SEMICONDUCTOR PHYSICS

HALBLEITERPHYSIK (HL)

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OVERVIEW OF INVITED TALKS AND SESSIONS

(lecture rooms HSZ 01, BEY 118, BEY 154, POT 51, POT 151)

Invited Talks

HL 1.1	Mon	09:30	(HSZ 01)	**From ultraviolet light emitting diodes to microcavity disk lasers - New frontiers in InAlGaN optoelectronics**, Michael Kneissl
HL 8.1	Mon	14:30	(HSZ 01)	**Counting statistics of single electron transport in a quantum dot**, Renaud Leturcq, Simon Gustavsson, Barbara Simovic, Roland Schleser, Thomas Ihn, Paul Studerus, Klaus Ensslin, Dan C. Driscoll, Art C. Gossard
HL 10.1	Tue	09:30	(HSZ 01)	**Coherent spin transport by acoustic fields in GaAs quantum wells**, Paulo Santos, James Stotz, Odilon Couto, Fernando Iikawa, Rudolph Hey, Klaus Ploog
HL 11.1	Tue	10:15	(HSZ 01)	**Spin accumulation dynamics in semiconductors close to ferromagnetic contacts**, Gerrit E.W. Bauer
HL 17.1	Tue	14:30	(HSZ 01)	**QED in a Pencil Trace**, Andre Geim, Kostya Novoselov
HL 37.1	Thu	09:30	(HSZ 01)	**Superconducting boron-doped single crystal diamond**, Etienne Bustarret, Jozef Kacmarcik, Thierry Klein, Benjamin Sacépé, Claude Chapelier, Christophe Marcenat, Emmanuel Bourgeois, Xavier Blase
HL 38.1	Thu	10:15	(HSZ 01)	**Coherent optical generation and decay of charge and spin currents in semiconductor heterostructures analyzed by microscopic theory**, Torsten Meier, Quang Tuyen Vu, Huynh Thanh Duc, Hartmut Haug, Stephan W. Koch
HL 45.1	Thu	14:30	(HSZ 01)	**Atomic scale analysis of magnetic doping atoms and self-assembled III/V semiconductor nanostructures**, P.M. Koenraad
HL 51.1	Fri	10:15	(HSZ 01)	**Andreev reflection in Nb-InAs structures: Phase-coherence, ballistic transport and edge channels**, JonathanEroms, Dieter Weiss

Internal symposia within HL

Internal symposium: THz-quantum cascade lasers

Organization: W. Wegscheider (Universität Regensburg)

HL 2.1	Mon	10:15	(HSZ 01)	**Designing the emission of THz Quantum Cascade Lasers with surface plasmon photonic structures**, Alessandro Tredicucci
HL 2.2	Mon	10:45	(HSZ 01)	**THz generation and mixing using Quantum Cascade Lasers**, Carlos Sirtori
HL 2.3	Mon	11:15	(HSZ 01)	**Progress in single frequency and long wavelength quantum cascade lasers**, Jerome Faist, G. Scalari, L. Sirigu, L. Ajili, C. Walther, M. Giovannini, A. Dunbar, R. Houdre

HL 2.4	Mon	11:45	(HSZ 01)	**Growth and Processing of GaAs quantum cascade lasers**, Gottfried Strasser, Aaron Maxwell Andrews, Tomas Roch, Gernot Fasching, Alexander Benz, Sebastian Golka, Maximilian Austerer, Christian Pfluegl, Werner Schrenk, Karl Unterrainer
HL 2.5	Mon	12:15	(HSZ 01)	**GaInAs/AlAsSb quantum cascade lasers: a new approach towards 3-to-5 μm semiconductor lasers**, Joachim Wagner, Quankui Yang, Christian Manz, Wolfgang Bronner, Christian Mann, Klaus Köhler

Internal symposium: Quantum optics in semiconductors
Organization: M. Bayer (Universität Dortmund)

HL 12.1	Tue	11:15	(HSZ 01)	**Quantum Light Generation from Semiconductor Quantum Dots**, Andrew Shields
HL 12.2	Tue	11:45	(HSZ 01)	**Size-tunable exchange interaction in InAs/GaAs quantum dots**, U. W. Pohl, A. Schliwa, R. Seguin, S. Rodt, K. Pötschke, D. Bimberg
HL 12.3	Tue	12:15	(HSZ 01)	**Quantum Optics of Excitons in Semiconductors**, Heinrich Stolz
HL 12.4	Tue	12:45	(HSZ 01)	**Microscopic Theory of Semiconductor Quantum Optics**, Mackillo Kira, Stephan W. Koch
HL 18.1	Tue	15:15	(HSZ 01)	**Light Matter Interaction Effects in Quantum Dot Microcavities**, S. Reitzenstein, C. Hofmann, A. Löffler, J. P. Reithmaier, M. Kamp, A. Forchel, G. Sek, V. D. Kulakovskii, A. Bazhenov, A. Gorbunov, L. V. Keldysh, T. L. Reinecke
HL 18.2	Tue	15:45	(HSZ 01)	**CQED with II-VI nanocrystals**, Ulrike Woggon, Nicolas LeThomas, Oliver Schoeps, Mikhail Artemyev
HL 18.3	Tue	16:00	(HSZ 01)	**Deutsch-Jozsa Algorithm using Triggered Single Photons from a Single Quantum Dot**, Oliver Benson, Matthias Scholz, Thomas Aichele, Sven Ramelow
HL 18.4	Tue	16:30	(HSZ 01)	**Imaging the Local Density of Photonic States in Photonic Crystal Nanocavities**, Michael Kaniber, Felix Hofbauer, Simon Grimminger, Max Bichler, Gerhard Abstreiter, Jonathan J. Finley
HL 18.5	Tue	16:45	(HSZ 01)	**Theory of optical properties for quantum dots in microcavities**, Frank Jahnke, Jan Wiersig, Norman Baer, Christopher Gies

Internal symposium: New phenomena in edge transport of QHE systems
Organization: L. Sorba (Università di Modena e RE)

HL 27.1	Wed	14:30	(HSZ 01)	**Bending the quantum Hall effect: Novel metallic and insulating states in one dimension**, Matthew Grayson
HL 27.2	Wed	15:00	(HSZ 01)	**Particle-hole symmetric Luttinger liquids in a quantum Hall circuit**, Vittorio Pellegrini, Stefano Roddaro, Fabio Beltram, Lucia Sorba, Giorgio Biasiol , Loren N. Pfeiffer, K.W. West
HL 27.3	Wed	15:30	(HSZ 01)	**The Detection and Spectroscopy of Millimeter Wave Radiation based on the Interference of Edge-Magnetoplasmons**, Jurgen Smet, Igor Kukushkin, Chunping Jiang, Sergey Mikhailov, Klaus von Klitzing
HL 27.4	Wed	16:00	(HSZ 01)	**Selective edge excitations - inter-edge magnetoplasmon mode and inter-edge spin diode**, Frank Hohls, Gennadiy Sukhodub, Rolf J. Haug

Internal symposium: Photonic metamaterials
Organization: M. Wegener (Universität Karlsruhe)

