 0.7-3.0 eV for chalcogenide alloys. Two mechanisms dominate an optical spectra: interband transitions and free carriers. The focus of our investigations is on the free carriers which can be decribed by Drude's theory. In principle the resistivity, carrier concentration and mobility can be deduced. We show the opportunities and limits of optical techniques regarding transport phenomena.

HL 51.17 Thu 16:30 Poster D

Towards efficient detection of single photons at telecommunication wavelengths — •Gesine Steudle[1], Sander Dorenbos[2], Ingmar Müller[1], Elisabeth Reiger[2], Val Zwiller[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, AG Nano-Optik, Hausvogteiplatz 5-7, 10117 Berlin, Germany — [2]TU Delft, Kavli Institute of Nanoscience, Lorentzweg 1, 2628 CJ Delft, Netherlands

One of the main challenges of fiber-based single photon devices is the efficient and feasible detection of single photons at telecommunication wavelengths. A promising approach is the use of superconducting detectors. In our case these detectors consist of a small superconducting wire which is arranged in a meander. The wire structure is made of thin NbN layers by electron beam lithography. To provide optimal coupling to the experimental setup a 1.55 μm single mode fiber is glued directly on the detector area. The main advantages of this type of detectors are high count rates of the order of 1 Ghz, a time resolution below 100 ps and quantum efficiencies of 10 - 15 % at 1.55 μm. Further on one can improve the quantum efficiency by adding a cavity structure and increase the count rate using an array of parallel meanders.

HL 51.18 Thu 16:30 Poster D

Annealing effects on the crystalline resistivity of phase change materials — •Michael Woda, Stephan Kremers, Kostiantyn Shportko, and Matthias Wuttig — I. Insitute of Physics (IA), RWTH Aachen University, Germany

Phase change materials (PCM) show a pronounced property contrast (electrical resistivity, optical reflectivity) between the amorphous and the crystalline state and fast crystallization processes. Suitable PCM can be reversibly switched between the states with either a current or laser pulse on a ns timescale. They are utilized in rewritable optical data storage and the emerging non-volatile memory PRAM. The latter is expected to replace Flash memory in the near future. The electrical conduction properties of different PCM have to be characterized and understood in order to find superior PCM for promising PRAM applications. In this study the effect of different annealing conditions on the electrical resistivity of various PCM in the crystalline state is investigated. Our data are compared with other techniques including x-ray reflectometry and x-ray diffraction to understand the nature of the resistance changes observed upon annealing.

HL 51.19 Thu 16:30 Poster D

Surface plasmon polaritons in metal-semiconductor hybrid structures — •Patrick Scholz, Stephan Schwieger, David Leipold, and Erich Runge — Technische Universität Ilmenau, Institut für Physik, 98693 Ilmenau

We present Finite Difference Time Domation (FDTD) and finite element simulations of nanostructured metal-semiconductor hybrid structures illuminated by visible and near IR light. Such structures will be important for novel optical devices, as they allow to confine the electromagnetic field in subwavelength dimensions and control the life time and the dispersion of the optical excitations. The considered systems consist of nanostructured metal layers (e.g. an array of nanometer-sized metal wires) embedded in a multilayer system that contains different semiconductor layers. We discuss the influence of the geometry of the semiconductor layers on surface plasmon polaritons excited at the metal nanostructures.

HL 51.20 Thu 16:30 Poster D

Wigner-cystalline order and massless Dirac fermions in 2 DES at high magnetic fields — •Guenther Meissner — Theoretische Physik, Universitaet des Saarlandes, Postfach 15 11 50, D-66041 Saarbruecken

A many-body approach for studying the nature of novel liquid and solid phases of interacting two dimensional (2D) electrons in high magnetic fields is reexamined. Effects on collective excitations from including weak random disorder and from considering various quasi particles of composites of electrons and magnetic flux quanta are discussed in view of microwave resonance and inelastic light scattering experiments on high quality 2D electron systems. Modifications resulting from the be-

havior of electrons in graphene as massless Dirac fermions are pointed out. The insulator terminating the series of fractional quantum Hall liquids at high magnetic fields is identified with the electron quantum solid being related to the Wigner crystal.

HL 51.21 Thu 16:30 Poster D

Magnetotransportuntersuchungen an gekrümmten zweidimensionalen Elektronensystemen in Halbleiter-Mikroröllchen mit spezieller Kontaktgeometrie — •Karen Peters, Olrik Schumacher, Andrea Stemmann und Wolfgang Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Wir stellen Magnetotransportuntersuchungen an zweidimensionalen Elektronensystemen in Halbleiter-Mikroröllchen vor, deren Herstellung auf der Ausnutzung von Relaxationsprozessen in dünnen verspannten Halbleiterschichten basiert. Bei den aufgerollten Systemen handelt es sich um Strukturen, die in einer speziellen H-förmigen Kontaktgeometrie präpariert wurden. Es werden insbesondere Messungen und Simulationen in Längsgeometrie präsentiert, bei denen die Richtung des eingeprägten Stroms entlang der Röllchenkrümmung liegt und die Messung des Widerstands parallel zur Modulation des Magnetfelds verläuft. Es zeigt sich eine gute Übereinstimmung der Simulation mit den winkelabhängigen Messungen. Liegt zwischen den Kontakten kein Nulldurchgang der senkrechten Magnetfeldkomponente vor so können die Ergebnisse ebenfalls mit Hilfe des Randkanalbilds erklärt werden.

HL 51.22 Thu 16:30 Poster D

Micromechanical cantilever magnetometer with in situ tunable sensitivity on a rotational stage — •Wolfgang Krenner, Xuting Huang, Tjark Windisch, Marc A. Wilde, and Dirk Grundler — Physik Department E10, Technische Universität München, James-Franck-Str. 1, D-85748 München

We report on a micromechanical cantilever magnetometer (MCM) mounted on a rotational sample stage incorporating a piezoceramics nanopositioning system. The MCM is read out by measuring the capacitance between the metalized backside and a fixed counter electrode. By tuning the piezoceramics we optimize the MCM's sensitivity at 300 mK in situ and in a magnetic field B of up to 16 T. With this setup we investigate the de Haas-van Alphen (dHvA) effect of 2D electron systems in III-V semiconductor heterostructures. At low temperature T the magnetization $M = -\frac{\partial U}{\partial B}$ provides direct information on U, the ground state energy. We discuss InAs-based and Mn-doped heterostructures where spin-orbit interaction is expected to induce beating patterns in the dHvA oscillations. The ability to rotate the sample allows us to adjust perpendicular and in-plane magnetic field components, which affect the Landau and Zeeman splitting differently. By this means we intend to investigate the spin splitting mechanisms in detail. First results will be presented.
We thank O. Roesler for technical assistance, A. Fontcuberta i Morral, Ch. Heyn, T. Schaepers, and W. Wegscheider for providing samples and the DFG for financial support via the "Nanosystems Initiative Munich (NIM)"and SPP 1285 Halbleiter Spinelektronik.

HL 51.23 Thu 16:30 Poster D

De Haas-van Alphen effect in two-component two-dimensional electron systems — •X. Huang[1], T. Windisch[1], S. Dasgupta[2], M. A. Wilde[1], A. Fontcuberta i Morral[2], M. Grayson[2,3], G. Abstreiter[2], and D. Grundler[1] — [1]Physik-Department E10, Tech. Univ. München, D-85747 Garching — [2]Walter Schottky Institut, Tech. Univ. München, D-85747 Garching — [3]Department of Electrical Engineering and Computer Science, Northwestern University, Evanston, Illinois 60208, USA

Two-component electron systems can be realized, e.g., in AlAs quantum wells, in which electrons occupy two X valleys in the ground state, or in Si/SiGe quantum wells [1] with two occupied Δ_2 valleys. Applying a magnetic field in the direction perpendicular to the quantum wells leads in both cases to spin splitting and, in addition, to a valley splitting in the energy spectrum. A further example is the tunneling-coupled double-layer electron system in a GaAs heterostructure, where the layer degree of freedom plays the role of the pseudo-spin degree of freedom. To investigate the characteristics of the two-dimensional electron systems (2DESs) confined to a modulation-doped AlAs quantum well, we have studied the de Haas-van Alphen (dHvA) effect at 300 mK using highly sensitive micromechanical cantilever magnetometer (MCM).

We acknowledge financial support of the German Excellence Initiative via the "Nanosystems Initiative Munich (NIM)"and GR1640/1.

[1]M. A. Wilde, M. Rhode, Ch. Heyn, D. Heitmann, U. Zeitler, F. Schaeffler, R. J. Haug and D. Grundler, Phys. Rev. B 72, 165429 (2005)

HL 51.24 Thu 16:30 Poster D

Fiber optical interferometer for ultra-sensitive displacement detection in cryogenic and high magnetic field environment. — •Martin Borowski, Tjark Windisch, Marc A. Wilde, and Dirk Grundler — Physik Department E10, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

A fiber optical interferometer with sub-Å resolution and in-situ four-axis nanopositioning sample holder for cryogenic (300 mK) and high magnetic field (15 T) applications is presented.

By probing the magnetization $M = -\frac{\partial U}{\partial B}|_{N,T}$ at low temperatures information can be gained about the ground state energy of a low dimensional electron system. For this we use micromechanical GaAs-based cantilever magnetometers (MCMs) with integrated or flip-chip mounted electron systems. This technique is established for large-area two-dimensional electron systems. The study of micron-sized samples e.g. graphene flakes, however calls for miniaturized cantilevers and a setup, where the sensitivity can be optimized in situ. The challenge is to achieve a sufficiently small footprint to fit the setup into a commercially available ^{3}He cryostat. The realization and characterization of the magnetometer will be reported.

We thank Jan Ivo Springborn and Niels Ruhe for technical assistance and the German Excellence Initiative for financial support via the "Nanosystems Initiative Munich (NIM)".

HL 51.25 Thu 16:30 Poster D

Magnetotransport measurements on a GaAs/GaAlAs high mobility sample — •Lina Bockhorn[1], Frank Hohls[1], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We study the fractional Quantum-Hall effect in a high mobility two-dimensional electron system (2DES). The Hall geometry is created by photolithography on a GaAs/GaAlAs heterostructure containing a 2DES. The mobility and the density of electrons are manipulated by illuminating the sample with an infrared LED and by using a topgate. Driving a constant current along the Hall bar we measure the longitudinal and the transversal resitance depending on an external magnetic field and we observe Shubnikov-de Haas (SdH) oscillations. For a given density of electrons we study the SdH oscillations for different temperatures.

HL 51.26 Thu 16:30 Poster D

Long-lived hole spin dynamics in a 2D system at sub-Kelvin temperatures — •Anton Wagner, Tobias Korn, Robert Schulz, Andreas Maurer, Michael Hirmer, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

The spin dynamics of holes in semiconductors have, so far, been less intensely studied than the electron spin dynamics. We performed time-resolved Faraday rotation (TRFR) measurements on a 2D hole system within a 15nm wide, modulation-doped GaAs/AlGaAs quantum well grown on a [001] substrate. In the TRFR measurements, the sample is excited by a circularly-polarized laser pulse tuned to the exciton energy. An in-plane magnetic field up to 10 T is applied, causing a precession of the photocreated carriers. At 4.5 K temperature only the fast electron spin precession is observed, whereas a second, long period precession, superimposed on the electron spin precession, appears and gets more intense as the temperature is lowered from 1.2 K to 0.4 K. We identify this signal as the hole spin precession, which has a low frequency due to the small g-factor of holes along the [001] direction. The hole g-factor is highly anisotropic, which we measured by varying the angle of incidence of the pump beam relative to the sample plane. The appearance of the long-lived hole spin precession only at very low temperatures indicates that the hole spin lifetime is increased by localization. Surprisingly, while the hole spin lifetime increases drastically at lower temperatures, the electron spin lifetime is reduced. We acknowledge financial support by the DFG via SFB 689 and SPP 1285.

HL 51.27 Thu 16:30 Poster D

Phonon-induced carrier relaxation and hot phonon dephasing dynamics in graphene — •Frank Milde, Stefan Butscher,

Ermin Malic, Matthias Hirtschulz, and Andreas Knorr — TU Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

We investigate the influence of the electron-phonon coupling (EPC) in graphene within the density-matrix formalism. To determine the EPC matrix elements Kohn anomalies in the phonon dispersions are used [1].

Our approach is used to microscopically calculate the relaxation dynamics of photoexcited electrons in graphene. Similar to recent experiments in graphite [2], hot phonons lead to a delayed decay of the electronic temperature. Our numerical simulations reproduce these observations [3] and give new insight into the ultrafast dynamics of the first 500 fs after excitation not yet accessible by the experiment. At these times an initially ultrafast energy dissipation and a non-thermal phonon occupation of the highest optical phonon modes are found. We also calculate the temporal evolution of the electronic temperature and find good agreement with recent experimental results [2].

[1] Piscanec et al., Phys. Rev. Lett. 93, 185503 (2004)
[2] Kampfrath et al., Phys. Rev. Lett. 95, 187403 (2005)
[3] Butscher et al., Appl. Phys. Lett. 91, 203103 (2007)

HL 51.28 Thu 16:30 Poster D

On the doping of Si nanowires grown by molecular-beam epitaxy — •Pratyush Das Kanungo, Otwin Breitenstein, Peter Werner, Nikolai Zakharov, and Ulrich Goesele — Max Planck Institute of Microstructure Physics, Weinberg 2, Halle D06120, Germany

Silicon nanowires (NWs) are potential candidates as building blocks for new semiconductor devices and sensors. Because of their quasi one-dimensional structure, high surface-to-volume ratio and low number of defects, Si NWs are expected to have specific electrical properties. As an example, the resistivity might be influenced by quantum confinement effects as well as by surface states. In order to make devices based on NWs it is necessary to dope them as well as to form p-n or p-i-n junctions. We describe two different techniques to dope Si NWs and methods to determine their electrical behavior.

First, in-situ doping of Si NWs with boron (B) was successfully done in a molecular beam epitaxy (MBE) chamber. By controlling the B flux it was possible to dope the whole NW, as well as make p-n and p-i-n junctions with the substrate. Second, we also demonstrated an ex-situ doping by the spin-on-glass technique. In-situ electrical measurements of the NWs were performed to confirm the desired behavior.