HL 39.1	Thu	11:00	(HSZ 01)	**Magnetoinductive waves in magnetic metamaterials**, Ekaterina Shamonina
HL 39.2	Thu	11:30	(HSZ 01)	**Photonic metamaterials: Magnetism and negative index of refraction at optical frequencies**, Stefan Linden, Martin Wegener, Christian Enkrich, Matthias. W. Klein, Manuel Decker, Gunnar Dolling, Nils Feth, Costas. M. Soukoulis, Sven Burger, Frank Schmidt
HL 39.3	Thu	12:00	(HSZ 01)	**Metamaterials: Going Optical**, Vladimir Shalaev
HL 39.4	Thu	12:30	(HSZ 01)	**Negative refraction without absorption in the optical regime**, Michael Fleischhauer

Sessions

HL 1	**Invited Talk Kneissl**	Mon	09:30–10:15	HSZ 01	HL 1.1–1.1
HL 2	**Symposium THz-quantum cascade lasers**	Mon	10:15–12:45	HSZ 01	HL 2.1–2.5
HL 3	**III-V semiconductors I**	Mon	10:15–13:15	POT 51	HL 3.1–3.12
HL 4	**New materials**	Mon	10:15–12:15	BEY 154	HL 4.1–4.8
HL 5	**SiC**	Mon	12:15–13:00	BEY 154	HL 5.1–5.3
HL 6	**Quantum dots and wires: Transport properties I**	Mon	10:15–13:15	BEY 118	HL 6.1–6.12
HL 7	**Quantum dots and wires: Optical properties I**	Mon	10:15–13:00	POT 151	HL 7.1–7.11
HL 8	**Invited Talk Leturcq**	Mon	14:30–15:15	HSZ 01	HL 8.1–8.1
HL 9	**Poster I**	Mon	15:15–17:45	P3	HL 9.1–9.107
HL 10	**Invited Talk Santos**	Tue	09:30–10:15	HSZ 01	HL 10.1–10.1
HL 11	**Invited Talk Bauer**	Tue	10:15–11:00	HSZ 01	HL 11.1–11.1
HL 12	**Symposium Quantum optics in semiconductors I**	Tue	11:15–13:15	HSZ 01	HL 12.1–12.4
HL 13	**Spin controlled transport I**	Tue	11:00–13:15	BEY 118	HL 13.1–13.9
HL 14	**II-VI semiconductors I**	Tue	11:00–13:15	POT 151	HL 14.1–14.9
HL 15	**III-V semiconductors II**	Tue	11:00–13:15	POT 51	HL 15.1–15.9
HL 16	**Semiconductor laser I**	Tue	11:00–13:15	BEY 154	HL 16.1–16.9
HL 17	**Invited Talk Geim**	Tue	14:30–15:15	HSZ 01	HL 17.1–17.1
HL 18	**Symposium Quantum optics in semiconductors II**	Tue	15:15–17:15	HSZ 01	HL 18.1–18.5
HL 19	**Quantum dots and wires: Optical properties II**	Tue	17:15–19:30	HSZ 01	HL 19.1–19.9
HL 20	**Spin controlled transport II**	Tue	15:15–16:30	BEY 118	HL 20.1–20.5
HL 21	**Transport properties I**	Tue	16:30–19:30	BEY 118	HL 21.1–21.12
HL 22	**Semiconductor laser II**	Tue	15:15–17:15	BEY 154	HL 22.1–22.8
HL 23	**Interfaces/surfaces**	Tue	17:15–19:30	BEY 154	HL 23.1–23.9
HL 24	**Ultra fast phenomena**	Tue	15:15–18:00	POT 151	HL 24.1–24.11
HL 25	**C/diamond**	Tue	18:00–19:00	POT 151	HL 25.1–25.4
HL 26	**II-VI semiconductors II**	Tue	15:15–18:45	POT 51	HL 26.1–26.14
HL 27	**Symposium New phenomena in edge transport of QHE systems**	Wed	14:30–16:30	HSZ 01	HL 27.1–27.4
HL 28	**Transport in high magnetic field/Quantum Hall-effect**	Wed	16:30–17:00	HSZ 01	HL 28.1–28.2
HL 29	**Transport properties II**	Wed	17:00–18:15	HSZ 01	HL 29.1–29.5
HL 30	**Quantum dots and wires: Transport properties II**	Wed	18:15–19:15	HSZ 01	HL 30.1–30.4
HL 31	**Organic semiconductors**	Wed	14:30–19:00	POT 51	HL 31.1–31.17
HL 32	**Photovoltaic**	Wed	14:30–19:15	BEY 118	HL 32.1–32.18
HL 33	**GaN: Preparation and characterization**	Wed	14:30–17:15	BEY 154	HL 33.1–33.11
HL 34	**Impurities/Amorphous semiconductors**	Wed	17:15–18:30	BEY 154	HL 34.1–34.5
HL 35	**II-VI semiconductors III**	Wed	14:30–16:15	POT 151	HL 35.1–35.7
HL 36	**Optical properties**	Wed	16:15–19:15	POT 151	HL 36.1–36.12
HL 37	**Invited Talk Bustarret**	Thu	09:30–10:15	HSZ 01	HL 37.1–37.1
HL 38	**Invited Talk Meier**	Thu	10:15–11:00	HSZ 01	HL 38.1–38.1
HL 39	**Symposium Photonic metamaterials**	Thu	11:00–13:00	HSZ 01	HL 39.1–39.4
HL 40	**Quantum dots and wires: Optical properties III**	Thu	11:00–13:15	POT 151	HL 40.1–40.9
HL 41	**Heterostructures**	Thu	11:00–12:45	BEY 154	HL 41.1–41.7
HL 42	**Quantum dots and wires: Preparation and characterization I**	Thu	11:00–13:00	POT 51	HL 42.1–42.8
HL 43	**GaN: Devices I**	Thu	11:00–12:15	BEY 118	HL 43.1–43.5
HL 44	**Si/Ge**	Thu	12:15–13:15	BEY 118	HL 44.1–44.4
HL 45	**Invited Talk Koenraad**	Thu	14:30–15:15	HSZ 01	HL 45.1–45.1
HL 46	**Quantum dots and wires: Preparation and characterization II**	Thu	15:15–16:30	POT 51	HL 46.1–46.5
HL 47	**GaN: Devices II**	Thu	15:15–16:30	BEY 118	HL 47.1–47.5
HL 48	**Preparation and characterization**	Thu	15:15–16:30	POT 151	HL 48.1–48.5

HL 49	**Devices**	Thu	15:15–16:30	BEY 154	HL 49.1–49.5
HL 50	**Poster II**	Thu	16:30–19:00	P3	HL 50.1–50.109
HL 51	**Invited Talk Eroms**	Fri	10:15–11:00	HSZ 01	HL 51.1–51.1
HL 52	**Quantum dots and wires: Optical properties IV**	Fri	11:00–14:00	POT 151	HL 52.1–52.12
HL 53	**Hybrid systems**	Fri	11:00–11:15	BEY 154	HL 53.1–53.1
HL 54	**Metal-insulator transitions**	Fri	11:15–11:30	BEY 154	HL 54.1–54.1
HL 55	**Photonic crystals**	Fri	11:30–13:15	BEY 154	HL 55.1–55.7
HL 56	**Quantum dots and wires: Preparation and characterization III**	Fri	11:00–13:15	POT 51	HL 56.1–56.9
HL 57	**Theory of electronic structure**	Fri	11:00–12:45	BEY 118	HL 57.1–57.7