HL 51.29 Thu 16:30 Poster D

Charge accumulation in a type-II Ge/Si-heterostructure — Christoph Henkel[1], Gisela Biehne[1], Marius Grundmann[1], Gerald Wagner[2], Mathieu Stoffel[3], Oliver Schmidt[4], and •Heidemarie Schmidt[5] — [1]Universität Leipzig, Institut für Experimentelle Physik II — [2]Universität Leipzig, Institut für Mineralogie, Kristallographie und Materialwissenschaft — [3]MPI für Festkörperforschung, 70569 Stuttgart — [4]IFW Dresden, Institut für Integrative Nanowissenschaften — [5]Forschungszentrum Dresden-Rossendorf e.V., Institut für Ionenstrahlphysik und Materialforschung

The main motivation for mixing a small amount of Ge into Si for example by the self-organized growth of a stack of Ge dots into Si [1], is the controlled modification of the electronic band structure in strained Si namely charge carrier mobility and optical transition probabilities. We report on charge accumulation in fivefold stacks of Ge quantum dots embedded in the n-region of a p+n-Si diode. By means of thermal admittance spectroscopy, capacitance voltage and deep level transient spectroscopy measurements [2] electron confinement in the type II Ge/Si-heterostructures, barrier effects of the quantum wells and wetting layers and defect states in the n-region of the sample associated with the surrounding Si-matrix have been probed. By relating these results to the self consistently modeled electronic band-structure and capacitance voltage characteristic charge accumulation in quantum confined electron states in the investigated type II Ge/Si-heterostructures is clearly revealed. [1] A. Malachias et al., Thin Solid Films 515, 5587 (2007)[2] M. Gonschorek et al., Phys. Rev. B 74, 115312 (2006)

HL 51.30 Thu 16:30 Poster D

MBE-growth and analysis of Si and Ge nanowires and corresponding heterostructures — •Andreas Wolfsteller, Pratyush Das Kanungo, Trung-Kien Nguyen-Duc, Gerhard Gerth, Nikolai Zakharov, Peter Werner, and Ulrich Gösele — Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle (Saale), Germany

Nanowires (NW) are expected to be building blocks for future electronic and optical devices, e. g. new field-effect transistors or chemical sensors. The most common growth mechanism for the synthesis of epitaxial free-standing nanowires is the vapour-liquid-solid (VLS) mechanism, which can in principle also be applied to grow Si NW and nanowire-based SiGe heterostructures by molecular beam epitaxy (MBE) as it has been reported earlier [1]. Now also Ge NW have been grown and the use of Au colloids with 15-18 nm diameter as precursors for NW growth instead of the former deposition of a thin Au film drastically decreased the thickness of both the Si and Ge NW due to the prevention of Ostwald-ripening. Concerning the nanowire-based SiGe heterostructures, by varying the temperature during growth the maximum Ge concentration in selected layers within the NW could be improved from 10% to 26%. Furthermore we present the results from electrical (I-V) and optical (PL) measurements on Si and Ge NW and corresponding nanowire-based heterostructures. The morphology, crystal structure and chemical composition was analyzed by TEM, SEM, and EDX.

[1] N. D. Zakharov et al., J. Cryst. Growth 290 (2006) 6

HL 51.31 Thu 16:30 Poster D

I-V - Characteristics of chalcogenide glasses during threshold switching — •Hanno Volker, Carl Schlockermann, Gunnar Bruns, and Matthias Wuttig — 1. Physikalisches Institut 1A, RWTH Aachen, Germany

Phase Change Memories (PCMs) use the contrast in electrical conductivity between the amorphous and the crystalline phase of nanoscale cells of various chalcogenides. This memory technology has very promising scaling properties in contrast to the established flash memories. Switching from the crystalline to the amorphous phase (RESET) is achieved by applying a short, but high, current pulse. This heats the material above the melting temperature. Subsequent rapid quenching creates an amorphous phase. Switching from the amorphous phase to the crystalline phase (SET) is performed by applying a lower, but longer current pulse which heats up the material above the crystallization temperature.

This current can be applied at voltages of the same order of magnitude as for the reset pulse due to an effect called threshold-switching: At a specific threshold voltage, the amorphous material switches from a low-conductive (OFF) state to a high-conductive (ON) state. Several competing models which describe the conduction mechanism in the amorphous state can explain this effect.

Using an extremely fast measurement setup, we have gained a deeper insight both in the life time and I-V properties of this highly non-linear behavioir.

HL 51.32 Thu 16:30 Poster D

Pressure-induced phase transition in Cu_3N — •Komalavalli Thirunavukkuarasu[1], Dieter Rau[2], Rainer Niewa[2], and Christine A Kuntscher[1] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Department Chemie, Technische Universität München, 85474 Garching, Germany

Cu_3N has attracted a lot of attention since the 1980ies because of its possible application prospect as an optical storage medium [1]. Cu_3N decomposes into Cu and N_2 at temperatures 300 - 470°C and undergoes a semiconductor-to-metal transition; therefore, it can be used as a write-once optical recording material upon heating. The relatively low decomposition temperature of this compound indicates weak Cu-N bonding and therefore high sensitivity with respect to pressure modifications. Furthermore, the relatively small band gap of 1 eV suggests that a pressure-induced metallization could be induced at modest pressures. Indeed, a semiconductor-to-metal transition induced at around 5 GPa is observed by pressure-dependent resistivity measurements [2,3]. We performed pressure-dependent transmittance measurements on Cu_3N powder samples in the infrared-visible frequency range for pressures up to 11 GPa. The evidence for a pressure-induced semiconductor-to-metal transition in the optical properties of this compound is discussed. *We acknowledge the ANKA Angströmquelle Karlsruhe for the provision of beamtime and the DFG for financial support.*

[1] T. Maruyama et al., Appl. Phys. Lett., **69**, 890 (1996).
[2] L. X. Yang et al., Chin. Phys. Lett., **23**, 426 (2006).
[3] J. G. Zhao et al., phys. stat. sol (b), **243**, 573 (2006).

HL 51.33 Thu 16:30 Poster D

High pressure investigations of the Mott insulator GaV_4S_8 — Xin Wang[1], •Martin K. Forthaus[2], Karl Syassen[1], Ingo Loa[1], Dirk Johrendt[3], and Mohsen M. Abd-Elmeguid[2] — [1]Max-Planck-

Institut für Festkörperforschung, Stuttgart, Germany — [2]II Physikalisches Institut, Universität zu Köln, Köln, Germany — [3]Department Chemie and Biochemie der Ludwig-Maximilians-Universität München, München, Germany

AM_4X_8 (A=Ga; M=V, Mo, Nb, Ta; X=S, Se) compounds with the cubic fcc $GaMo_4S_8$ type structure represent a new class of Mott insulators in which the electronic conduction originates from hopping of localized electrons ($S = 1/2$) among widely separated tetrahedral M_4 metal clusters. Current research on $GaNb_4Se_8$ and $GaTa_4Se_8$ show that their ground state is closely related to a structural instability: at ambient pressure they are nonmagnetic insulators, but under pressure transform to a metallic and superconducting state. In contrast, GaV_4S_8 is a ferromagnetic insulator ($T_C = 10$ K) at ambient pressure.

For a better understanding of the electronic correlations, we have investigated the effect of pressure on the electrical transport, crystal structure, Raman modes, and infrared response of the Mott insulator GaV_4S_8. We discuss our observation of a pressure-induced insulator metal transition above 18 GPa and its possible connection to a structural instability, Raman modes and infrared response.

HL 51.34 Thu 16:30 Poster D

Anomalously localized states at the metal-insulator transition in the Anderson model of localization — •Philipp Cain and Michael Schreiber — Institut für Physik, Technische Universität, D-09107 Chemnitz

Exceptional statistical fluctuations of the disordered potential lead to very strongly localized states. These so-called anomalously localized states (ALSs) appear also among the critical eigenstates at the metal-insulator transition (MIT) and might influence the behaviour of the critical properties. We identify ALSs for the Anderson model of localization at the MIT in the band centre of three-dimensional disordered samples. From the study of the multifractal correlation exponent $z(q)$ and the correlation dimension D_2 we can conclude that ALSs affect the critical properties at the MIT. Therefore the ALSs should be excluded from the ensemble in order to achieve a better characterization of the critical behaviour. However, in our investigation the improvement is not as good as it has been found in the 2D symplectic case.

HL 51.35 Thu 16:30 Poster D

Investigations of the Quality of $Mg_xZn_{1-x}O$-ZnO Quantum Well Interfaces grown by pulsed laser deposition — •Martin Lange, Susanne Heitsch, Gabriele Benndorf, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

$Mg_xZn_{1-x}O$-ZnO single quantum wells with $x \sim 0.2$ and nominal thickness of 4 nm have been grown on a-plane sapphire substrates by pulsed laser deposition. The samples were grown at an oxygen pressure of 2×10^{-3} mbar and a temperature of ∼620 °C. Before and after the deposition of the quantum well, growth interruptions with a duration of up to 10 minutes were performed. During the growth interruption the growth parameters have been kept constant. The samples have been investigated with photoluminescence at room temperature and at 2 K and atomic force microscopy. At low temperature a small blueshift as well as an increase of the full width at half maximum value of the quantum well peaks were observed for longer interruptions. The roughness of the interfaces within each sample was estimated by calculating a roughness parameter from the peak position and the width of the peak. A quantum well with finite barrier height was used as a model. Possible reasons for the blueshift will be suggested.

HL 51.36 Thu 16:30 Poster D

White luminescence of vanadium implanted ZnO PLD films — •Sven Müller[1], Carsten Ronning[1], Michael Lorenz[2], Christian Czekalla[2], Gabriele Benndorf[2], Holger Hochmuth[2], Marius Grundmann[2], and Heidemarie Schmidt[3] — [1]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany — [3]Forschungszentrum Dresden-Rossendorf e.V., Bautzner Landstraße 128, 01328 Dresden, Germany

Pulsed laser deposited ZnO films were implanted with vanadium ions using ion energies between 30 and 250 keV in order to create a box-like doping profile. Different fluences yielded into vanadium concentrations of 0.8, 2.5 and 5 at.%, and a reference sample was implanted with Ar. After annealing under oxygen ambient at 800°C, broad yellow, green, and blue photoluminescence bands were observed for all V-implanted ZnO samples whereas the Ar-implanted ZnO sample exhibits a red-yellow luminescence band. The green luminescence band of V-implanted ZnO shows a modulated fine structure and the complete luminescence reveals a white color in the eye of the beholder. Therefore, the light emission was quantified using the color space map of the Commission internationale de l'Éclairage (CIE). The origin of the red-yellow and green luminescence as well as the luminescence emission properties will be discussed in the presentation.

HL 51.37 Thu 16:30 Poster D

Structural properties of ZnO Nanorods before and after Ga-Implantation in a Focused-Ion-Beam-System — •Michael Dürrschnabel[1], Daniel Weissenberger[1], Dagmar Gerthsen[1], Anton Reiser[2], Günther Prinz[2], Martin Feneberg[2], Klaus Thonke[2], and Rolf Sauer[2] — [1]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe, D-76128 Karlsruhe, Germany — [2]Institut für Halbleiterphysik, Universität Ulm, D-89081 Ulm, Germany

The structural properties of ZnO nanorods grown by the vapor-liquid-solid technique on sapphire were studied by transmission electron microscopy. Implantations were carried out in a focused-ion-beam system with 30 keV Ga^+ ions and doses D from 10^{11} to 10^{16} cm^{-2}. The nanorods are almost free of defects before implantation. Small defects with extensions below 9 nm and a density of 5x10^{15} cm^{-3} are found for $10^{11} \leq D \leq 10^{12}$ cm^{-2}. At $D = 10^{14}$ cm^{-2}, dislocation loops with diameters up to 20 nm and a concentration of 1.8x10^{17} cm^{-3} are formed. The dislocation loops bind stacking faults which consist of inserted or missing (0002) planes oriented perpendicular to the [0001] nanorod axis. At $D = 10^{16}$ cm^{-2}, the planar defects agglomerate and form three-dimensionally defective regions. Energy dispersive X-ray analysis yield a Ga-concentration of about 1 % for $D = 10^{16}$ cm^{-2} leading to a resistivity decrease from 0.04 Ωcm before implantation to 0.003 Ωcm after implantation despite the high defect density which strongly lowers the mobility.

HL 51.38 Thu 16:30 Poster D

Magneto transport properties of codoped ZnCoO — •Christoph Knies[1], Matthias T. Elm[1], Jan Stehr[1], Peter J. Klar[1], Detlev M. Hofmann[1], Tom Kammermeier[2], Andreas Ney[2], and Nikolai Romanov[3] — [1]I. Physikalisches Institut, Justus-Liebig Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — [2]Univ. Duisburg-Essen, Germany — [3]Ioffe Institute, St. Petersburg, Russia

Current models predict that ZnO with ferromagnetic properties can be obtained by alloying the material with Co. Additionally a co-doping with shallow donors is needed to mediate the exchange interaction. We have prepared thin film of such materials by colloid chemical methods with Co concentrations up to 30%. For Co concentrations higher than 15 % the formation of secondary phases becomes evident from X-ray diffraction. All samples are high resistive in the as grown state and can be converted to n-type conduction by an annealing step in Zn vapour (450 °C, for 10 min.), which is believed to create Zn interstitial shallow donors. This process is reversible, subsequent annealing in air or O2 causes high resistivity again. The conducting films are suitable for temperature dependent magneto-transport measurement in order to investigate a possible spin-polarisation of carriers. We find the usual weak negative magneto-resistive effect in the ZnO reference sample. In the Co doped samples this effect is superimposed by a positive magneto-resistive effect at temperatures below 40 K. It is due to the alloy scattering caused by the Co ions. The results of further detailed characterisation of the co-doped ZnCoO will be discussed.

HL 51.39 Thu 16:30 Poster D

Tunnelling process in ZnSe/ZnMnSe double-quantum-well structures — •Stephanie Jankowski, Tobias Niebling, and Wolfram Heimbrodt — Phillipps-University Marburg, Department of Physics and Matrial Science Center, Renthof 5, 35032 Marburg

Asymmetric ZnSe/ZnMnSe double-quantum-well (DQW) structures with different barrier width have been grown between ZnMnSe cladding layers on a (100) GaAs substrate with a ZnSe buffer. The ZnSe wells are under tensile strain in these DQW structures yielding the light-hole exciton states to be the energetically lowest lying states. This is different to earlier papers , where tunnelling of carriers and excitons have been studied in DQW structures made of diluted magnetic semiconductors with heavy hole excitons to be the lowest lying states. In an external magnetic field we were able to manipulate the barrier

height due to Giant Zeeman effect of the ZnMnSe barriers. Hence we can study the tunnelling processes in these structures in dependence of the height and width of the barrier by photoluminescence, photomodulated reflectivity as well as time resolved measurements. Surprisingly, very different results to heavy hole tunnelling have been found. The obtained results and differences will be discussed in detail.

HL 51.40 Thu 16:30 Poster D

Epitaxial ferroelectric BTO/ZnO heterostructures — •Brandt Matthias[1], Holger Hochmuth[1], Michael Lorenz[1], Nurdin Ashkenov[1,2], Matthias Schubert[3], Venkata Voora[3], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für ExperimentellePhysik II, Leipzig, Germany — [2]Now at Opteg GmbH, Leipzig, Germany — [3]Department of Electrical Engineering, University of Nebraska-Lincoln, Lincoln, U.S.A.

Ferroelectrics are a material class of increasing importance in electronics, including ferroelectric switches, capacitors, non–volatile memory elements, optical switches and thin film transistors. While the polarization in ferroelectric materials is switchable by external electric fields, wurtzite ZnO exhibits a permanent spontaneous polarization. Previously, polarization coupling effects have been observed by us in experiments on Pt/BTO/ZnO/Pt structures on Si [1]. Asymmetric current-voltage (I–V), capacitance-voltage (C–V) and field dependent polarization P(E) hysteresis loops were demonstrated [2]. Detailed investigations on the homogeneity of fabricated wafers have been carried out, and were compared to data obtained on Pt/BTO/Pt samples. Further a model of the polarization exchange coupling was developed, and is applied to analyze the experimental data. The model is tested on experimental P(E) curves obtained at different voltages and probe frequencies.

[1] B. N. Mbenkum et al.: Appl. Phys. Lett. **86**, 091904 (2005).
[2] N. Ashkenov et al.: Thin Solid Films **486**, 153-157 (2005).

HL 51.41 Thu 16:30 Poster D

Magneto-transport measurements on artifically structured ZnO epitaxial layers — •Matthias T. Elm, Stefan Lautenschläger, Torsten Henning, and Peter J. Klar — Institute of Experimental Physics, Justus-Liebig-University of Giessen, Germany

ZnO layers with a thickness of about 1000 nm were grown homoepitaxically on ZnO substrate by chemical vapor deposition. The layers are n-type with electron concentrations of about 10^{17} cm^{-3}. Different parts of the as grown samples were artificially structured by photolithography. The patterns consist of regular arrays of holes with different hole diameters and spacings, which were transferred into the layer by chemical etching. In some of the samples the holes were filled in an additional preparation step with a metal, e.g. Au or Al, by either sputtering or electron beam evaporation. These structures were investigated by magneto-transport measurements in a temperature range from 2 to 280 K in external magnetic fields up to 10 T. The differences in the temperature-dependent behavior as well as in the magneto-resistance between samples with and without metal content are discussed.

HL 51.42 Thu 16:30 Poster D

Epitaxially grown artificially structured ZnO layers investigated by thermoelectric measurements — •Gert Homm[1], Jörg Teubert[1,2], Stefan Lautenschläger[1], Torsten Henning[1], Peter J. Klar[1], and Bruno K. Meyer[1] — [1]Institute of Experimental Physics I, Justus-Liebig-University Gießen, Germany — [2]Department of Physics and Science Center, Philipps-University Marburg, Germany

ZnO layers of about 1000 nm thickness were grown homoepitaxially on ZnO substrates by chemical vapor deposition. The layers are n-type with electron concentrations of about 10^{17} cm^{-3}. Stripes of the as grown samples were artificially structured by photolithography. The patterns consist of regular arrays of holes with different spacings and hole diameters. The patterns were transferred either by wet-chemical etching or by ion-beam etching. The Seebeck coefficient is measured in the temperature range of 50 to 300 K. The influence of the artificial structuring on the Seebeck coefficient is discussed.

HL 51.43 Thu 16:30 Poster D

Empirical pseudopotential calculation of strain induced birefringence in ZnO — Daniel Fritsch[1] and •Heidemarie Schmidt[2] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, PO Box 270116, D-01171 Dresden, Germany — [2]Forschungszentrum Dresden-Rossendorf e.V., PO Box 510119, D-01314 Dresden, Germany

One big challenge in the fabrication of ZnO-based heterostructure devices is the lattice mismatch between ZnO films and substrates and the different thermal expansion coefficients inducing biaxial strain. There is currently also much interest in ZnO doped with 3d transition metal ions for spintronics applications and the detection of ferromagnetic signatures by magneto-optical measurements of ordering induced birefringence being most intense around the critical point structure of the dielectric function. A quantitative understanding of Zeeman splitting far away from the center of Brillouin zone is still an open question and requires a separation of strain and magnetic field induced modifications of the electronic band structure. We report on the effect of strain on the birefringence in ZnO films grown on Al_2O_3 or on SiC substrates. The imaginary part of the dielectric function has been calculated by means of the empirical pseudopotential method. Thereby we also accounted for relativistic effects in form of the spin-orbit interaction, for the energy-dependence of the crystal potential through the use of nonlocal model potentials, and for excitonic contributions to the dielectric function due to discrete excitonic states and Coulomb-enhanced band-to-band transitions.

HL 51.44 Thu 16:30 Poster D

Artificially structured epitaxially grown ZnO layers investigated by transport measurements — •Markus Piechotka[1], Matthias T. Elm[1], Sebastian Eisermann[1], Achim Kronenberger[1], Thomas Wassner[2], Torsten Henning[1], Martin Eickhoff[2], Peter J. Klar[1], and Bruno K. Meyer[1] — [1]Institute of Experimental Physics I, Justus Liebig University, Heinrich Buff Ring 16, D 35392 Giessen, Germany — [2]Walter Schottky Institut, Technische Universitaet Muenchen, Am Coulombwall 3, D-85748 Garching, Germany

Several n-type ZnO layers were grown heteroepitaxially on Al_2O_3 substrates either by MBE with a thickness of 300 nm to 400 nm on a 20 nm MgO buffer layer or by cathode sputtering with a thickness of 1100 nm. Stripes of the as grown samples were artificially structured by photolithography. Each pattern consists of two contact pads with a regular array of wires of the same width in between. The wire thickness varies throughout the series of patterns from 4 μm to 1000 μm whereas the total cross section area of the wires is kept constant. The patterns were transferred either by wet-chemical etching or by ion-beam etching. The resistance of the wire patterns was measured in the temperature range from 2 to 300 K and in magnetic fields of 0 to 10 T. The analysis of the resistivity as a function of wire width yields information about the depth of the surface damage caused during the etch process.

HL 51.45 Thu 16:30 Poster D

Zeitaufgelöste Photolumineszenz an Zinkoxidnanoröhren: Einfluss der Oberfläche und Identifikation einer Oberflächensignatur — •Alexej Chernikov[1], Swantje Horst[1], Sangam Chatterjee[1], Wolfgang Rühle[1], Peter K. Klar[2] und Michael Tiemann[3] — [1]Fachbereich Physik, Philipps-Universität Marburg, Germany — [2]Institute of Experimental Physics I, JLU, Giessen, Germany — [3]Institute of Inorganic and Analytical Chemistry, JLU, Giessen, Germany

Es wurde zeitaufgelöste Photolumineszenz (PL) an doppelt invertierten Zinkoxidnanoröhren mit unterschiedlicher Oberfläche und an Zinkoxidvolumenmaterial gemessen. Zur Anregung wurde ein gepulster Titan-Saphir-Laser mit 80MHz in Kombination mit einem Frequenzverdreifacher verwendet. Die Pulslänge betrug 100fs und die Photonenergie nach der Verdreifachung 4,28eV. Detektiert wurde die PL nach spektraler Zerlegung durch ein Spektrometer mit einer Streakkamera. Es zeigt sich bei der PL der Nanoröhren eine Bande, deren Intensität abhängig von der Oberflächengröße ist und bei den PL-Spektren des Volumenmaterials nicht auftritt.

HL 51.46 Thu 16:30 Poster D

n-type doped ZnO nanorods for heterostructure application — •Janos Sartor, Hujuan Zhou, Johannes Fallert, Felix Stelzel, Roman J. B. Dietz, Mario Hauser, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe(TH), Germany

ZnO is considered as a promising material for blue/ultraviolet (UV) light emitting diode (LED) or laser diode (LD) structures. Due to the difficulty of the growth of reproducible p-type ZnO, heterojunctions of n-type ZnO grown on p-type material are under intense investigation. We have reported in earlier work the growth of ordered, vertically

aligned, dense arrays of single crystal ZnO nanorods with a chemical vapor transport method. In this work we present the growth of highly indium doped n-type ZnO nanorods on GaN thin films. Low temperature photoluminescence measurements show predominant emission in the UV region. Compared with the nominally undoped ZnO nanorods, the indium relevant donor bound exciton is overwhelming in the In-doped nanorods, while the A-free exciton can be observed, indicating the good crystal quality of the rods. Investigations on the luminescence properties as well as the possible lasing behavior from heterostructures are in progress.

HL 51.47 Thu 16:30 Poster D

Density-Functional Tight-Binding Calculations on Functionalized ZnO Surfaces — •Ney Henrique Moreira, Andreia Luisa da Rosa, and Thomas Frauenheim — BCCMS, Universität Bremen, Am Fallturm 1, 28359, Bremen, Germany

Organic coated semiconductor materials have attracted a lot of attention due to their possible applications in electronic and optoelectronic devices, since organic molecules can induce significant changes on the electronic and optical properties of nanostructures when attached to their surfaces. Zinc oxide is usually recognized as one of the most promising materials for optoelectronics due its wide bandgap (3.3 eV), large excitonic binding energy, low cost and environmental friendly processability. Recent Density Functional Theory (DFT) based theoretical investigations [1-3] had enlightened the understanding of the geometry and electronic structure of bare ZnO surfaces and nanowires. In our present work we use the Density-Functional based Tight-Binding method to investigate polymer-functionalized ZnO surfaces. We demonstrate how the presence of organic molecules can change their physical properties when compared with bare surfaces.

[1] Xu H., Rosa AL., Frauenheim Th., et al. Appl. Phys. Lett., 91, Art. No. 031914 (2007).
[2] Fan W., Xu H., Rosa AL., Frauenheim Th., et al, Phys. Rev. B, 76, Art. No. 073302 (2007).
[3] Xu H., Zhang RQ., Zhang X., Rosa AL., and Frauenheim Th., Nanotech., 18, 485713(2007).

HL 51.48 Thu 16:30 Poster D

Polarisation dependence of the free discrete exciton luminescence in ZnO microwires — •Rüdiger Schmidt-Grund, Helena Hilmer, Christian Czekalla, Bingqjang Cao, Chris Sturm, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Inst. für Exp. Physik II, Linnéstr. 5, 04103 Leipzig

We report on the polarisation dependence of the free discrete exciton luminescence recorded from unstrained single-crystal ZnO microwires at temperatures between 10 K and room temperature. The threefold split topmost valence band in ZnO gives rise to the formation of three excitons (labeled A, B, C for increasing energy) with different energies and different selection rules for the coupling to light polarised parallel (pc) or perpendicular (sc) to the ZnO optical axis, specified by the symmetry of the valence bands. The sign of the spin-orbit and crystal field interaction and therefore the symmetry order of the three valence bands for ZnO is still a subject under debate. For our samples, at temperatures larger than 180 K, the emission from the A- and B-excitons was found to dominate the photoluminescence spectra for polarisation sc, while the C-exciton is more pronounced in the spectra for polarisation pc. This finding is concordant with predictions made for a valence band order Γ_7-Γ_9-Γ_7. At very low temperatures, no luminescence of the C-exciton for any polarisation could be detected, but the luminescence from the A- and B-excitons is suppressed for the polarisation pc. As the intensity of the C-exciton luminescence increases with increasing temperature, we attribute this finding to be caused in the temperature dependence of the occupation function of the exciton states.

HL 51.49 Thu 16:30 Poster D

Magneto-optical properties of ZnO with Mn ion-beam implantation — Limei Chen[1], Samer Al-Azzaui[1], •Wolfram Heimbrodt[1], Daniel Stichenoth[2], Sven Müller[2], and Carsten Ronning[2] — [1]Department of Physics, Philipps Universtiy of Marburg, Renthof 5, 35032 Marburg — [2]II. Institute of Physics, Georg-Augusta University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We studied optical and magneto-optical properties of a series of (Zn,Mn)O samples with various Mn contents. The samples were prepared by ion-beam implantation with ^{55}Mn into ZnO substrates. Multiple ion energies ranging from 20 to 450 keV were used in order to create a box-like homogeneous distribution of the implanted ions. By choosing different ion fluencies, samples with Mn concentrations from 0.1 % to 4 % were obtained. Post-implantation annealing procedures were performed at different temperatures and various lengths of time to remove the implantation-introduced damage and to reduce the Mn killer center density. The evolution of optical and magneto-optical properties as a function of Mn concentration and the effect of annealing process were studied in order to obtain better understanding of Mn incorperation into ZnO.

HL 51.50 Thu 16:30 Poster D

CVD growth of ZnMgO — •Sebastian Eisermann, Stefan Lautenschläger, Joachim Sann, Niklas Volbers, Markus Piechotka, Peter J. Klar, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

ZnMgO thin films and heterostructures grown by MOCVD usually require quite high substrate temperatures (approx. 800°C - 900°C), at high growth temperatures both, n-type and p-type doping, is quite difficult. It was our aim to explore the growth of ZnMgO thin films using a CVD process at much lower substrate temperatures. The growth temperature was between 550°C and 700°C. We used metallic precursors (Zn, Mg) and NO_2 as oxygen precursor. The grown thin films have been investigated by low temperature photoluminescence, the magnesium content was determined by SIMS and EDX. We were able to produce samples with a homogenious Mg concentration as well as samples with a linear gradient of the Mg concentration (0% - 3%) over the thin film surface. The band-edge photoluminescence shows a linear dependence on the Mg content, same for the shift of the Raman modes. The maximum magnesium content in our samples was 14 +/- 2 %.

HL 51.51 Thu 16:30 Poster D

Magneto-optic photoluminescence and spin flip Raman spectroscopy on $Cd_{1-x}Mn_xTe/Cd_{1-y}Mg_yTe$ quantum well samples — •Christian Kehl, Georgy Astakhov, Jean Geurts, and Wolfgang Ossau — Universität Würzburg, Physikalisches Institut, Experimentelle Physik III, Am Hubland, 97074 Würzburg

Using magneto-optic photoluminescence and spin flip Raman spectroscopy up to 4.5 tesla at 1.7 Kelvin, $Cd_{1-x}Mn_xTe$ quantum wells (QW) embedded in $Cd_{1-y}Mg_xTe$ barriers were investigated. The PL spectra show excitonic and trionic excitations of the quantum well. For the Raman study of paramagnetic resonance spin flips of Mn-ions resonant excitation of excitons in the QW was applied. In this way, multiple spin flips up to the fourth order were observed. We studied the effect of additional carriers in the QW both by increasing the illumination intensity at the excitonic level and by additional illumination beyond the barrier gap.

The results are discussed in terms of (i) the increase of trion intensity at the expense of the excitons, (ii) the influence of the photogenerated carriers on the multiple spin flip intensities and on the Mn g-factor. Thus, we gain insight into the effect of additional free carriers on the Mn-Mn-exchange interaction.

HL 51.52 Thu 16:30 Poster D

Characterisation of deep defects in ZnO thin films by means of optical deep level transient spectroscopy — •Martin Ellguth[1], Robin Weirauch[1], Matthias Schmidt[2], Holger von Wenckstern[1], Rainer Pickenhain[1], and Marius Grundmann[1] — [1]Universität Leipzig, Leipzig, Germany — [2]Forschungszentrum Dresden–Rossendorf e.V., Dresden, Germany

We investigated Schottky diodes on ZnO thin films grown by pulsed laser deposition using thermal admittance spectroscopy (TAS), deep level transient spectroscopy (DLTS), optical DLTS (ODLTS), and photocurrent spectroscopy (PC). The typically occuring impurities E1, L2, E3, E4, and E5 were found in DLTS and/or TAS measurements.

ODLTS measurements in the spectral range from 0.4 to 3.5 eV indicated that E1, L2, and E3 are optically inactive. For some samples we detected an optically active impurity by ODLTS which was not accessible to thermal capacitance spectroscopical methods due to its high binding energy. The experimentally determined optical capture cross section reveals that this impurity causes a high lattice distortion. Furthermore, there are at least three states generated by this defect which are situated 50 meV below the conduction band edge, in the mid–gap, and several meV above the valence band edge. ODLTS spectra showed a broad absorption band around 2.4 eV which coincides with the green luminescence in ZnO known from photo luminescence measurements.

A configuration coordinate diagram for these defect states is presented.