Annual General Meeting of the Section Semiconductor Physics

Thu 19:00–20:00 HSZ 01

Tagesordnung:
1. Begrüßung und Bericht
2. Stichwortkatalog
3. Verschiedenes

Sessions

– Invited, Keynote, Contributed Talks and Posters –

HL 1 Invited Talk Kneissl

Time: Monday 09:30–10:15 Room: HSZ 01

Invited Talk HL 1.1 Mon 09:30 HSZ 01

From ultraviolet light emitting diodes to microcavity disk lasers - New frontiers in InAlGaN optoelectronics — •Michael Kneissl — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10123 Berlin, Germany

Over the past decade group III nitrides have evolved into one of the most important and versatile semiconductor materials. GaN-based blue, green and white light emitting diodes as well as violet laser diodes are already commonplace and have entered many areas of everyday life. Here we will discuss some of the new fields of research for InAlGaN materials and devices and review progress in the development of deep ultraviolet light emitting diodes and lasers, growth and optical properties of InN and indium rich alloys, the role of GaN-based quantum dots for novel light emitters, and work on spiral microcavity disk lasers.

HL 2 Symposium THz-quantum cascade lasers

Time: Monday 10:15–12:45 Room: HSZ 01

Keynote Talk HL 2.1 Mon 10:15 HSZ 01

Designing the emission of THz Quantum Cascade Lasers with surface plasmon photonic structures — •Alessandro Tredicucci — NEST CNR-INFM , Scuola Normale Superiore, Piazza dei Cavalieri 7, 56126 Pisa, Italy

The development of quantum cascade lasers operating at terahertz frequencies is proceeding at a very rapid pace. For their successful practical implementation, specific requirements have now to be addressed, particularly concerning the properties of the emitted radiation. Single-mode THz lasers with distributed feedback resonators have been achieved and a new technique involving surface plasmon gratings has been demonstrated to improve performances. The latter also offers the possibility of constructing distributed Bragg gratings as a replacement for high-reflection coatings or to implement vertical emitting devices. Solutions allowing broad tuneability are examined, either relying on external cavity set-ups or more unconventional external electrical control.

Keynote Talk HL 2.2 Mon 10:45 HSZ 01

THz generation and mixing using Quantum Cascade Lasers — •Carlos Sirtori — Matériaux et Phénomènes Quantiques, Université Denis Diderot - Paris 7, Paris, France

THz quantum cascade (QC) lasers are electrically pumped semiconductor devices based on electronic intersubband transition in quantum wells. Recently, we have been investigating lasers with emission frequency at 3THz and 1.9THz ($\lambda = 100\mu$m and $\lambda = 160\mu$m). The latter is the longest wavelength ever achieved in QC lasers without the help of a magnetic field. At 3THz we were able to obtain 100mW of peak power and a maximum operating temperature of 100K. After a brief introduction on the state-of-the-art, I will present our results on novel THz waveguide structures, allowing "buried"structures and ultra-low threshold currents. Finally, I will introduce a scheme in which a beam at telecom frequencies can be injected into a QC lasers for coherent THz modulation and up-conversion.

Keynote Talk HL 2.3 Mon 11:15 HSZ 01

Progress in single frequency and long wavelength quantum cascade lasers — •Jerome Faist[1], G. Scalari[1], L. Sirigu[1], L. Ajili[1], C. Walther[1], M. Giovannini[1], A. Dunbar[2], and R. Houdre[2] — [1]University of Neuchâtel, Switzerland — [2]EPFL Lausanne, Switzerland

The realization of terahertz QC lasers has attracted much attention because of its potential applications in imaging and spectroscopy. Spatial and spectral control of the mode profile are therefore of paramount importance. Single mode distributed feedback, as well as devices with photonic crystal mirrors will be demonstrated. Electrically switchable, multi-color emission based on magnetic confinement with a record low frequency of 1.39 THz will also be discussed. Finally, results with InP-based terahertz quantum cascade will be described.

Keynote Talk HL 2.4 Mon 11:45 HSZ 01

Growth and Processing of GaAs quantum cascade lasers — •Gottfried Strasser, Aaron Maxwell Andrews, Tomas Roch, Gernot Fasching, Alexander Benz, Sebastian Golka, Maximilian Austerer, Christian Pfluegl, Werner Schrenk, and Karl Unterrainer — TU Wien, Zentrum für Mikro- und Nanostrukturen, Floragasse 7, 1040 Wien

We report on growth and processing of GaAs-based quantum cascade lasers above and below the reststrahlenband. Despite the advances in mid-infrared (MIR) QCLs, THz QCLs remain difficult to fabricate. The tolerances in alloy composition, layer thickness, and doping are lower for THz QCLs than their MIR counterparts. Processing of GaAs QC lasers at THz frequencies isin spite of the relaxed dimensions, still a demanding task. This is particularly true for micro cavities. Double plasmon waveguides, single plasmon and double metal waveguide scenarios will be discussed. We will report about various THz resonators [1] (circular and ring shaped micro cavities) as well as surface emitting concepts (2nd order dfbs), where smart dfb designs can be used for wavelength selection of e.g. surface SHG [2] versus facet fundamental light output.

[1] G. Fasching, A. Benz, K. Unterrainer, R. Zobl, A.M. Andrews, T. Roch, W. Schrenk, G. Strasser; "THz Microcavity Quantum Cascade Lasers"; Appl. Phys. Lett. 87, (21.11.2005)

[2] C. Pflügl, M. Austerer, W. Schrenk, G. Strasser; "Second-harmonic generation in GaAs-based quantum-cascade lasers grown on <100> substrates"; Electron. Lett., in print (2005)

Keynote Talk HL 2.5 Mon 12:15 HSZ 01

GaInAs/AlAsSb quantum cascade lasers: a new approach towards 3-to-5 μm semiconductor lasers — •Joachim Wagner, Quankui Yang, Christian Manz, Wolfgang Bronner, Christian Mann, and Klaus Köhler — Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Tullastrasse 72, 79108 Freiburg, Germany

Quantum cascade (QC) lasers based on the GaInAs/AlInAs-on-InP materials combination yield high-performance devices in the 5-to-10 μm wavelength range. These lasers can be operated in cw mode up to room-temperature and in pulsed mode up to 400-500K. Towards shorter wavelengths GaInAs/AlInAs QC laser performance rolls off due to insufficient carrier confinement caused by the limited available conduction- band offset, which is in the 500-700 meV range. A more than twofold increase in con-duction band offset can be achieved when using lattice matched AlAsSb rather than AlInAs as barrier material. For the GaInAs/AlAsSb materials combination the offset for the direct conduction band minimum amounts to 1.6 eV. Compared to alternative con-cepts for large conduction band offset QC structures, such as the GaN/AlN or InAs/AlSb materials combinations, the present approach has the significant advantage to make use of the mature fabrication technology available for InP-based lasers.
In spite of the challenges in materials growth, GaInAs/AlAsSb and even quaternary barrier GaInAs/AlGaAsSb QC lasers emitting in the 4-4.5

μm range have been grown by molecular-beam epitaxy. In pulsed mode operation, GaInAs/AlAsSb QC lasers ex-hibit a peak output power of up to 900 mW room-temperature, while their maximum operating temperature lies above 400 K. Furthermore, GaInAs/AlAsSb DFB QC lasers have been demonstrated, showing single-mode emission at 4.08 μm for pulsed mode room-temperature operation.