HL 51.53 Thu 16:30 Poster D

Study of the solubility limits and secondary phase formation for ZnO:TM (TM = V, Fe, Co, Ni) mixed crystals by Raman spectroscopy — •Martin Koerdel[1], Marcel Schumm[1], Fabian Bach[1], Huijuan Zhou[2], Wojciech Szuszkiewicz[3], Sven Mueller[4], Carsten Ronning[4], and Jean Geurts[1] — [1]Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Institut für angewandte Physik, Universität Karlsruhe — [3]Polish Academy of Science, Warsaw — [4]II. Physikalisches Institut, Universität Göttingen

For ZnO alloyed with transition metal (TM) ions the possibility of room temperature ferromagnetism is predicted if the TM ions occupy cation sites. To investigate the incorporation of various TM ions (V, Fe, Co, Ni) and to check their solubility limits in the ZnO crystal lattice we study the ZnO:TM and possible TM-oxide vibrations by Raman spectroscopy. Three ZnO:TM systems are compared: (i) layers prepared by sol-gel technique from nanocrystals, (ii) ion implanted layers and (iii) bulk crystals grown (900°C) by vapor phase transport. TM ion concentration ranges up to 20 at.%. An annealing sequence (700°C, 900°C) is applied to systems (i) and (ii). Each annealing step significantly improves the crystal order. Below the solubility limit the incorporation of the TM ions only activates symmetry-forbidden ZnO host lattice phonon modes proportional to the TM ion fraction incorporated in the ZnO lattice. No TM local vibration modes are observed. TM solubility limits are typically below 10% and, moreover, depend strongly on the sample growth method. TM-oxides are identified not only by their phonons but also by magnetic excitations.

HL 51.54 Thu 16:30 Poster D

Sputter deposition of ZnO thin films at high substrate temperatures — •Achim Kronenberger, Sebastian Eisermann, Andreas Laufer, Swen Graubner, Angelika Polity, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

For the use of sputter deposited ZnO thin films in semiconductor devices, not only the electrical behaviour but also to maintain high crystal quality of the deposited films is important.

Pure ZnO thin films have been prepared on quartz glass and sapphire substrates by radio-frequency (RF) sputtering using a ceramic ZnO target. The substrate-temperature during the deposition could be adjusted from RT up to 735 °C. Argon was used as sputter-gas and oxygen as reactive-gas to change the stoichiometry of the deposited thin films.

The crystallinity of the deposited films has been analysed by XRD measurements. For optical and electrical characterisation optical transmission and Hall-effect measurements have been performed. To investigate impurities the films have been analysed by EDX and SIMS.

The focus was set on the electrical and optical properties of the deposited ZnO thin films and their changing behaviour in the cause of the different deposition parameters such as gas pressures, substrate temperature and rf-power. The aim was to gain control over changing the resistivity in a wide range, while keeping the films transparent in the visible region of the electromagnetic spectra and simultaneous maintain a high crystal quality.

HL 51.55 Thu 16:30 Poster D

Polycrystalline Mn-alloyed indium tin oxide films — •Camelia Scarlat[1], Heidemarie Schmidt[1], Qingyu Xu[1], Mykola Vinnichenko[1], Andreas Kolitsch[1], Manfred Helm[1], and Felicia Iacomi[2] — [1]Forschungszentrum Dresden-Rossendorf e.V., Bautzner Landstraße 128, 01328 Dresden, Germany — [2]Al. I. Cuza University, Faculty of Physics, Carol I, 700506, Iasi, Romania

Magnetic ITO films are interesting for integrating ITO into magneto-optoelectronic devices. We investigated n-conducting indium tin oxide (ITO) films with different Mn doping concentration which have been grown by chemical vapour deposition using targets with the atomic ratio In:Sn:Mn=122:12:0, 114:12:7, and 109:12:13 [1]. The average film roughness ranges between 30 and 50 nm and XRD patterns revealed a polycrystalline structure. Magnetotransport measurements revealed negative magnetoresistance for all the samples, but high field positive MR can be clearly observed at 5 K with increasing Mn doping concentration. Spectroscopic ellipsometry (SE) has been used to prove the existence of midgap states in the Mn-alloyed ITO films revealing a transmittance less than 80%. A reasonable model for the ca. 250 nm thick Mn-alloyed ITO films has been developed to extract optical constants from SE data below 3 eV. Depending on the Mn content, a Lorentz oscillator placed between 1 and 2 eV was used to model optical absorption below the band gap.[1]C. Baban et al. E-MRS 2007, Straßbourg.

HL 51.56 Thu 16:30 Poster D

The structural impact of Mn implantation on a ZnO host lattice and the magnetic interaction of the implanted Mn ions studied by Raman scattering and Electron Paramagnetic Resonance — •Marcel Schumm[1], Martin Koerdel[1], Sven Mueller[2], Hayo Zutz[2], Carsten Ronning[2], Jan Stehr[3], Detlev M. Hofmann[3], and Jean Geurts[1] — [1]Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Physikalisches Institut, Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

We study the magnetic and structural properties of Mn implanted ZnO by Raman scattering and Electron Paramagnetic Resonance for Mn contents from 0.1% to 4%. EPR reveals that the Mn ions substitutionally occupy Zn sites in the ZnO Wurtzite lattice. The Mn ions in the implanted layer show an antiferromagnetic dipolar interaction which results in broad, unstructured EPR spectra. No secondary phases are detected with EPR, Raman, TEM, or XRD. In the low temperature Raman spectra, scattering from a magnetic excitation is observed and studied for temperatures 5K < T < 200K. Raman spectroscopy also yields detailed information on the Mn incorporation and the induced disorder. Spectral features related to the Mn implantation exhibit a strong dependence on the Mn content and the applied annealing steps (up to 900°C). They allow the distinction between implantation damage and impurity induced disorder, and identification of one peak as a candidate for a localized vibration mode of Mn in ZnO.

HL 51.57 Thu 16:30 Poster D

Effect of Se predeposition on the electronic and structural porperties of n-ZnSe layers grown on n-GaAs(001) by molecular beam epitaxy — •Alexander Frey, Suddhosatta Mahapatra, Claus Schumacher, Laurens W. Molenkamp, and Karl Brunner — Universität Würzburg

We have fabricated n-doped ZnSe layers on n-GaAs(001) wafers by molecular beam epitaxy with different conditions employed at the II-VI growth start. The samples have been studied by RHEED, HRXRD, defect etching, temperature dependent I-V measurements through the n-ZnSe/n-GaAs interface and electrochemical C-V profiling. It is found that controlled deposition of selenium in the fractional monolayer range reduces the conduction band offset at the heterointerface from 470meV (Zn-rich interface) down to 65meV, while at the same time improving the structural quality of the layers. Such structures with low offset could be employed for efficient spin injection from ZnSe based dilute magnetic semiconductors into GaAs.

HL 51.58 Thu 16:30 Poster D

Investigation and analysis of ZnS substrates — •Oliver Graw[1], Stefan Lautschläger[1], Joachim Sann[1], Niklas Volbers[1], Swen Graubner[1], Andreas Laufer[1], Dietrich Schwabe[1], Bruno K. Meyer[1], Jürgen Bläsing[2] und Alois Krost[2] — [1]I. Physics Institute, Justus-Liebig-University, Giessen, Germany — [2]Institut for Experimental Physics, Otto-von-Guericke University, Magdeburg, Germany

ZnS with its direct bandgap of 3.6 eV at room temperature and its cubic crystal structure is an suitable candidate material for optoelectronic devices in the UV region. It has some advantages compared to its direct opponents ZnO and GaN for example its lack of crystal field or piezo electricity. We investigated commercially available ZnS single crystals, obtained from different suppliers, regarding to structural quality, photoluminescence, impurity content and electric properties. Comparisons with single crystals grown in our institute have been undertaken.

HL 51.59 Thu 16:30 Poster D

Donor doping of ZnO with group VII elements — •Melanie Pinnisch[1], Joachim Sann[1], Niklas Volbers[1], Andreas Laufer[1], Sebastian Zöller[1], Stefan Lautenschläger[1], Kay Potzger[2], and Bruno K. Meyer[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany — [2]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 51 01 19, 01314 Dresden, Germany

In order to produce ZnO-based devices not only p-type doping, but

also controlled n-type doping is essential. For the group VII elements F, Cl, Br, I substituting O neither their donor levels nor their influence on photoluminescence spectra have been intensely studied. In this work we doped ZnO single crystals with F, Cl, Br or I by diffusion through the surface and by ion implantation with fluences of about 10^{14} ions/cm^2. The samples have been investigated by Secondary Ion Mass Spectroscopy to verify the dopant incorporation. Low temperature high resolution photoluminescence measurements have been performed to identify the respective donor bound exciton recombination. We will make a correlation between doping and PL-recombinations.

HL 51.60 Thu 16:30 Poster D

Determination of charge state in Co- and Mn-doped ZnO films — •Daniel Markó[1], Kay Potzger[1], Karsten Küpper[1], Qingyu Xu[1], Shengqiang Zhou[1], Heidemarie Schmidt[1], Jürgen Fassbender[1], Michael Lorenz[2], Elke Arenholz[3], and Jonathan D. Denlinger[3] — [1]Forschungszentrum Dresden-Rossendorf e.V., Institut für Ionenstrahlphysik und Materialforschung, Bautzner Landstr. 128, D-01328 Dresden, Germany — [2]Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik, PO Box 100920, D-04009 Leipzig, Germany — [3]Advanced Light Source, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA

We have investigated Co- and Mn-alloyed ZnO films grown by pulsed laser deposition (PLD) on a-plane sapphire substrates. X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) measurements have been performed at beamline 8.0.1 and beamline 6.3.1 at the Advanced Light Source in Berkeley, USA. From XAS spectra, recorded in both total electron yield and total fluorescence yield mode, the valence states of Mn and Co have been determined. No ferromagnetic properties have been observed by means of XMCD at 20 K at the $L_{2,3}$-absorption edges of Mn and Co, respectively. This observation agrees with the purely paramagnetic response of those Co- and Mn-alloyed ZnO films from SQUID magnetometry and Hall effect measurements.

HL 51.61 Thu 16:30 Poster D

Characterization of $Mg_xZn_{1-x}O$-layers grown by plasma assisted molecular beam epitaxy — •Bernhard Laumer, Thomas A. Wassner, Stefan Maier, Jochen Bruckbauer, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

In order to reduce the large lattice mismatch, an optimized MgO-ZnO double buffer structure was employed to grow $Mg_xZn_{1-x}O$ layers on (0001)-sapphire by plasma assisted molecular beam epitaxy. The Mg concentration x was varied between 0 and 0.3. Structural analysis was carried out by high resolution X-ray diffraction (HRXRD) to extract the lattice parameters as well as the density of edge- and screw-type dislocations as a function of the Mg-content. The c-lattice parameter was found to decrease with increasing Mg content, whereas the a-lattice parameter remained constant. The influence of Mg-incorporation on the optical properties was investigated by temperature-dependent photoluminescence and absorption spectroscopy. With increasing Mg content effects due to disorder introduced by the Mg incorporation like a pronounced Stokes-shift and alloy broadening were observed. The background charge carrier concentration as determined by Hall measurements decreased with increasing Mg incorporation from $5 \cdot 10^{18}$ to $7 \cdot 10^{17}$ cm^{-3}.

HL 51.62 Thu 16:30 Poster D

Comparison of the crystalline and optical properties of VLS- and VS-grown ZnO nanopillars — •Anton Reiser, Vahid Raeesi, Dalia Omar Zayan, Günther M. Prinz, Martin Schirra, Martin Feneberg, Klaus Thonke, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm

Zinc oxide (ZnO) nanostructures were grown by two different methods, and their crystalline and luminescence properties are compared. In one series of experiments the vapor-liquid-solid (VLS) carbo-thermal mechanism was used to grow ZnO nanowires with gold particles acting as catalyst. In another series, a uniform basic zinc acetate (BZA)/ZnO nanocrystalline seed-layer was used as a template for the vapor-solid (VS) growth of the ZnO nanowires. In the first case, we observe real VLS and VLS-initiated growth of well-aligned ZnO nanowire arrays, where real VLS growth is defined by Zn-Au alloy droplets sitting directly on top of the wires. The related photoluminescence (PL) spectra show near-band edge features as typical for bulk ZnO. Line widths of below 0.7 meV for the donor-bound exciton transitions stand for good crystal quality. In the second case, we also observe well-aligned ZnO nanowire arrays, however with line widths down to 250 μeV.

HL 51.63 Thu 16:30 Poster D

Arsenic-doping of ZnO — Niklas Volbers[1], Stefan Lautenschläger[1], •Thomas Leichtweiss[1], Andreas Laufer[1], Swen Graubner[1], Bruno K. Meyer[1], Kay Potzger[2], and Shengqiang Zhou[2] — [1]1. Physics Institute, Justus-Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Institute for Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, PO Box 51 01 19, D-01314 Dresden, Germany

Arsenic is considered a potential candidate for p-type doping of zinc oxide (ZnO). Most of the publications on this topic discuss the electrical or optical properties. However, it is not always clear whether the formation of secondary phases, e.g. arsenic oxide clusters, might be the source for the observed effects.

To gain further insight into this topic, we have studied the incorporation of arsenic into zinc oxide using two different approaches.

The first series of samples consisted of zinc oxide single crystals implanted with ^{75}As ions with high doses of 10^{16}cm^{-2} at an energy of 200 keV. We have investigated the influence of annealing using Rutherford backscattering in channeling geometry (RBS/C), secondary ion mass spectrometry (SIMS), X-ray diffraction (XRD) and X-ray photospectroscopy (XPS). The results discuss the diffusion of the arsenic and of the impurities and the formation of secondary phases.

The second series of samples was grown using chemical vapour deposition (CVD), as this method can provide defect-free films of high crystalline quality. The samples were analysed regarding their homogenity and composition.

HL 51.64 Thu 16:30 Poster D

Structure, phase stability, and gaps of wurtzite MgZnO and CdZnO alloys — •Matthias Eisenacher[1], André Schleife[1], Lara Kühl Teles[2], Jürgen Furthmüller[1], and Friedhelm Bechstedt[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität and European Theoretical Spectroscopy Facility (ETSF), Max-Wien-Platz 1, 07743 Jena, Germany — [2]Departamento de Física, Instituto Tecnológico de Aeronáutica, Comando-Geral de Tecnologia Aeroespacial, 12228-900 São José dos Campos, SP, Brazil

Recently II-VI compounds became more and more important as materials with potential applications in optoelectronic devices. For pseudomorphic heterostructures it is highly desirable to adjust the material properties carefully. Alloys allow to tailor a certain material property. Also from a theoretical point of view the investigation of mixed crystals is a challenge.

We apply density functional theory and the generalized quasichemical approximation together with a cluster approximation to study MgZnO and CdZnO alloys in the wurtzite structure. The combination of these *ab initio* approaches enables us to study the thermodynamics of these systems as well as the structural and electronic properties with varying composition. We construct phase diagrams versus composition and temperature and calculate bond lengths as well as gap-bowing parameters for the two alloys versus average composition.

HL 51.65 Thu 16:30 Poster D

Optimization of PLD grown ZnO thin films using in-situ RHEED — •Alexander Hirsch, Christian Wille, Frank Ludwig, and Meinhard Schilling — TU Braunschweig, Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, Hans-Sommer-Straße 66, D-38106 Braunschweig, Germany

Due to its wide and direct band gap ZnO is an interesting semiconducting material. For application in combination with other oxides a smooth surface is indispensible. In-situ reflection high energy electron diffraction (RHEED) is a powerful tool for optimizing thin film quality.

The ZnO thin films were grown using pulsed laser deposition (PLD) technique. All targets were prepared by standard ceramics synthesis. As substrates Al_2O_3 in (0001) orientation was used. To obtain atomically flat sapphire surfaces an annealing treatment was applied. The epitaxial growth of the films is investigated by in-situ RHEED supplemented by X-ray diffraction and atomic force microscopy.

The dependence of the PLD parameters on the growth conditions is analyzed. To investigate the influence of the temperature, five thin films at deposition temperatures between 110 °C and 820 °C were prepared and analyzed. Deposition temperatures of 300 °C and 820 °C lead to high quality crystalline films with rms roughnesses of approx. 1 nm. Besides, the impact of Al doping on the structural film quality was investigated at a deposition temperature of 300 °C. Four thin

films with Al concentrations between 0 % and 2 % were grown under equal conditions. In addition, using in-situ RHEED characterization, the effect of interval deposition on the thin film quality was analyzed.

HL 52: Symposium Semiconducting Nanoparticles for Nano-Optics and Optoelectronics

Time: Friday 10:30–13:00 Location: ER 270

Invited Talk HL 52.1 Fri 10:30 ER 270

Semiconducting nanoparticles in industrial applications — •Martin Trocha, André Ebbers, Anna Prodi-Schwab, and Heiko Thiem — Evonik Degussa GmbH

Nanoscale semiconducting particles are already in use for large scale industrial applications since decades. Some examples are UV and IR absorbers in coatings, as absorbing additives in polymers and plastics, and for antistatic coatings on surfaces. Nevertheless the semiconducting nanoparticles play only a passive role as a mere additive.

From the industrial point of view semiconducting nanoparticles are also attractive to be used as active material in optoelectronic devices. Their particulate character allows the fabrication of dispersions and inks. Therefore efficient and cost-saving printing processes, even on flexible substrates, can be used to produce optoelectronic devices.

First applications developed by Evonik Industries are printed transparent conductive films in luminescent devices based on ITO and field effect transistors based on different semiconducting nanoparticles. In this presentation the current status and the future prospective of semiconducting nanoparticles will be outlined.

Invited Talk HL 52.2 Fri 11:00 ER 270

Silicon and Germanium Nanoparticles: Spectroscopy and Electronic transport — •Cedrik Meier, Stephan Lüttjohann, Matthias Offer, Sonja Hartner, Hartmut Wiggers, and Axel Lorke — CeNIDE-Center for NanoIntegration Duisburg-Essen, Lotharstraße 1,47057 Duisburg

Silicon nanoparticles are attractive candidates for photovoltaic and optoelectronics applications, as they allow to combine the advantages of a semiconducting material with the ease of handling of dispersed particles. However, for the realization of optoelectronic devices, one needs to optimize both, the optical efficiency of the emitter as well as the current transport in thin particle films.

In this talk, I will present spectroscopic results and discuss the fundamental limits of silicon nanoparticles as a quantum mechanical emitter in the strong confinement regime. Moreover, the excitonic fine structure in silicon nanoparticles which can be controlled via the temperature as an external parameter will be discussed.

Finally, results on electronic transport through nanoparticle films are presented. While the conductance of unsintered silicon nanoparticles is still unsufficient for most device applications, I will present recent results on magnetotransport through Germanium nanoparticle layers which are promising for applications.

Supported by the DFG via SFB 445-'Nanoparticles from the gas phase' and GRK 1240-'Nanotronics'.

Invited Talk HL 52.3 Fri 11:30 ER 270

Photoluminescence Spectroscopy of Semiconductor Nanorods and Their Hybrid Structures — •Andrey Rogach — Physics Department and CeNS, LMU Munich

Colloidal semiconductor nanocrystals can be produced nowadays in a variety of sizes, shapes and compositions. Due to their flexible surface chemistry, colloidal nanocrystals are also very attractive objects for use as building blocks in different functional hybrid structures within the bottom-up assembly approaches. Starting from a general overview on semiconductor nanocrystals and their assemblies, we will switch to ensemble and single particle photoluminescence spectroscopy data on the 'nanocrystals of mixed dimensionality', consisting of spherical CdSe cores with elongated CdS shells. The quantum confined Stark effect is in particular pronounced in these nanorod-like particles, and we demonstrate this by direct manipulation of the excited state of the nanorods using strong external electric fields. Electrical control of energy transfer will be addressed on hybrid structures of CdSe/CdS nanorods and organic dye molecules.

Invited Talk HL 52.4 Fri 12:00 ER 270

Charge carrier dynamics of surface modified semiconductor nanocrystals — •Alf Mews, Ma Xuedan, Jessica Völker, Maxime Tchaya, and Herbert Kneppe — Physical Chemistry, University of Siegen, 57068 Siegen, Germany

The optical and electronic properties of semiconductor nanostructures are strongly related to their inorganic and molecular surface modification. This is a direct consequence of surface passivation and/or the electronic interaction between the molecular surface ligands and the inorganic semiconductor cores. For example, photo induced charge transfer from the nanocrystals to the attached surface ligands will have a strong effect on both, the fluorescence intensity and the fluorescence lifetime of the nanocrystals.

Here we present a detailed study of different core/shell nanoparticels and several nanoparticle-ligand combinations, which are investigated by a combination of optical spectroscopy and cyclic voltametry (CV), respectively. This allows to measure the absolute energetic positions of the electronic NC- and ligand-levels by CV and compare them to the respective band-gaps and fluorescence intensities from the optical spectra. In addition we present different functional ligands, where the energetic levels are depending on the chemical environment. Finally we present results from single nanoparticle fluorescence spectroscopy to get a deeper insight into the fluorescence dynamics of individual surface modified nanocystals.

Invited Talk HL 52.5 Fri 12:30 ER 270

Ultrafast Exciton Relaxation Dynamics in Silicon Quantum Dots — •Carola Kryschi, Volker Kuntermann, Carla Cimpean, Vincent Groenewegen, and Anja Sommer — Institut für Physikalische Chemie I, FAU, Egerlandstr. 3, D-91058 Erlangen

A fundamental objective in nanoelectronics is to understand and to control electron flow between semiconductor nanoparticles which is mediated by chromophores attached to the nanoparticle surfaces. Our research activities are directed to the development of silicon quantum dots (Si qdots)with optical and electronic properties which may be adjusted by strong electronic interactions with suited chromophores. Therefore Si qdots with covalently bound chromophores were prepared which exhibit photoluminescence (PL) in the visible with quantum yields up to 37 %. The spectral features of the PL were observed to strongly depend on both, the quantum dot size and the conjugation of the electron system of the chromophores. In order to elucidate the electronic interactions between chromophore states and Si bulk states the PL properties of Si qdots dispersions were examined conducting stationary and time-resolved PL spectroscopy experiments, while ultrafast exciton rise and decay dynamics were studied using femtosecond transient absorption spectroscopy. A pyridine based chromophore was observed to provide nearly resonant electronic interactions with bulk states, whereas the temporal evolution of the transient absorption spectra obtained from a thiophene based chromophore gave unambiguous indication of excitation energy transfer from the chromophore to the Si bulk.

HL 53: Optical properties

Time: Friday 10:30–14:00 Location: EW 201

HL 53.1 Fri 10:30 EW 201

Long coherence times of yellow 1S-paraexciton polaritons in Cu_2O — •Jan Brandt[1], Dietmar Fröhlich[1], Christian Sandfort[1], Manfred Bayer[1], and Heinrich Stolz[2] — [1]Institut für Physik, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Fachbereich Physik, Universität Rostock, D-18051 Rostock, Germany

In a magnetic field the otherwise forbidden lowest exciton in Cu_2O (paraexciton of symmetry Γ_2^+) gives rise to a narrow absorption line of 80 neV at a temperature of 1.2 K. By time resolved spectroscopy of polariton propagation beats we can distinguish between homogenous and inhomgenous broadening. A small damping and therefore a long coherence time up to 40 ns at 1.2 K is observed. The temperature dependence of the homogenous linewidth is compared with the linewidth from transmission experiments and discussed in terms of longitudinal acoustic phonon scattering.

HL 53.2 Fri 10:45 EW 201

Energy transfer and excitation dynamics in doped 1D- and 2D-nanostructures — •Tobias Niebling[1], Manuel Demper[1], Limei Chen[1], Wolfram Heimbrodt[1], Peter J. Klar[2], Daniel Stichtenoth[3], and Carsten Ronning[3] — [1]Department of Physics and Material Sciences Center, Philipps University Marburg, Germany — [2]Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany — [3]II. Institute of Physics, University of Göttingen, Germany

Migration of optical excitation trapped in localized states is a general feature of doped semiconductors. However, the basic physical processes are not yet entirely clarified. Therefore ZnS and ZnO wires and ribbon-like crystals with diameters varying between 100 nm and 1 μm are synthesized in a vapour-liquid-solid process (VLS). Different doping elements are incorporated by ion beam implantation with variing fluencies. The energy transfer and migration processes inside the subsystem of the doping as well as the subsequent transfer to defect or radiationless centres are investigated by time-resolved photoluminescence spectroscopy in the range of 1 ns to 1 ms after the excitation pulse. ZnS and ZnO doped with manganese, rare earth elements and variing 'killer' centre concentrations induced by noble gas ion bombardment are studied. To explain the results, the well established Förster-model for energy transfer processes is modified for reduced dimensionality. It can be shown that the dimensionality of the nanostructures is defined by the ratio of the mean distance between the dopings and the 'killer' centres as well as the morphology of the nanowires.

HL 53.3 Fri 11:00 EW 201

Spin and energy structure of positively and negatively charged excitons in CdTe/CdMgTe quantum wells subject to strong magnetic fields of 33 Tesla — •Gregor Bartsch[1], Michael Gerbracht[1], Dmitri Yakovlev[1], Manfred Bayer[1], Janneke Blokland[2], Peter Christianen[2], and Jan Kees Maan[2] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]High Field Magnet Laboratory, Radboud University Nijmegen, 6525 Nijmegen, Netherlands

Optical studies of energy and spin structure of charged exciton complexes are reported for a 20 nm wide CdTe/CdMgTe quantum well. The sample is modulation p-type doped and contains resident holes, which give rise to formation of positively charged excitons. The type of resident carriers is inverted by above-barrier illumination to the electrons, which allows a comparative study of positively and negatively charged excitons in the same sample. Polarized photoluminescence and reflectivity spectra are measured at temperatures of 0.4 and 4 K and in external magnetic fields up to 33 T. Emission lines of singlet states of these complexes have opposite signs of circular polarization. The binding energy of the positively charged exciton decreases with growing magnetic field, which is qualitatively different from the behaviour of the negatively charged excitons. In high magnetic fields triplet states become bound both for negatively and positively charged excitons.

HL 53.4 Fri 11:15 EW 201

Die Strichlängenmethode: Verbesserte Auswertung — •Michael Schwalm[1], Christoph Lange[1], Sangam Chatterjee[1], Wolfgang W. Rühle[1], Nils Gerhardt[2], Shane R. Johnson[3], Jiangbo Wang[3] und Young-Hang Zhang[3] — [1]Fachbereich Physik, Philipps-Universität Marburg — [2]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum — [3]Center for Solid State Electronics Research and Department of Electrical Engineering, Arizona State University

Die Strichlängenmethode ist ein einfaches Verfahren zur Bestimmung der optischen Verstärkung beziehungsweise Abschwächung eines Mediums unter konstanten Anregungsbedingungen. Für die Auswertung der gewonnenen Messdaten standen in der Vergangenheit zwei verschiedenartige Auswertungskonzepte zur Verfügung, die in der praktischen Anwendung einige Probleme offenbarten.

Diese Probleme werden analysiert und neue, alternative Auswertungsverfahren entwickelt. Anhand theoretischer Betrachtungen im Rahmen der Fehlerfortpflanzung lassen sich Rückschlüsse auf die Rauschanfälligkeiten der neuen Methoden ziehen. Die Anwendung auf experimentelle Rohdaten erlaubt eine vergleichende Bewertung unter realen Bedingungen.

Die neu entwickelte "l/xl"-Methode erweist sich hierbei als ein robustes und verlässliches Verfahren, welches über einen breiten Bereich optischer Verstärkung, beziehungsweise Abschwächung einsetzbar ist und die Probleme der früheren Methoden umgeht [1].

[1] C. Lange et. al., Appl. Phys. Lett. **91**, 191107 (2007)

HL 53.5 Fri 11:30 EW 201

Carrier spin dynamics in GaAs/AlGaAs quantum wells, studied by time-resolved Kerr rotation — •Liudmila Fokina, Dmitri Yakovlev, and Manfred Bayer — TU Dortmund,Experimentelle Physik II,D-44221 Dortmund

We study of the electron spin coherence in GaAs/AlGaAs quantum wells heterostructures with a low-dense as well high dense two dimensional electron gas with help of the pump-probe time-resolved Kerr rotation technique. To explore the spin relaxation mechanism, we performed a systematic study of the dependence of the spin dephasing time on the characteristic parameters as temperature, magnetic field and electron concentration. Electron spin beats have been measured in magnetic field, which a precession frequency allows to determine the transverse component of the electron g-factor. When the spin dephasing times becomes longer than several ns, we used the technique of the resonant spin amplification (RSA), which has been developed to extract spin lifetimes that exceed the pulse repetition interval. We describe an interesting behaviour of the RSA signal in the interval of zero magnetic field.

HL 53.6 Fri 11:45 EW 201

Terahertz spectroscopy on a two-dimensional electron gas: Theory — •Daniel Golde[1], Sangam Chatterjee[1], Torben Grunwald[1], David Köhler[1], Klaus Pierz[2], Mackillo Kira[1], and Stephan W. Koch[1] — [1]Fachbereich Physik, Philipps-Universität, Renthof 5, D-35032 Marburg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We present a microscopic theory for the THz response of a two-dimensional electron gas (2DEG) embedded in a high electron mobility transistor. Since the fundamental excitation of electron gases, the plasmon, is typically related to THz frequencies in semiconductors, we can apply this theory for studying the plasmonic properties of the 2DEG. Although it is widely accepted that the two-dimensional plasmon frequency vanishes in the long wavelength limit, our calculations predict a clear plasmon peak of the inverse dielectric function. Based on these observations, we can conclude that the bare plasmon is independent of the dimension and only its self consistent field depends on the surrounding conditions. Furthermore, our analysis shows that the THz response of the 2DEG is strongly affected by many-body interactions.

Our theoretical results are in excellent agreement with corresponding experiments which will be presented by T. Grunwald in "Terahertz spectroscopy on a two-dimensional electron gas: Experiment".

HL 53.7 Fri 12:00 EW 201

***Ab initio* study of strain influence on electronic and optical properties of ZnO** — •André Schleife, Claudia Rödl, Frank Fuchs, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität and European Theoretical Spectroscopy Facility (ETSF), Max-Wien-Platz 1, 07743 Jena, Ger-

many

ZnO is a material which has been in the scientific focus for many decades. Recently, this strong interest was renewed because of two aspects: First, ZnO is a promising material for optoelectronic applications due to the availability of high-quality single crystals in combination with large exciton binding energies. Second, it is an interesting semiconductor, especially since p-doping seems to become possible.