HL 3 III-V semiconductors I

Time: Monday 10:15–13:15 Room: POT 51

HL 3.1 Mon 10:15 POT 51

Surface concentration mapping of InAs/GaAs quantum dots — •S. Heun[1], G. Biasiol[1], G. B. Golinelli[2], A. Locatelli[3], T. O. Mentes[3], F. Z. Guo[4], C. Hofer[5], C. Teichert[5], and L. Sorba[1,2] — [1]Laboratorio TASC INFM-CNR, 34012 Trieste, Italy — [2]Universita degli Studi di Modena e Reggio Emilia, 41100 Modena, Italy — [3]Sincrotrone Trieste, 34012 Trieste, Italy — [4]JASRI/SPring-8, 1-1-1, Kouto, Mikazuki, Sayo, Hyogo 679-5198, Japan — [5]Institute of Physics, University of Leoben, 8700 Leoben, Austria

With x-ray photoemission electron microscopy we obtained two-dimensional maps of the in-plane surface composition of InAs/GaAs self-assembled quantum dots [1]. This provides complementary information to cross-sectional studies of InAs dots, which could open the way to a full 3D mapping of the dot composition and to a better knowledge of their formation mechanisms. Besides, the extreme surface sensitivity of our technique (photoelectron escape depth 0.5 nm) yields information essentially on the composition of the growth front. Our data clearly demonstrate that the surface composition of the dots is neither pure InAs nor homogeneous $In_xGa_{1-x}As$, but we observe an In concentration gradient from the center (high concentration) to the borders (lower concentration) of the dots. In addition, we observe a strong In segregation ($x \approx 0.9$) to the surface of the dots and of the surrounding wetting layer. Such segregation, well known for two-dimensional InAs/GaAs growth, had not been directly observed so far on top of the dots, and should be considered to model size and composition of GaAs-overgrown structures.

[1] G. Biasiol *et al.*, Appl. Phys. Lett. **87** (21), in press (2005).

HL 3.2 Mon 10:30 POT 51

Spin polarization in a two dimensional electron gas with spin-orbit interaction — •Mathias Duckheim and Daniel Loss — Department of Physics and Astronomy, University of Basel, Switzerland

Spin-orbit interaction in semiconductor structures can be visualized as an effective magnetic field with direction and magnitude depending on the electron momentum. It thus offers indirect control of the spin via the orbital degree of freedom and can be utilized to achieve coherent spin manipulation by tuning electric gates. In this context, we calculate the polarization of electrons in a disordered, two-dimensional semiconductor structure with spin-orbit interaction in a corresponding field configuration and find an analytical result for a finite measureable magnetization.

HL 3.3 Mon 10:45 POT 51

Carbon doped high mobility hole gases — •Christian Gerl, Johannes Bauer, Ursula Wurstbauer, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D- 93040 Regensburg

Two dimensional hole gases (2DHGs) in the GaAs/AlGaAs heterosystem are of renewed interest since their quality has been increased by utilizing Carbon as an acceptor for MBE growth [1, 2]. They exhibit a pronounced Rashba effect, a mechanism that is proposed for spintronic applications in which a macroscopic electric field gives rise to a spin splitting of subbands for finite values of k [3]. The Shubnikov-de-Haas effect can be used to determine the individual subband populations. We introduce Carbon doped 2DHGs in the (100) and (110) crystallographic direction in various structure designs with low temperature mobilities beyond 10^6cm^2/Vs, grown in our MBE system. Applying a surface gate bias to the samples the tunability of the Rashba induced spin splitting as well as the density dependence of the hole mobility is analyzed.

[1] B. Gribic, Appl. Phys. Lett. 85, 2277 (2004) [2] C. Gerl, Appl. Phys. Lett. 86, 252105 (2005) [3] Y. A. Bychkov, J. Phys. C 17, 6039 (1984)

HL 3.4 Mon 11:00 POT 51

Evidence of material mixing during local anodic oxidation nanolithography — •S. Heun[1], G. Mori[1], M. Lazzarino[1], D. Ercolani[1], G. Biasiol[1], A. Locatelli[2], and L. Sorba[1] — [1]Laboratorio Nazionale TASC INFM-CNR, 34012 Trieste, Italy — [2]Sincrotrone Trieste, 34012 Trieste, Italy

We investigated the chemical properties of nanostructures fabricated by local anodic oxidation (LAO) on epitaxial GaAs/AlAs/GaAs layers by means of laterally-resolved photoemission spectroscopy. We find evidence for the unexpected presence of Al compounds located in the topmost surface layers of the LAO structures. We studied the evolution of the surface chemical composition of these nanostructures as a function of x-ray exposure time (photon energy hv=130 eV), and we found a reduction in the amount of the surface Ga oxide compounds with respect to the Al compounds [1]. Our results cannot be explained within the framework of the commonly accepted mechanism that describes the growth of the LAO oxides in terms of diffusion of oxygen-rich ions through the growing oxide. A more general mechanism that explains our experimental findings is proposed [2].

[1] G. Mori, M. Lazzarino, D. Ercolani, G. Biasiol, A. Locatelli, L. Sorba, and S. Heun, Nucl. Instrum. Methods Phys. Res. B, in press.
[2] G. Mori, M. Lazzarino, D. Ercolani, G. Biasiol, L. Sorba, S. Heun, and A. Locatelli, J. Appl. Phys., in press.

HL 3.5 Mon 11:15 POT 51

Agglomeration of As Antisites in As-rich LT-GaAs: Nucleation without a critical nucleus size — •Torsten E.M. Staab[1], Risto M. Nieminen[2], Martina Luysberg[3], and Thomas Frauenheim[4] — [1]Helmholtz Institut für Strahlen- und Kernphysik,Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 14-16,D-53115 Bonn, Germany — [2]Laboratory of Physics, Helsinki University of Technology,P.O. Box 1100, FIN–02015 HUT, Finland — [3]Institut für Festkörperforschung,Forschungszentrum Jülich, D–52425 Jülich, Germany — [4]University GH Paderborn, Department of Physics, Theoretical Physics, D–33098 Paderborn, Germany

To investigate the early stages of nucleation and growth of As precipitations in GaAs grown at low substrate temperature (LT-GaAs) we make use of a self-consistent-charge density-functional based tight-binding method. Since already a pair of As-antisite shows a significant binding energy which increases when attaching more As-antisites, there is no critical nucleus size. Provided that all excess As has precipitated the clusters may grow in size since the binding energies increase with increasing agglomeration size. These findings close the gap between experimental investigation of point defects and the detection of nanometer-size precipitations in the TEM [1].