We study the effect of biaxial strain on the electronic band structure and the optical transitions near the absorption edge by means of an *ab initio* approach. Starting from density functional theory in combination with a nonlocal exchange-correlation functional we compute quasiparticle energies within Hedins *GW* approximation to obtain a correct electronic band structure. Excitonic effects are considered by solving the Bethe-Salpeter equation. The corresponding Hamiltonian is constructed using a GGA+U starting point in combination with hybrid **k**-point meshes.

We calculate the positions of the Γ_9, Γ_7, Γ_7 valence levels and the corresponding excitons. The results may explain the long-standing problem of the correct valence-band ordering in ZnO by residual strain. Furthermore, we are able to derive $\mathbf{k} \cdot \mathbf{p}$ parameters for this material.

15 min. break

HL 53.8 Fri 12:30 EW 201

Terahertz spectroscopy on a two-dimensional electron gas: Experiment — •Torben Grunwald[1], Sangam Chatterjee[1], David Köhler[1], Klaus Pierz[2], Daniel Golde[1], Mackillo Kira[1], and Stephan W. Koch[1] — [1]Fachbereich Physik, Philipps-Universität, Renthof 5, D-35032 Marburg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We present THz transmission experiments on a two-dimensional electron gas (2DEG) with variable density. The THz response clearly shows a plasmon pole whose spectral position shifts to higher energies with increasing carrier density. This THz response of an unambiguously 2-dimensional system is similar to the response of a 3-dimensional system, observed by Huber et. al[3]. Furthermore, our measurements are in excellent agreement with a recently developed microscopic theory, indicating, that the bare plasmon properties are independent of dimensionality. A detailed analysis will be presented by D. Golde in "Terahertz spectroscopy on a two-dimensional electron gas: Theory".

[3]Huber, R. et al., Nature 414, 286-289 (2001)

HL 53.9 Fri 12:45 EW 201

Ab-initio Calculations of Raman scattering in SnO_x — •Ralf Meyer — Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

Oxidic semiconductors like ZnO_x and SnO_x have recently attracted a lot of attraction as possible optical materials for novel technological applications. Experimental studies of $SnO_{1.5}$ nanoparticles have shown strong differences between the Raman spectra of this material compared to the Raman spectra of bulk SnO_2 [1]. In order to understand these differences, ab-initio calculations of the Raman scattering properties of bulk SnO_2 and $SnO_{1.5}$ have been performed. It is shown that the spectra obtained from these calculations compare qualitatively well with the experimental findings. From this, it is concluded that the differences in the experiments are an effect of the bulk materials. An analysis of the nature of the calculated Raman active vibrational modes makes it possible to draw further conclusions on the reasons behind the differences between both types of materials.

[1] C. Meier et al., J. Appl. Phys. **99**, 113108 (2006).

HL 53.10 Fri 13:00 EW 201

The influence of size, shape, and targeted surface modification on the optical properties of small nanodiamonds — •Lasse Landt[1], David Wolter[1], Peter Schreiner[2], Andrey Fokin[2], Jeremy Dahl[3], Robert Carlson[3], Thomas Möller[1], and Christoph Bostedt[1] — [1]Technische Universität Berlin, Germany — [2]Justus-Liebig-Universität, Giessen, Germany — [3]MolecularDiamond Technologies, USA

Diamondoids are a new exciting class of nano-carbon materials which can be considered the smallest possible cage-like subunits that can be excised from diamond lattice. They form a series of perfectly size- and shape-selectable, neutral nanodiamonds that grow only one crystal cage - or 4 carbon atoms - at a time. Therefore investigations on the size and shape dependence of the optical properties of these group IV nanocrystals have become feasible with atomic precision.

We have measured the optical absorption of diamondoids ranging from 0.5 to 1 nm in size, among them several isomeric structures. Our data show that the optical properties in this size regime are dominated by the crystal arrangement. In effect, it is found that the rearrangement of a single crystal cell outweighs a 30% size increase. We also present optical data on specifically surface modified diamondoids. Comparing the data sets of pristine and surface modified diamondoids represents a powerful tool to define the exact influence of selected surface modifications on the optical properties of such nanocrystals. All data were taken from neutral, high purity samples in the gas phase yielding unprecedented comparability to theoretical predictions.

HL 53.11 Fri 13:15 EW 201

Three-dimensionally Confined Optical Modes in Microtube Bottle Resonators — •Hagen Rehberg, Christian Strelow, Christoph M. Schultz, Holger Welsch, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

We report on three-dimensional confinement of optical modes in microtube ring resonators induced by a radius modulation. Our microtubes are fabricated by the use of the self-rolling mechanism of thin strained bilayers. The radius modulation is caused by local additional windings forming two rings around the tube. Spatially resolved microphotoluminescence measurements show modes which are axially confined between the rings. We observe axial field distributions which resemble standing waves in an optical bottle with intensity enhancements at the classical turning points. The confining mechanism is discussed in terms of a squeezing of the tube by the additional rings. Calculations using an adiabatic approximation define a quasi-potential for the slow propagation along the tube axis. This quasi-potential induced by the fast propagation around the tube axis depends strongly on the radius of the tube. Correlations of both calculations and measurements give an insight into the actual size and form of the radius modulation. The reported technique of radius modulation allows a tailoring of the mode energies and to realize a two-port device which can be used as an optical filter. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508 and GrK 1286 "Functional Metal-Semiconductor Hybrid Systems".

HL 53.12 Fri 13:30 EW 201

Subwavelength gratings as polarization selective reflectors — •Niko-Stephan Münzenrieder, Taek Lim, Alexander Bachmann, Kaveh Kashani-Shirazi, and Markus-Christian Amann — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Highly reflecting mirrors are an essential part of vertical cavity surface emitting lasers (VCSELs) which are known for their superior properties regarding single-mode behaviour, circular beam shape and low manufacturing costs compared to other semiconductor lasers. However, due to their cylindrical symmetry these devices are not intrinsically polarization stable. One concept to solve this issue is to use polarization selective mirrors which can be realized with grating structures. Another advantage of suitable grating designs is their high reflectivity which can improve VCSEL properties and simplify the device processing.

In this talk we present a concept for structures which can be easily integrated in established VCSEL devices with dielectric Bragg mirrors. Optimal grating parameters such as period, layer thicknesses and filling factors for given material combinations can be found using standard wave-optical methods like FDTD. Challenging aspects during the manufacturing of the gratings are the small dimensions which have to be significantly smaller than the vacuum wavelength of the VCSEL light. The technological realization of grating structures based on common dielectrics like amorphous silicon and silicon dioxide is investigated considering the compatibility to the VCSEL process.

HL 53.13 Fri 13:45 EW 201

Theory of surface plasmon polariton - exciton interaction — •Stephan Schwieger[1], Parinda Vasa[1,2], and Erich Runge[1] — [1]Technische Universität Ilmenau, Institut für Physik, 98693 Ilmenau — [2]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26129 Oldenburg

A detailed understanding of the coupling of surface plasmon polaritons (SPPs) and excitons allows to control basic SPP properties, e.g., their life time and dispersion relation, by the design of special metal-semiconductor hybrid structures. We present a theory of SPP-exciton

coupling. The SPP dispersion relation, the electromagnetic field distribution, and the far field reflectivity are calculated and discussed for an hybrid system that consists of an array of metal wires on top of a GaAs/AlGaAs quantum well. Clear indications for strong SPP-exciton interaction are found.

HL 54: Si/Ge

Time: Friday 10:30–15:00 Location: EW 202

HL 54.1 Fri 10:30 EW 202

Defect Formation Energies without the Band-Gap Problem: Combining DFT and *GW* for the Silicon Self-Interstitial — •Patrick Rinke[1,2], Anderson Janotti[1], Chris G. Van de Walle[1], and Matthias Scheffler[1,2] — [1]University of California at Santa Barbara, CA 93106 — [2]Fritz-Haber-Institut der MPG, Berlin

For the self-interstitial in silicon, a defect of high technological relevance, density functional theory (DFT) in the widely applied local-density approximation (LDA) underestimates the formation energies of different configurations in the neutral charge state by about 1.5 eV compared to diffusion Monte Carlo (DMC) calculations [1,2]. We attribute this to artificial self-interaction and the absence of the derivative discontinuity in the exchange-correlation potential in the LDA that give rise to the band-gap problem. Here we present a new formalism that combines LDA with quasiparticle energy calculations in the G_0W_0 approximation to overcome these deficiencies. The formation of the neutral defect is expressed as successive charging of its 2+ charge state, for which the defect level is unoccupied. This allows us to decompose the formation energy into a lattice (LDA) and an electron addition part (G_0W_0) [3]. The G_0W_0 corrections increase the LDA formation energy of the neutral state by ∼1.1 eV. Moreover, the G_0W_0-corrected charge transition levels, which are also readily available, agree well with recent measurements [4]. [1] E. R. Batista *et al. Phys. Rev. B* **74**, 121102(R) (2006), [2] W.-K. Leung *et al. Phys. Rev. Lett.* **83**, 2351 (1999), [3] M. Hedström *et al. Phys. Rev. Lett.* **97**, 226401 (2006), [4] H. Bracht *et al. Phys. Rev. B* **75**, 035211 (2007)

HL 54.2 Fri 10:45 EW 202

Point defects in germanium - theory and experiment — •Sibylle Gemming, Clemens Wündisch, and Matthias Posselt — Forschungszentrum Dresden-Rossendorf, D-01314 Dresden, Germany.

The functionality of standard silicon-based semiconductor devices is achieved by careful point defect engineering, hence tremendous efforts have been made to arrive at a quantitative understanding of the underlying interactions. Germanium has distinct advantages over silicon, for instance the lower energy gap between occupied and empty electronic states and the resultant lower carrier injection barriers. However, germanium is less well studied than silicon. Thus, both theoretical and experimental investigations were carried out to study the interaction of point defects in germanium. Conductivity measurements of phosphorus-implanted germanium indicate that not all dopant atoms are electronically active. Therefore density-functional calculations were carried out to study the properties of Ge vacancies, substitutional phosphorus defects and their interaction. Stable defect clusters are obtained, and in the limit of high dopant concentration an electrically inactive form of the P dopant is predicted.

HL 54.3 Fri 11:00 EW 202

Red-shift in SiNW Raman spectra - influence from thermal properties — •Sevak Khachadorian, Harald Scheel, and Christian Thomsen — Institute für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

The Raman spectra of silicon nanowires are studied as a function of laser excitation power and temperature. With increasing temperature and laser excitation power we observe an amplification of the red-shift of the Raman frequency as well as of the broadening of the Raman peak. The Raman frequency varies linearly with the temperature. We observe a change of the slope in the frequency- excitation power diagram from a critical excitation power, which depends on the surrounding gas. From homogeneously heated experiments using a heating stage we find that the change of the slope in the frequency- excitation power diagram can be explained with inhomogeneous heating in the Raman volume generated by the Gaussian distribution of the intensity of the laser. With vacuum measurements we can rule out effects due to convection.

HL 54.4 Fri 11:15 EW 202

Atomistic simulation of amorphous germanium — •Alice-Agnes Gabriel and Matthias Posselt — Forschungszentrum Dresden-Rossendorf e. V.

Electrical doping of Ge is usually performed by ion implantation and subsequent annealing. In many cases ion bombardment leads to formation of an amorphous layer. During annealing the layer recrystallizes by solid-phase epitaxial regrowth. In order to investigate this process by classical molecular dynamics simulations, first of all amorphous Ge with realistic properties must be prepared. This is the subject of the present work. The atomistic simulations use the Stillinger-Weber interatomic potential with a parameter set that yields correct or reasonable structural, thermodynamic and defect properties of diamond-structure Ge. In the first simulation step liquid Ge is prepared. Then, the system is cooled down slowly to 300 K using the method of Luedtke and Landman which was applied to simulate amorphous silicon. Finally, an equilibration at 300 K and zero pressure is performed. The characterization of amorphous Ge obtained in this manner includes density and cohesive energy, radial distribution function and static structure factor, coordination number, bond-angle distribution, distribution of interatomic distances as well as melting temperature and heat of fusion. The simulation results show very good agreement with experimental data and are consistent with previous theoretical investigations.

HL 54.5 Fri 11:30 EW 202

Hydrogen passivation of low temperature polycrystalline silicon thin films for electronic applications — •Christian Jaeger, Tobias Antesberger, Michael Scholz, Matthias Bator, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

Polycrystalline silicon on low cost substrates is gaining importance for many applications of large area electronics. A promising method to obtain high quality polycrystalline Si films with a small thermal budget is the aluminum-induced layer exchange (ALILE) process. Here, an Al/oxide/amorphous Si layer stack is annealed at temperatures below 577 °C. This leads to an exchange of the position of the initial layers and the crystallization of the Si. Due to the high solid solubility of Al in Si, the resulting layers are highly p-doped. For most electronic applications such high carrier concentrations are not desirable. Therefore, the influence of hydrogen passivation on the electronic properties of thin poly-Si films prepared by ALILE has been investigated. We observe an increase of the resistivity after hydrogen passivation, which is the more pronounced, the thinner the samples. For the thinnest layers an increase of more than five orders of magnitude is observed. This is attributed to a combination of two effects - acceptor passivation by hydrogen and additional compensation of the free holes remaining after hydrogenation by interface states. The field effect in these passivated layers has been characterized in gated structures, both in bottom and top gate configuration. A significant field effect has been observed in H-passivated films with a thickness of 20 nm.

HL 54.6 Fri 11:45 EW 202

Proton irradiation of germanium isotope multilayer structures — •Sebastian Schneider[1], Hartmut Bracht[1], Martin Petersen[2], John Lundsgaard Hansen[2], and Arne Nylandsted Larsen[2] — [1]Institute of Materials Physics, University of Münster, Germany — [2]Department of Physics and Astronomy, University of Aarhus, Denmark

Irradiation of germanium (Ge) isotope heterostructures with 2.5 MeV protons have been performed at 550 deg C. The applied proton flux was varied between 1.0 and 1.5 microampere leading to various rates of Frenkel pair production. After rradiation, concentration profiles of the Ge-isotopes were recorded by means of secondary ion mass spectrometry. An inhomogeneous broadening of the isotope structure was observed that in addition to irradiation enhanced self-diffusion is affected by the formation of microscopic defects. Atomic force and scan-

ning electron microscopy show that the microscopic defects are most probably resulting from an aggregation of vacancies formed during irradiation. Numerical analysis of Ge profiles not disturbed by microdefect formation indicates a significant contribution of self-interstitials to self-diffusion under irradiation.

HL 54.7 Fri 12:00 EW 202

Structural and electronic properties of ultra-thin polycrystalline Si layers on glass prepared by aluminum-induced layer exchange — •Tobias Antesberger, Christian Jäger, Michael Scholz, Chiara Cordioli, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, Am Coloumbwall 3, 85748 Garching, Germany

Polycrystalline silicon thin films on low cost substrates are attractive for large area electronics and solar cell applications. A promising method to obtain large-grained high quality polycrystalline films by low-temperature crystallization of an amorphous precursor material is the aluminum-induced layer exchange (ALILE). In this approach, an Al/amorphous Si layer stack, separated by a thin oxide film, is annealed at temperatures below the Al-Si eutectic temperature of 850 K, leading to a complete exchange of the positions of the initial Al and Si layers and to the crystallization of the amorphous Si. We have studied the dynamics of the ALILE process as well as the structural and electronic properties of resulting ultra-thin polycrystalline Si layers (5 nm - 100 nm) prepared on silica substrates. Raman spectroscopy gives evidence of a good crystalline quality of the layers down to a thickness of 10 nm. Hall effect and conductivity measurements show a decreasing carrier density and an increasing mobility with increasing layer thickness. Due to the solubility of aluminum in silicon the resulting poly-Si layers are highly p-doped reaching carrier densities between 3x10^{18} cm^{-3} and 9x10^{19} cm^{-3} and hole mobilities up to 20 $cm^2/(Vs)$.

HL 54.8 Fri 12:15 EW 202

Oxidation and graphitization of 6H-SiC (0001) — Maxim Eremtchenko[1], Anita Neumann[1], Jens Uhlig[1], Rolf Öttking[1], Roland J. Koch[1], Katharina Kloeckner[1], Thomas Haensel[1], Syed Imad-Uddin Ahmed[1], and •Juergen A. Schaefer[1,2] — [1]Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany — [2]Department of Physics, Montana State University, P.O. Box 173840, Bozeman, MT 59717-3840, USA

The silicon rich 6H-SiC (0001) surface, its oxidation, graphitization and possible graphene layer formation has been investigated using high resolution electron energy loss spectroscopy in combination with X-ray induced photoelectron spectroscopy and low energy electron diffraction. Annealing up to 1000°C resulted in SiO_2 formation, while graphitization and finally the build up of graphitic clusters followed annealing up to 1170°C. Characteristic changes in surface cleanliness, stoichiometry (Si-rich to C-rich) and different surface structures induced drastically different depletion layers with different band bendings as a function of isochronal annealing temperatures. A key feature of this work is that the semimetallic character of graphite and/or graphene formation of intentionally low doped (2.5 x 10^{15} cm^{-3} n-type) SiC (0001) material could be precisely monitored by analyzing the continuous background of inelastically reflected electrons in HREELS-experiments. This result is very promising for future studies related to the identification of the presence and morphology of graphene layer formation on top of silicon carbide, and to its electronic as well as vibrational structure.

15 min. break

HL 54.9 Fri 12:45 EW 202

Grain boundary conduction in undoped laser-crystallized polycrystalline silicon-germanium thin films — •Lars-Peter Scheller[1], Moshe Weizman[1], Norbert H. Nickel[1], and B. Yan[2] — [1]Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Ovonic Corporation, 1100 West Maple Road Troy, MI 48084, USA

Due to its enhanced optical absorption in the IR and visible spectral range polycrystalline silicon-germanium (poly-SiGe) is a promising absorber material for future thin film and tandem solar cells.
In this study the electrical transport properties of laser-crystallized poly-$Si_{1-x}Ge_x$ thin films ($0 \leq x \leq 1$) on quartz were investigated by temperature dependent Hall and conductivity measurements. All intentionally undoped samples showed p-type conduction that in some cases was accompanied by an astonishing high conductivity in the range of 0.1 to 10 $(\Omega cm)^{-1}$. Depending on the germanium content and the used crystallization procedure, three different transport mechanisms were identified: a) thermally activated transport with an activation energy of approximately 350 meV, b) Mott's variable range hopping and c) a nearly temperature independent metallic like transport. In addition, a subsequent remote hydrogen plasma treatment led to a pronounced decrease in the conductivity and a transition from metallic to activated transport. This surprising behavior is explained in terms of carrier transport in a defect band induced by Ge dangling bond defects at the grain boundaries.

HL 54.10 Fri 13:00 EW 202

Remote plasma process with independent control of physical and chemical etching of Si / Ge — •Helmut Lochner[1], Martin Amberger[2], Therese Chabert[2], Martin Sterkel[3], Walter Hansch[3], Markus Reinl[1], and Ignaz Eisele[1] — [1]Universität der Bundeswehr München, Institut für Physik — [2]PVA Tepla AG, Feldkirchen — [3]TU München

In the fabrication of electrical and mechanical devices there are several possibilities to structure the surface. An established and state of the art technology is dry etching with plasma-activated gases. There are differences in activation and the use of the plasma. The most important difference is either using a chemical effect or a physical effect for etching with advantages and disadvantages in each case. Although there are reactors combining both effects (e.g. reactive ion etching), you cannot separate them absolutely or control them decoupled.

In our experiments the advantages of the cold remote downstream plasma of the silicon star 12M (PVA Tepla AG, with a 2,45 GHz microwave radical generator) with pure chemical etching (fluorine radicals) were investigated. The process was supplemented with a physical etch component which is independent controllable. This concept was realized with an additional electrical field, called "BIAS". The "BIAS" creates and accelerates Ar ions and generates an ion beam towards the surface.

As a result, the etch rates on Si and Ge as well as the aspect ratio increase. Anisotropic etching of silicon can be achieved. Furthermore the etching of other materials like SiC becomes possible.

HL 54.11 Fri 13:15 EW 202

Electrical and optical properties of laser-crystallized polycrystalline silicon-germanium thin films — •Moshe Weizman[1], Lars-Peter Scheller[1], Norbert Nickel[1], and Baojie Yan[2] — [1]Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Ovonic Corporation 1100 West Maple Road Troy, MI 48084, USA

The SiGe thin films investigated in this study were deposited on quartz by glow-discharge decomposition of a mixture of disilane, germane, and hydrogen and subsequently crystallized employing a XeCl excimer laser. Our investigations reveal that the grain boundaries in the poly-SiGe films critically influence the electrical and optical behavior of this material. Hall effect and electron spin resonance (ESR) measurements show evidence for the formation of a defect band on grain boundaries due to dangling bonds. This defect band appears preferably in Ge rich alloys with a critical dangling bond concentration of about $5 \cdot 10^{18}$ cm^{-3} and causes high metallic-like conductivities at low temperatures. Optical absorption measured with photothermal deflection spectroscopy (PDS) reveals a direct band gap characteristic that suggests the absorption occurs primarily at the grain boundaries. Sub-bandgap absorption indicates that the position of the neutrally charged dangling bond D^0 is about 150 meV above the valance band, which is probably the reason the Fermi level is pinned at the lower half of the bandgap and the layers exhibit p-type conductivity. We will discuss these surprising properties in terms of solar cell potential applications

HL 54.12 Fri 13:30 EW 202

Diffusion of Si and Ge in SiGe-isotope structures — •Rene Kube[1], Hartmut Bracht[1], John Lundsgaard Hansen[2], and Arne Nylandsted Larsen[2] — [1]Institute of Materials Physics, University of Münster, Germany — [2]Department of Physics and Astronomy, University of Aarhus, Denmark

The diffusion of Si and Ge in SiGe isotope heterostructures with Ge contents x = 0, 0.05, and 0.25 at.% were performed at temperatures between 870 and 1270 deg C. The concentration profiles of the stable Si- and Ge-isotopes were recorded by means of time-of-flight secondary ion mass spectrometry (Tof-SIMS). For all compositions, an Arrhenius

type temperature dependence of diffusion was observed. The activation enthalpy of Si diffusion is equal to that of Ge diffusion. However, the preexponential factor of Si diffusion is lower. Our results are compared to radiotracer diffusion studies reported recently.

HL 54.13 Fri 13:45 EW 202

Dopant-induced states in two-dimensional semiconductors — •Philipp Ebert, Sebastian Landrock, and Knut Urban — Institut für Festkörperfoschung, Forschunsgzentrum Jülich, 52425 Jülich

Intentionally inserted impurities, referred to as dopant atoms, are the lifeline of semiconductor devices. They provide free charge carriers into the bands of the host crystal and thereby allow to tune almost all properties of semiconducting materials. These free carriers are generated by the introduction of localized states into the band gap. For suitable dopant atoms these states are close enough to the band edges, that either electrons from the valence band can thermally populate these states (acceptor type states) or electrons in these states can be thermally excited into the conduction band (donor type states). In order to address the origin of these states, we used scanning tunneling microscopy and spectroscopy to probe the local density of states above dopant atoms in a two-dimensional semiconducting $\sqrt{3}\times\sqrt{3}$ Ga overlayer on Si(111) substrates. We observe two dopant-induced states and additional changes in the density of states. Using a momentum dependent analysis we demonstrate that the presence of dopant atoms shifts parts of the local density of states. These results are discussed using existing models.

HL 54.14 Fri 14:00 EW 202

Phosphorus doping of Si nanocrystals — •Andre R. Stegner[1], Rui N. Pereira[1], E. Ulrich Stützel[1], Hartmut Wiggers[2], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Inst., Technische Universität München, Garching — [2]Universität Duisburg-Essen, Inst. for Combustion and Gas Dynamics, Duisburg

Si nanocrystals (Si-ncs), in particular in the form of deposited or self-organized thin films are an interesting option for printed electronics and solar cells. However, the doping of individual Si-ncs, as well as its influence on the electronic properties of Si-ncs films is essentially unexplored. Here, we have used electron paramagnetic resonance (EPR) to study the P doping of Si-ncs grown by microwave-induced decomposition of silane and phosphine. EPR spectra of the as-grown Si-ncs show characteristic resonances from isolated as well as exchange-coupled P donors and an intense line originating from Si dangling bonds (Si-dbs) at the Si/SiO2 interface. While the P concentration determined with secondary ion mass spectroscopy is in good agreement with the doping level calculated from the phosphine concentration during synthesis, a quantitative analysis of the EPR data reveals that only a small fraction of the donors contributes to the characteristic EPR signal. This discrepancy increases strongly for Si-ncs smaller than 15 nm and is discussed taking into account effects like self purification and charge compensation by Si-dbs. Using electrically detected magnetic resonance to study the spin-dependent transport in thin films of Si-ncs, we show that P donor states in the core of the Si-ncs and Si-dbs at the nanocrystal surface are actively involved in the current transport.

HL 54.15 Fri 14:15 EW 202

Diffusion and defect reactions between donors, carbon and vacancies in germanium — •Hartmut Bracht[1], Sergej Brotzmann[1], John Lundsgaard Hansen[2], and Arne Nylandsted Larsen[2] — [1]Institute of Materials Physics, University of Münster, Germany — [2]Department of Physics and Astronomy, University of Aarhus, Denmark

The diffusion of self-atoms and n-type dopants such as phosphorus (P), arsenic (As), and antimony (Sb) was studied by means of isotopically controlled germanium multilayer structures doped with carbon. The diffusion profiles reveal an aggregation of the dopants within the carbon-doped layers and a retarded penetration depth compared to dopant diffusion in high purity natural Ge. Dopant aggregation and diffusion retardation is strongest for Sb and similar for P and As. In addition, the shape of the dopant profiles changes for high dopant concentrations. Accurate modeling of the simultaneous self- and dopant diffusion is achieved on the basis of the vacancy mechanism and additional reactions that take into account the formation of neutral carbon-vacancy-dopant and neutral dopant-vacancy complexes. The stability of these complexes is compared to recent theoretical calculations. The overall consistency between the experimental and theoretical results support the stabilization of donor-vacancy complexes in Ge by the presence of carbon and the dopant deactivation via the formation of dopant-vacancy complexes.

HL 54.16 Fri 14:30 EW 202

MBE-growth and characterization of highly P doped delta layers in silicon — •Ulrich Abelein, Peter Iskra, Martin Schlosser, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany

The controlled and reproducible growth of highly doped and ultra thin delta layers in silicon by MBE is an important task for the study of a wide range of phenomena in semiconductor physics (like resonant tunneling) as well as for the development of novel devices (like the TFET or the vertical I-MOS).

While the fabrication of boron doped delta layers with excellent electrical properties is quite well understood, the preparation of phosphorus doped delta layers is more difficult. High phosphorus doping leads to the formation of phosphorus clusters which cause crystal defects and degenerate electrical properties. In this work 3 nm thick delta layers with doping levels $> 10^{20}$ cm^{-3} were grown by MBE and characterized using secondary ion mass spectroscopy (SIMS). Furthermore such delta layers were used to fabricate triangular barrier diodes (TBD, i. e. p^+-i-n^+-δ-i-p^+ layer stacks). The electrical characteristics of these test devices show a very good barrier formation by the delta layers which indicates good crystal quality.

HL 54.17 Fri 14:45 EW 202

Einfluss der Dotierung auf die elastischen Eigenschaften von Silizium — •Nicole Santen und Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik, Nußallee 14-16, 53115 Bonn

Für die Herstellung von Hochleistungshalbleiterbauelementen wird heutzutage sog. *strained silicon*, also gedehntes Silizium, verwendet. Dadurch ist es möglich die Ladungsträgerbeweglichkeit und damit die Schaltgeschwindigkeiten von Transistoren zu erhöhen und eine Verbesserung der Gesamtleistung zu erzielen.

Die Methode der gestörten γ-γ-Winkelkorrelation (PAC) ist sehr gut für die Untersuchung solcher lokaler Verspannungen in Silizium geeignet, da sie mikroskopische Beobachtungen der unmittelbaren Umgebung eines Sondenkerns ermöglicht. Auf diese Art können zum einen extern angelegte Zug- und Druckspannungen untersucht werden, aber auch Gitterverzerrungen, wie sie in implantierten Bereichen auftreten.

Mit der PAC-Sonde ^{111}In wird der Einfluss von Dotierungsatomen auf die elastischen Eigenschaften von Silizium untersucht. Frühere Messungen weisen darauf hin, dass das Siliziumgitter abhängig von der Art der Dotierungsatome unterschiedlich auf eine mechanische Verspannung reagiert. Neuere Messungen zeigen, dass man durch Implantation von Donatoren und Akzeptoren die elastischen Eigenschaften unterschiedlich beeinflussen kann. Dies wird anhand von Phosphor- und Bor-dotiertem Silizium verdeutlicht.

HL 55: GaN: preparation and characterization II

Time: Friday 10:30–13:45 Location: ER 164

HL 55.1 Fri 10:30 ER 164

Time dependent changes of the spontaneous polarization field in GaN investigated via UHV-cathodoluminescence and photoluminescence — •Martina Finke, Daniel Fuhrmann, Holger Jönnen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, 38106 Braunschweig

In GaN-based quantum well structures, the spontaneous and piezoelectric fields have a strong effect on the optical properties. The spontaneous field is normally screened by charged species on the surface. Since the spontaneous field counteracts the piezoelectrical field, a reduction of the quantum confined Stark effect (QCSE) indicated by a blueshift in the peak position of luminescence and an increased inten-

sity is expected by descreening the spontaneous field. We use cathodoluminescence under well controlled surface conditions. This leads to metastable changes of the QW emission spectra as a function of irradiation dose, which was investigated via photo(PL)- and cathodoluminescence(CL) in an UHV environment. As samples we used various GaInN quantum well structures with or without AlGaN electron barrier and a variation in GaN cap thickness. The electron-beam produces electron-hole pairs in the sample, which can be separated by the spontaneous field. The holes created in the buffer layer reduce the spontaneous field, which can be observed as a redshift and decrease in intensity of emitted light. Simultaneous measurements of PL and CL allow us to study the screening and descreening of the spontaneous field due to electron-hole pairs at various electron-beam penetration depths.