[1] T.E.M. Staab, R.M. Nieminen, M. Luysberg, and Th. Frauenheim, *Phys. Rev. Lett.* **95** (2005) 12550

HL 3.6 Mon 11:30 POT 51

Resonant Tunneling through space-charge layers at GaAs surfaces — •S. Loth[1], M. Wenderoth[1], L. Winking[1], R. G. Ulbrich[1], S. Malzer[2], and G. H. Döhler[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Universität Erlangen-Nürnberg, Max-Planck-Research Group, Institute of Optics, Information, and Photonics, Germany

Recent work in the field of the tunneling magneto resistance showed that charge transport through tunnel junctions has to be treated beyond Bardeen's basic model: the tunnel process must be described within the framework of the complex band structure [1]. Usually this approach is not necessary for the interpretation of Scanning Tunneling Microscope (STM) measurements, because the current is mediated by real states in the sample and by evanescent states only in the vacuum gap. We demonstrate that for a class of well known experiments - Scanning Tunneling Spectroscopy (STS) on GaAs - the evanescent gap states are most relevant:

We studied p-doped GaAs {110} cleavage surfaces with a low temperature STM. The observed negative differential conductivity is due to a

resonant enhancement of the tunneling probability through the depletion layer mediated by individual shallow acceptors. Energetically and spatially resolved spectra show that the pronounced anisotropic contrast pattern of shallow acceptors occurs exclusively for the energy interval of this specific transport channel. Our results indicate that structural properties of the complex band structure can be probed with the STM.

[1] P. Mavropoulos et al., Phys. Rev. Lett. **85**, 1088 (2000).

HL 3.7 Mon 11:45 POT 51

Atomically resolved imaging of the GaAsN(110) surface — •V. Vossebürger[1], D. Martin[1], L. Ivanova[1], A. Lenz[1], R. Timm[1], H. Eisele[1], M. Dähne[1], O. Schuhmann[2], L. Geelhaar[2], and H. Riechert[2] — [1]Technische Universität Berlin, Institut fürFestkörperphysik, Hardenbergstr. 36, D-10623 Berlin — [2]Infinion Technologies, Corporate Research Photonics,D-81730 München

$GaAs_{1-x}N_x$ is a highly interesting material because of its giant composition dependent optical bowing, which is theoretically described by the band anticrossing model (BAC)[1].
In order to determine the arrangement of nitrogen atoms in GaAsN alloys with low nitrogen concentration x between 1% and 2% as well as its electronic structure, cross-sectional scanning tunneling microscopy (XSTM) and spectroscopy (XSTS) experiments were performed of GaAsN layers in GaAs grown by molecular beam epitaxy (MBE).
Using high resolution voltage dependent XSTM images and simultaneously acquired XSTS images, we derive a structure model of the GaAsN(110) surface. In differential conductance spectra, displaying the local density of states, we observe a reduced band gap and an additional nitrogen-induced state. This state is related to the theoretically found band splitting in the BAC model.
This work was supported by the SFB 296, and project Da 408/8 of the DPG.

[1] W. Shan et al., Phys. Rev. Lett. **82**, 1221 (1999)

HL 3.8 Mon 12:00 POT 51

Structure and scanning tunneling microscopy images of Auadsorbed on GaAs(111)B-($\sqrt{3}\times\sqrt{3}$)-$R30°$ — •Hongsuk Yi[1], Peter Kratzer[1], Emelie Hilner[2], Anders Mikkelsen[2], and Edwin Lundgren[2] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195Berlin, Germany — [2]Institute of Physics, LundUniversity, Box 118, SE-22100 Lund, Sweden

Adsorption of gold on GaAs surfaces is interesting both for metallic contacts and for "catalyzing"growth of GaAs nanorods. Recently, it has been observed that small amounts of Au induce a well-ordered ($\sqrt{3}\times\sqrt{3}$) reconstruction on the GaAs(111)B surface, replacing the (2×2) As-trimer structure of the clean surface. We investigate the stable adsorption sites and simulate scanning tunneling microscopy (STM) images of Au absorbed on the GaAs(111)B surface, using the GGA approximation of density functional theory, and plane-wave/pseudopotential calculations.

We propose an energetically favorable model for the Au/GaAs(111)B-($\sqrt{3}\times\sqrt{3}$) surface with one Au per unit cell located in a threefold hollow site. From the calculated potential energy surface we obtain a diffusion barrier height of 0.45 eV for Au adatoms. In the simulated filled-state STM images the Au atoms appear as triangular structures whose edges point towards neighboring As atoms. The proposed structural model is in agreement with experimental data from low-energy electron diffraction and STM.

HL 3.9 Mon 12:15 POT 51

Scanning Tunneling Spectroscopy on single Mn-acceptors in InAs — •Felix Marczinowski[1], Jens Wiebe[1], Focko Meier[1], Katsushi Hashimoto[1], Markus Morgenstern[2], Roland Wiesendanger[1], Jiang-Ming Tang[3], and Michael E. Flatté[3] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]2. Physikalisches Institut, RWTH-Aachen, Templergraben 55, 52056 Aachen — [3]OSTC and Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242, USA

Ferromagnetic semiconductors like InMnAs receive a great amount of interest as the pivotal material for future spintronic devices. Recent experiments using STM suggest that the anisotropic shape of the acceptor wave function might affect the interaction of the magnetic dopants. [1,2] We performed scanning tunneling spectroscopy on Mn-doped InAs at low temperatures. In STM images, we find an anisotropic, cross-like shape of the Mn, which fits nicely to the Mn-acceptor wave function as calculated with the tight binding method. In contrast to the GaAs-case[1], Mn appears as a cross-like protrusion in the occupied density-of-states (DOS), and as a cross-like depression in the unoccupied DOS. These differences are probably explained by the different band-bending properties of InAs and GaAs. Additionally, we found several discrete states in dI/dU-curves which also reflect the symmetry of the Mn-acceptor wave function. The similarity of our findings to the GaAs-case[1] suggest that the cross-like shape is universal for Mn-acceptors in III-V-semiconductors.

[1] Yakunin *et al.*, PRL **92**, 216806 (2004)
[2] Arseev *et al.*, JETP Lett. **77**, 172 (2003)

HL 3.10 Mon 12:30 POT 51

Nitrogen induced properties in $Ga_{1-x}In_xN_yAs_{1-y}$ observed by cross-sectional scanning tunneling microscopy — •D. Martin[1], V. Vossebürger[1], L. Ivanova[1], A. Lenz[1], R. Timm[1], H. Eisele[1], M. Dähne[1], O. Schumann[2], L. Geelhaar[2], and H. Riechert[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Infineon Technologies, Corporate Research Photonics, 81730 München, Germany

The incorporation of nitrogen at low concentrations of up to 5% in GaInAs alloys induces a massive redshift in emission wavelength. In this way semiconductor laser diodes can reach the industrially important emission wavelengths of 1.3 μm and 1.55 μm. In order to improve the efficiency of these devices, a detailed investigation of the spatial and electronical properties of the GaInNAs alloy induced by nitrogen and indium atoms is required.
GaInNAs layers with different In and N concentrations embedded in GaAs were grown using molecular beam epitaxy. Cross-sectional scanning tunneling microscopy was used to study the spatial composition of GaInNAs alloys on an atomic scale. From high resolution images of the $Ga_{1-x}In_xN_yAs_{1-y}(110)$ surface (with $0.013 \leq x \leq 0.087$ and $0.004 \leq y \leq 0.029$), details on the spatial distribution of indium and nitrogen atoms were derived.
This work was supported by the SFB 296 and project Da 408/8 of the DPG.