HL 55.2 Fri 10:45 ER 164

Influence of Si and Mg on the growth mechanism of GaN nanorods on Si (111) — •Florian Furtmayr[1], Christoph Stark[1], Martin Stutzmann[1], Martin Eickhoff[1], Jordi Arbiol[2], and Joan Ramon Morante[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]TEM-MAT, Serveis Cientificotecnics, Universitat de Barcelona, Barcelona, CAT, Spain

The self assembled growth of GaN nanorods (NRs) on Si (111) substrates without the use of extrinsic catalysts by PAMBE under nitrogen-rich conditions is investigated. A thin amorphous silicon nitride layer is formed in the initial stage of the growth which impedes nucleation on the substrate surface at high growth temperatures, preventing the formation of a wetting layer. Investigation of the nucleation process by SEM reveals a nucleation diameter of (12 ± 3) nm and a non-linear dependence of the nucleation density on the growth time. The observation of the low lateral growth rate of 1.7 Å/min and the homogeneous NR height distribution indicate strong desorption from the NR sidewalls, which inhibits diffusion transport to the top surface. The incorporation of Mg leads to a decrease of the nucleation time and to an increase of the lateral growth rate. In the case of Si-doping the increase of the lateral growth rate is smaller, but the rod morphology is changed to widening cones for high Si fluxes. We discuss these results in terms of the growth kinetics and show that during growth the presence of a Ga droplet on the NR top surface is very likely. PL spectroscopy as well as HRTEM have been employed.

HL 55.3 Fri 11:00 ER 164

Optische Untersuchungen zum exzitonischen Transport in GaN Epitaxieschichten — •M. Noltemeyer[1], F. Bertram[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2] und O. Schulz[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]AZZURRO Semiconductors AG, Magdeburg

Es wurden optische Flugzeitmessungen an einer mittels MOVPE gewachsenen GaN Struktur mittels hoch orts- und zeitaufgelöster Kathodolumineszenz (KL) durchgeführt. Die aus der 1-dimensionalen Diffusionsgleichung hervorgehenden Transportkenngrößen sind die Diffusivität D und Beweglichkeit μ. Um diese zu bestimmen, wird aus ortsaufgelösten KL-Untersuchungen die Diffusionslänge und aus zeitaufgelösten KL-Untersuchungen die Lebensdauer von Exzitonen im GaN für eine jeweils feste Temperatur (7-300 K) bestimmt. Zur Bestimmung der Diffusion wird dazu die untersuchte Probe mit einer für die Lumineszenz undurchlässigen, e^-transparenten Ti-Maske versehen, über deren Kante der Intensitätsverlauf der Lumineszenz ausgewertet wird. Für eine Temperatur von 7 K wurde so eine Lebensdauer von 190 ps und eine Diffusionslänge von etwa 80 nm bestimmt. Bei Raumtemperatur liegen diese Werte im Bereich von 70 ps und 120 nm. Hieraus ergibt sich eine Beweglichkeit von etwa 500-200 cm^2/Vs für 7-300 K. Des Weiteren wird der Einfluss von Streumechanismen auf die Beweglichkeit diskutiert.

HL 55.4 Fri 11:15 ER 164

In-situ investigation on the surface electronic structure of GaN(0001)-2×2 — •Richard Gutt, Pierre Lorenz, 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 surface electronic structure of GaN(0001)-2×2 surfaces has been studied *in-vacuo* directly after growth. GaN thin films have been deposited on 6H-SiC(0001) by plasma assisted molecular beam epitaxy. After growth, the samples were cooled down in nitrogen plasma leading to a 2×2 reconstruction measured by reflection high energy electron diffraction. Further characterization by atomic force microscopy as well as *ex-situ* X-ray diffraction and photoluminescence proves a high sample quality. The presented X-ray photoelectron spectroscopy data show stoichiometric GaN with no evidence of contaminations and a bulk valence band structure in excellent agreement with recently published DFT calculations [1]. Ultraviolet photoelectron spectroscopy detects two additional surface states, 2 eV and 3 eV below E_F. The 2×2 reconstruction is a necessary condition for the occurrence of the state at 2 eV. Storage under typical UHV conditions ($< 2 \cdot 10^{-10}$ mbar) for several hours results in a disappearance of both the reconstruction and the 2 eV state, indicating an extremely high surface reactivity. In addition, a very high reactivity towards oxygen and water is found and will be discussed in another contribution.

[1] D. Segev, C.G. Van de Walle, J. Cryst. Growth 300 (2007) 199

HL 55.5 Fri 11:30 ER 164

Properties of GaN-based thin film LEDs grown by MOVPE in dependence on the Si substrate orientations — •F. Schulze[1], A. Dadgar[1,2], S. Fritze[1], J. Blaesing[1], M. Wieneke[1], A. Diez[1], and A. Krost[1,2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University, 39016 Magdeburg, Germany — [2]Azzurro Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg, Germany

The use of silicon as a substrate for GaN-based optoelectronic devices offers many advantages in terms of cost reduction and large size availability. For an optimization of the optical output performance, a subsequent delamination of the silicon substrates may be very helpful due to the absorbing properties of silicon in the range of visible light. Mechanical abrasion and chemical etching are a usual approach to obtain thin film LEDs on specular carriers with a good thermal conductivity. However, the crystallographic orientation of silicon strongly influences the abrasion resistance and the chemical etching rate. Therefore, GaN based LED structures were grown by MOVPE on different substrate orientations as Si(111), Si(011), and Si(001). We report on the quality of GaN-based devices in dependence on these surfaces. The influence of the thinning process will be discussed comparing the crystallographic properties of the device structures analysed by x-ray diffraction techniques. Furthermore, the impact of the different surface orientations on optical properties of the LEDs were analysed by electro- and cathodoluminescence.

HL 55.6 Fri 11:45 ER 164

Impact of seed and buffer layer growth on the quality of AlGaN on Si(111) — •P. Saengkaew, A. Diez, M. Noltermeyer, J. Blaesing, B. Bastek, F. Bertram, A. Dadgar, J. Christen, and A. Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, 39106, Magdeburg, Germany

AlGaN with its bandgap ranging from 3.4 to 6.3 eV, is a very attractive material to fabricate UV photodetectors and UV LEDs. For efficient devices, high-quality AlGaN films are required. Growing high-quality AlGaN grown on Si (111) by MOVPE, the lattice mismatch and different thermal expansion of them have to be overcome. Not only the growth parameters of AlGaN but also the seeding and buffer layers play an important role to improve the quality of AlGaN grown on them. Conventionally AlN layers are employed as a seeding layer to grow Al0.1Ga0.9N on Si. We investigated the impact of the growth seeding parameters as growth temperature, pressure, time, and V/III ratio of the AlN seeding and buffer layers on the crystalline quality and strain state of AlGaN by high-resolution X ray diffraction, AFM, and CL .Best values achieved for the simple AlN / AlGaN structure are 0.33 degree and 0.55 degree for the (0002) and (10-10) omega scans, respectively. A further improvement can be achieved by introducing an AlN based superlattice between the seeding and AlGaN buffer layer. For the best structure we achieve values for the (0002) and (10-10) omega scans of 0.15 degree and 0.39 degree, respectively.

15 min. break

HL 55.7 Fri 12:15 ER 164

Luminescence Characterization of GaN/InGaN Micro-disk Structures on Silicon — •A. Franke[1], F. Bertram[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2], K. X. Lin[3], S.L. Teo[3], and S. Tripathy[3] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Azzurro Semiconductors AG, Magdeburg, Germany — [3]Institute of Material Research and Engineering, Singapore 117602

The most common way to fabricate vertical surface emitting lasers like

micro-cavities lasers uses DBRs on both sides of the cavity. An alternative approach to achieve an optical confinement is the fabrication of free standing micro-disk emitters. The investigated micro-disk sample consists of a standard MOVPE grown GaN LED structure with InGaN quantum wells as the active region. The 3 μm thick structure was patterned into 300 μm circular columns using dry and subsequently wet etching to remove and undercut the silicon surrounding the micro-disk. To investigate the optical properties we use micro-photoluminescence (PL) and cathodoluminescence spectroscopy at 4 K. The local spectra exhibit two emission peaks: a dominant emission at 2.66 eV related to the InGaN/GaN QWL and at 3.46 eV stemming from the GaN emission. PL mapping across the surface of the disk shows a statistical distribution for the GaN emission. In contrast, for the QWL emission a symmetric circular pattern with a 5 – fold symmetry of alternating 2.69 eV emission interrupted by a 2.66 eV emission can be observed.

HL 55.8 Fri 12:30 ER 164

Degradation of InGaN quantum wells during high temperature growth steps — •Holger Jönen, Daniel Fuhrmann, Daniel Dräger, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig

The strong decrease of the internal quantum efficiency (IQE) of GaN based light emitters for longer wavelengths is well known. As possible reason for this behaviour the stronger piezoelectric field and a reduced material quality with increasing In content are often discussed. Furthermore, we found that with increasing In content the thermal stability of the layers becomes a critical issue. In this contribution we will focus on the thermal stability of InGaN QWs in LED structures grown by MOVPE. The quantum well growth is followed by a GaN spacer, AlGaN electron barrier and GaN capping layer. High temperatures are unavoidable during the MOVPE growth of these layers (e.g. for efficient Mg doping), in contrast to the low temperatures needed for high In concentration ($x_{\mathrm{In}} > 30\%$) in the quantum wells. Ramping the growth temperature is also commonly used for the barriers in MQW structures to improve the interface quality of the layers. The influence of such high temperature growth processes on the optical and structural properties of InGaN quantum wells is studied in detail. For this purpose we varied the growth parameters for the individual layers and found that the growth of the spacer layer is most critical and that the thermal budget of the GaN cap must be minimized.

HL 55.9 Fri 12:45 ER 164

Spatial distribution of structural defects in GaN — •I. Tischer[1], M. Schirra[1], M. Feneberg[1], G.M. Prinz[1], R. Sauer[1], K. Thonke[1], T. Wunderer[2], J. Hertkorn[2], F. Lipski[2], P. Brückner[2], F. Scholz[2], A. Chuvilin[3], U. Kaiser[3], I. Knoke[4], and E. Meissner[4] — [1]Institut für Halbleiterphysik, Universität Ulm — [2]Institut für Optoelektronik, Universität Ulm — [3]Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm — [4]Abt. Kristallzüchtung, FHG-IISB, Erlangen

Non-polar and semi-polar GaN facets with reduced piezo-electric fields are promising substrates for high-efficiency optoelectronic devices. Due to the lower material quality compared to c-plane GaN these substrates typically show luminescence lines at 3.30 and 3.41 eV which are related to structural defects such as stacking faults. Here we study selectively overgrown triangular shaped GaN stripes with stable $\{1\bar{1}01\}$ facets. They were purposely grown under non-optimal conditions so as to show the defect luminescence strongly.

Spatially resolved cathodoluminescence including monochromatic CL images and CL line scans of sample cross sections and of $\{1\bar{1}01\}$ facets yield the intensity distribution of the 3.41 and 3.30 eV lines. Correlation of CL results with those from TEM support literature reports that the 3.41 eV line is related with basal plane stacking faults. The 3.30 eV defect is found to appear frequently in the close vicinity of the 3.41 eV defects but not exclusively there. Details of the spatial distribution together with CL measurements at varying temperatures towards the electronic nature of the defect will be discussed.

HL 55.10 Fri 13:00 ER 164

The role of V-shaped pits in (AlGaIn)N LED structures — •Lars Hoffmann, Heiko Bremers, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, Technical University of Braunschweig, Germany

Despite the high density of threading dislocations generally found in group-III-nitride semiconductors, the light emission efficiency of GaInN/GaN quantum well (QW) structures is exceptionally high at room temperature. Therefore, nonradiative recombination processes of charge carriers in a QW must be suppressed. This can be explained by our V-shaped pit model, where every threading dislocation is decorated with a hexagonal V-shaped pit. The QWs inside a V-shaped pit are thinner compared with the QWs on c-plane. Thus the effective band gap is significant larger and the charge carriers will be kept away from the threading dislocations. In our GaInN/GaN QW structures with high internal quantum efficiency we find in TEM well-controlled V-shaped pits around the dislocations. In order to clarify the situation for commercial devices we investigated blue and green LEDs from various suppliers. We find that V-shaped pits are decorating virtually all threading dislocations in the QW region. This indicates that suppression of nonradiative recombination by V-shaped pits may be a desirable mechanism for achieving high light emission efficiency. We also discuss the effect of pits in GaN/AlGaN QW structures, where the typical emission efficiency is much lower than for GaInN/GaN structures.

HL 55.11 Fri 13:15 ER 164

Influence of anisotropic strain on excitonic transitions in a-plane GaN films — Marcus Röppischer[1], •Carsten Buchheim[1], Rüdiger Goldhahn[1], Gerhard Gobsch[1], Armin Dadgar[2], Matthias Wieneke[2], Jürgen Bläsing[2], and Alois Krost[2] — [1]Institute of Physics, Technical University Ilmenau, PF100565, 98684 Ilmenau, Germany — [2]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Universitätsplatz 2, 39016 Magdeburg, Germany

GaN films on non- or semipolar substrate surfaces are important for light emitters in the ultraviolet spectral region, because on these substrates the polarisation induced electric fields are minimized. With the optical axis in the sample plane, one has to account for both, the ordinary and the extraordinary dielectric function (DF) for the design of devices. Different thermal expansion coefficients and lattice mismatch for the two in-plane directions result in anisotropic in-plane stress. As a consequence the transition energies of the A-, B- and C-exciton are unequally shifted and the oscillatory strengths are changed. In this work the ordinary and extraordinary components of the DF of a-plane GaN films on r-plane sapphire are determined by spectroscopic ellipsometry. The optical selection rules are verified. The results are confirmed by polarisation dependent photoreflectance measurements in which the excitonic transition energies were determined for differently strained samples. Different oscillatory strengths are observed for the incident light polarized parallel and perpendicular to the optical axis. The experiments are supported by 6×6 $\vec{kp}$ band structure calculations.

HL 55.12 Fri 13:30 ER 164

SNOM studies of GaInN/GaN and GaN/AlGaN QW structures — •Peter Clodius, Frank Hitzel, Daniel Fuhrmann, Carsten Netzel, Holger Jönen, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technical University of Braunschweig, Institute of Applied Physics

Blue or green light emitting GaInN/GaN-based quantum well (QW) structures achieve quite high internal quantum efficiencies (IQE) at room temperature. In contrast In-free QW-structures based on GaN/AlGaN emitting in the UV-range suffer from low IQE values. This is caused by the high density of defects in this material and nonradiative recombination occuring at these defects. We present studies of photoluminescence with a high spatial resolution, performed on GaInN/GaN and GaN/AlGaN QW structures. The measurements were performed using a scanning near-field optical microscope (SNOM). The measurements on the GaInN/GaN QWs show that nearly every line defect in these structures is decorated by a so-called V-pit (an inverted hexagonal pyramid with $(10\bar{1}1)$ planes as sidewalls). On the sidewalls of these pits the growth rate of the QW is reduced, which leads to thinner QWs on the facets than on the c-plane. These thinner QWs form a barrier which prevents carriers from nonradiative recombination at the line defects. We investigate short wavelength GaInN/GaN and GaN/AlGaN structures with the aim of clarifying whether such pits play a role in such structures as well.