HL 3.11 Mon 12:45 POT 51

Atomistic and Continuum Description of Acoustic Phonons in Nanostructures — •Frank Grosse and Roland Zimmermann — Halbleitertheore, Institut für Physik an der Humboldt-Unversität Newtonstr. 15 12489 Berlin

Acoustic phonon spectra are calculated for semiconductor nanostructures. An irregular three-dimensional shape or realistic crystallographic symmetries allow only a numerical determination. Phonons are described within continuum linear elasticity theory as well as with atomistic models, which interaction parameters are determined by ab initio density functional calculations. Nanoparticles, especially when embedded in a different material, may be under substantial inhomogeneous stress. It is confirmed by atomistic calculations that their acoustic phonon modes can be described by modified inhomogeneous elastic constants going beyond linear elasticity. Implications for the dephasing of optical excitations in nanoparticles due to electron-acoustic phonon interaction are discussed.

HL 3.12 Mon 13:00 POT 51

Carrier transport by acoustic fields in InP-based structures — •Markus Beck[1], Maurício M. de Lima[1], Jörg Rudolph[1], Richard Nötzel[2], and Paulo V. Santos[1] — [1]Paul Drude Institut für Festkörperelektronik, Berlin, Germany — [2]Technische Universiteit, Eindhoven, Netherlands

We investigate the modulation of the optical properties and the ambipolar transport of photogenerated electrons and holes by surface acoustic waves (SAWs) in InGaAsP structures. The generation of SAWs using interdigital transducers (IDTs) in InP-based materials is limited by the low piezoelectric coupling. We succeed to generate strong SAW fields by coating them with a piezoelectric ZnO film (typically, 0.5 μm-thick) deposited using a low temperature ($< 200°C$) process. The insertion loss of acoustic delay lines on ZnO-coated InP-substrates could be reduced to 10 dB. The photoluminescence intensity of InGaAsP structures with emission wavelength of 1470 nm at 5 K is drastically reduced under acoustic excitation. This effect is attributed to the spatial separation and transport of the photogenerated electrons and holes by the piezoelectric field, as previously observed for GaAs. The carriers are acoustically transported over distances on the order of 200 μm. The photoluminescence from the transported carrier can be retrieved by forcing their recombination in an area where the ZnO film has been removed. These results demonstrate that acoustic fields can be used to control carriers in InP-based structures operating at telecommunication wavelengths. (Supported by the EU-ePIXnet consortium)

HL 4 New materials

Time: Monday 10:15–12:15 Room: BEY 154

HL 4.1 Mon 10:15 BEY 154

Influence of the stoichiometry on the crystal structure of phase change materials — •Julia Steiner, Henning Dieker, Christoph Steimer, and Matthias Wuttig — I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Phase change materials are characterized by a remarkable property combination. On the one hand they show a pronounced difference in their optical and electronic properties between the amorphous and the crystalline phase. On the other hand the transition between these two phases proceeds very fast. Because of this property combination phase change materials are of both great physical and technological interest. They are already used in optical data storage applications and are investigated as non-volatile electronic memories as well.

Nevertheless the correlation between stoichiometry, crystal structure and physical properties is not yet fully understood. To investigate the correlation between stoichiometry and crystal structure of phase change materials diffraction methods have been employed to identify the structure of different phase change alloys. This comparative analysis allows us to determine systematic trends in the structure of phase change media with changing stoichiometry.

HL 4.2 Mon 10:30 BEY 154

Kinetics of crystal nucleation in undercooled droplets of phase change alloys — •Dominic Lencer[1], Johannes Kalb[1], Frans Spaepen[2], and Matthias Wuttig[1] — [1]I. Insitute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany — [2]Division of Engineering and Applied Sciences, 29 Oxford Street, Cambridge MA 02138, USA

The demand for fast, reliable and inexpensive data storage and memory devices has led to the development of devices employing the difference in the physical properties of so-called phase change materials between the crystalline and the amorphous state to store information by switching between these two states.

While this technique is already widely used in optical devices such as CD-RW and DVD±RW, current research heads for competitive electrical memories called PCRAM (phase change random access memory).

The main challenge to turn PCRAMs into a viable alternative for FLASH chips or even DRAMs is related to an improvement in the understanding of the switching process and the crystallization kinetics.

To obtain such insight droplets of four tellurium-based phase change alloys ($Ag_1In_1Te_2$, $Ag_1Sb_1Te_2$, $Ge_1Bi_2Te_4$, $Ge_1Sb_2Te_4$) fluxed in B_2O_3 glass were prepared by annealing and subsequently undercooled below their liquidus temperature using a differential thermal analyzer (DTA).

The results of these measurements enabled us to estimate limits for both the crystal-melt interfacial energy and the steady-state crystal nucleation rate using the nucleation theory.

HL 4.3 Mon 10:45 BEY 154

Nucleation characteristics of silicon nanowires as a function of the metal catalyst — •Anna Fontcuberta i Morral[1,2], Billel Kalache[2], and Pere Roca i Cabarrocas[2] — [1]Walter Schottky Institut- TU Muenchen, Am Coulomwall, 3, 85748 Garching — [2]LPICM, Ecole Polytechnique, 91128 Palaiseau Cedex, France

A theoretical model of the Vapor-Liquid-Solid growth mechanism pertaining to the nucleation of silicon nanowires is presented. The model is based on the diffusion of the silicon through the solid catalyst and predicts an incubation time for the onset of nanowire growth. To validate the model, the incubation times of silicon nanowires obtained by Chemical Vapor Deposition and employing both gold and copper as a catalyst have been measured for the first time The experimentally observed incubation times are in excellent agreement with the presented model and diffusion characteristics of silicon through solid Au and Cu. The results can be applied to any other metal/semiconductor system for the synthesis of nanowires and provide a route to measure the phase space for the nanowire-synthesis.

HL 4.4 Mon 11:00 BEY 154

Band Offset Measurements of Quinternary (AlGaIn)(AsSb) — •Alexander Bachmann, Oliver Dier, Christian Lauer, Ralf Meyer, and Markus-Christian Amann — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Current MIR antimonide-based type-I diode lasers reach a wavelength of up to 3.3 μm. These heterojunction devices use GaInAsSb with maximum 55% of In as quantum-well material and AlGaAsSb with 20% to 30% of Al as barrier material. To enlarge the wavelength further, the active material has to be adjusted. InAsSb has the smallest band gap in the (AlGaIn)(AsSb) system (0.283 eV according to 4.38 μm), but it has type-II alignment if used with AlGaAsSb as barrier material. Therefore, AlInAsSb or the quinternary AlGaInAsSb may be used yielding a type-I arrangement. As it is not possible to grow AlInAsSb with higher Al or In concentrations due to the formation of clusters and a large miscibility gap, Ga-dominated AlGaInAsSb has been used. Because of one more degree of freedom, it is possible to adjust the valence band offset (VBO) and the conduction band offset (CBO) almost independently within a certain range. For a diode laser a sufficiently large VBO for better hole-confinement and moderately large CBO for a homogeneous injection of the electrons in every quantum well are needed. However, band offset calculations from literature yield very different results, depending on the set of material parameters used. In this talk, we therefore present measured band-offsets (by C-V profiling) on MBE-grown quinternary samples of various material combinations to determine the optimal band alignments for type-I lasers.

HL 4.5 Mon 11:15 BEY 154

Parametric Amplification of Magnetoinductive Waves in Bi-periodic Metamaterial Arrays — •Oleksiy Sydoruk[1], Oleksandr Zhuromskyy[1], Ekaterina Shamonina[1], and Laszlo Solymar[2] — [1]Department of Physics, University of Osnabrück,Osnabrück, Germany — [2]Department of Electrical and Electronic Engineering,Imperial College, London, United Kingdom

One of the promising fields of applications of Magnetoinductive Waves [1,2] is in Magnetic Resonance Imaging, where they can provide an elegant and effective solution for signal guiding [3] and detection [4]. Since the human body is a significant source of noise an improvement in the signal-to-noise ratio is always desirable. Amplification of the signal at an early stage in the receiving system (which in the case of a magnetoinductive receiver is a set of magnetically coupled resonators) will allow both noise reduction and compensation for ohmic losses.

Parametric amplification is an obvious candidate for investigations. It was suggested [5] that bi-periodic arrays of metamaterial elements can provide an environment where exact phase matching conditions for parametric amplification may be fulfilled. Here we present a theory of parametric amplification in bi-periodic metamaterial arrays with the required nonlinearity realized by varactor insertions.

[1] E. Shamonina, et. al, Electron. Lett. **38**, 371-373 (2002).
[2] E. Shamonina, et. al, J. Appl. Phys. **92**, 6252-6261 (2002).
[3] E. Shamonina and L. Solymar, J. Phys. D **37**, 362-367 (2004).
[4] L. Solymar, et. al, *submitted to J. Appl. Phys.*
[5] O. Sydoruk, et. al, Appl. Phys. Lett. **87**, 072501-1-3 (2005).

HL 4.6 Mon 11:30 BEY 154

Near Field Phenomena in Metamaterials — •Frank Hesmer[1], Olexander Zhuromskyy[1], Ekaterina Shamonina[1], and Laszlo Solymar[2] — [1]Department of Physics, University of Osnabrueck, Germany — [2]EEE Department, Imperial College London, United Kingdom

Metamaterials are a new class of electromagnetic materials, which are man-maid structures composed of small resonant elements. The electromagnetic response of metamaterials can differ from that of natural materials, because properties of each individual element can be varied in a wide range. In particular the electromagnetic fields can be manipulated on the scales much smaller than the wavelength.

Applications of metamaterials include subwavelength imaging due to evanescent fields and magnetic flux guiding based on magnetoinductive (MI) waves with potential applications in Magnetic Resonance Imaging.

We apply a number of numerical and analytical tools to study the near field phenomena in a large variety of metamaterial elements (capacitively loaded loops, split ring resonators and swiss rolls). We plot distributions of the magnetic field and also streamlines and magnitudes of the Poynting vector for visualising the near field phenomena in magnetic metamaterials.

Support from the German Research Foundation (DFG) Emmy-Noether-Program is gratefully acknowledged.

HL 4.7 Mon 11:45 BEY 154

Ellipsometry and Microreflection on Cylindrite — •Chris Sturm[1], Rüdiger Schmidt-Grund[1], Ronny Kaden[2], Bernd Rheinländer[1], Klaus Bente[2], and Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]Universität Leipzig, Fakultät für Chemie und Mineralogie, Institut für Mineralogie, Kristallographie und Materialwissenschaft, Scharnhorststraße 20, 04275 Leipzig

Cylindrite, $FeSn_4Pb_3Sn_2S_{14}$, is a sulfosalt mineral which naturally occurs as lamellae and cylinders. Thus, it is a promising material for micro- and nanostructures. Up to now the optical dielectric function is not known.
By CVT (chemical vapour transport) with iodine as transport agent the cylindrite crystals where synthesized as platelets as well as cylinders.
The samples were studied by ellipsometry in the spectral range from 0.75 eV to 3.5 eV and by microreflection technique in the spectral range from 1.8 eV to 3.2 eV. Using a layer structure model the dielectric function of Cylindrite was obtained. This dielectric function was found to be similar to those of a semiconductor. From the reflectivity spectra in the absorption range it can be concluded that the chemical composition of the cylindric and lamellar samples is different.

HL 4.8 Mon 12:00 BEY 154

Ferromagnetism and magnetic anisotropy in Co-implanted TiO_2 — •N. Akdogan[1], B. Rameev[2,3], L. Dorosinsky[4], H. Sozeri[4], R. Khaibullin[3], B. Aktas [2], L. Tagirov[3,5], A. Nefedov[1], A. Westphalen[1], and H. Zabel[1] — [1]Institute of Experimental Physics IV, Ruhr-University Bochum, D-44780 Bochum, Germany — [2]Gebze Institute of Technology, 41400 Gebze-Kocaeli, Turkey — [3]Kazan Physical-Technical Institute of RAS, 420029 Kazan, Russia — [4]TUBITAK-UME, PK 54, 41470 Gebze-Kocaeli, Turkey — [5]Kazan State University, 420008 Kazan, Russia

Oxide based diluted magnetic semiconductors have recently attracted considerable attention because of reports of room temperature ferromagnetism in several systems and their projected potential for spintronic devices. However, subsequent reports have raised concerns about the initially suggested intrinsic nature of ferromagnetism in these materials.

Magnetic anisotropy of cobalt implanted single-crystalline rutile has been studied by means of MOKE and SQUID techniques. We observed for the first time strong angular dependence of the remanent magnetization and coercive field in the plane of the implanted surface: twofold anisotropy for the (100)- and fourfold anisotropy for the (001)-substrate samples. Possible origins of ferromagnetism and anisotropies in single-crystalline TiO_2 samples after Co-ion implantation are discussed.

This work was partially supported by DFG through SFB 491 and by RFBR through grant no. 04-02-97505. N. Akdogan acknowledges a fellowship through the Max-Planck Research School "SurMat".

HL 5 SiC

Time: Monday 12:15–13:00 Room: BEY 154

HL 5.1 Mon 12:15 BEY 154

Electronic Raman Scattering of Phosphorus Donors in Silicon Carbide — •Martin Hundhausen, Roland Puesche, and Lothar Ley — Technische Physik, Universität Erlangen

We have studied temperature and polarization dependent electronic Raman scattering in phosphorus doped Silicon Carbide (SiC). We observe signals in the low temperature Raman spectra with Raman shifts between 2.2 meV and 5.3 meV depending on the polytype. We assign these energies to transitions between the donor 1s ground state to its valley-orbit split 1s excited state. Different valley-orbit energies are assigned to signals originating from donors substituting different inequivalent lattice sites of host Si atoms. The splitting results from the different symmetries of possible linear combinations of states at the nonequivalent conduction band minima of SiC. From the polarization dependence of the Raman signals for 6H- and 4H-SiC we conclude that the two possible 1s donor states belong to E_2 and A_1-symmetry of the C_{6v} point group of the crystal, respectively. The temperature dependent occupation of these states as monitored by the Stokes and Anti-Stokes intensities in the Raman spectra in combination with the known degeneracies g_{A1} and g_{E2} suggests that the A_1 state is the ground state.

HL 5.2 Mon 12:30 BEY 154

Electronic properties of the 2x1 3C-SiC surface reconstruction studied with resonant photoemission — •Massimo Tallarida, Rakesh Sohal, and Dieter Schmeisser — Angewandte Physik-Sensorik, Brandenburgische Technische Universität, Konrad Wachsmann Allee, 17-03046-Cottbus

We have studied the 2x1 reconstructed surface of the 3C-SiC polytype by means of photoemission spectroscopy. The reconstruction was characterized through Si2p and C1s core level and angle-integrated valence band spectroscopy, and confirmed by the observation of a two-domain 2x1 LEED pattern. The electronic properties of this surface were investigated by collecting valence band spectra at photon energies near the Si2p and C1s absorption edges. The results show a strong dependence of the photoemission intensity on the excitation energy with characteristic resonances for certain valence band features. With a detailed study of the resonances we are able to assign the electronic origin of the resonating states and the nature of the electronic transition near the absorption edges.

HL 5.3 Mon 12:45 BEY 154

Kinetic mechanisms for the deactivation of nitrogen — •Alexander Mattausch, Michel Bockstedte, and Oleg Pankratov — Theoretische Festkörperphysik, Staudtstr. 7/B2, 91058 Erlangen, Germany

Nitrogen is a common dopant in silicon carbide. It is known that nitrogen substitutes for carbon atoms. Yet surprisingly, recent experiments have shown [1] that the silicon co-implantation (which should support N incorporation on the C-sublattice) leads to a significant deactivation of nitrogen at high annealing temperatures. At the same time, the concentration of compensating centers decreases. Employing *ab initio* density functional theory calculations we investigate the interaction of the nitrogen dopants with self-interstitials and vacancy aggregates in 4H-SiC. We find that a silicon interstitial can kick-out the activated N_C, since the emission of a nitrogen interstitial from the $(N\text{-}Si)_C$ complex is favoured over the silicon emission by 1 eV. The reaction of N with carbon interstitials leads to (CN)-complexes which possess deep levels. These defects have dissociation energies between 2.6 eV and 3.2 eV and thus are thermally stable. Yet, the formation of these complexes requires moderate temperatures and cannot be responsible for the high temperature annealing behaviour after silicon co-implantation. A possible alternative is the formation of the highly stable vacancy clusters $(V_C)_n$-V_{Si}. Due to the high migration barrier of V_C this process is possible only at high temperatures. These defects can trap nitrogen interstitials, finally leading to the electrically passive $(N_C)_4$-V_{Si} complexes.

[1] F. Schmid and G. Pensl, Appl. Phys. Lett. **84**, 3064 (2004).

HL 6 Quantum dots and wires: Transport properties I

Time: Monday 10:15–13:15 Room: BEY 118

HL 6.1 Mon 10:15 BEY 118

Electrical and optical characterisation of GaN and InN Nanowires — •Thomas Richter[1], Michel Marso[1], Ralph Meijers[1], Ratan Debnath[1], Toma Stoica[1,2], Raffaella Calarco[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich,52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest, Romania

Nanostructures such as semiconductor nanowires have an increasing interest as possible candidates for novel nanodevice concepts beyond CMOS. This is strongly motivated by their high versatility and practical applications in optical, electrical and chemical devices. Despite promising achievements by researchers all over the world, fundamental physical properties of those nanoscaled devices are still unclear. Electrical transport and optical behavior of these whiskers are interesting fields of research. We report on the reproducible growth of GaN and InN nanowires by plasma-assisted molecular beam epitaxy on Si (111) substrates. To improve the growth conditions the wires have been analysed by cathodoluminescence spectroscopy. For the electrical characterisation they have been transferred to a Si (100) substrate covered with a layer of SiO_2. Subsequently single nanowire devices have been fabricated by e-beam lithography for individually chosen nanowires. Electrical transport properties of the resulting metal-semiconductor-metal nanostructures are analyzed by means of current voltage measurements in dark and under UV-illumination at different temperatures.

HL 6.2 Mon 10:30 BEY 118

Low temperature electronic transport in vertical sub-100 nm resonant tunneling diodes — •Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1], Jakob Wensorra[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten and Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

Using a top down approach, vertical GaAs/AlAs resonant tunneling diodes (RTD) with lateral dimensions down to 50 nm have been processed.

DC electrical measurements at very low temperatures have been carried out both in linear and nonlinear regimes. Investigations at room temperature have already shown that the electronic transport properties in these nanodevices are strongly influenced by the lateral depletion region, leading to a new interesting behavior [1]. The actual study allows to evaluate the suggested quantum collimation model, which was used to explain qualitatively the room temperature transport characteristics of the sub-100 nm RTDs.

[1] J. Wensorra, K. M. Indlekofer, M. I. Lepsa, A. Förster, and H. Lüth, Nano Letters, DOI: 10.1021/nl051781a.

HL 6.3 Mon 10:45 BEY 118

Resonant Tunneling in GaAs/AlAs Nanocolumns Improved by Quantum Collimation — •Jakob Wensorra[1], Klaus Michael Indlekofer[1], Mihail Ion Lepsa[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten and Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

DC electrical measurements on top-down processed resonant tunneling GaAs/AlAs nanocolumns have been carried out at room temperature. The dependence of the I-V characteristics on the device dimension has shown that the electronic transport properties of the smallest devices are strongly influenced by the lateral depletion region, which defines the vertical conductive channel within the device. In the I-V characteristics, a clearly pronounced region of negative differential conductance has been observed, down to 50 nm lateral dimensions. Simulations of the 2D-potential map of the device structure by means of a self-consistent semi-classical drift-diffusion solver suggest a transport model based on a quantum collimation effect [1] due to a sadle point in the potential profile. For the ultimately scaled structures, this quantum collimation effect can lead to a distinct improvement of the nanodevice performance at room temperature.

[1] J. Wensorra, K. M. Indlekofer, M. I. Lepsa, A. Förster, and H. Lüth, Nano Letters 10.121/nl051781a (2005).

HL 6.4 Mon 11:00 BEY 118

Enhanced Shot Noise in Tunneling through coupled InAs Quantum Dots — •P. Barthold[1], N. Maire[1], F. Hohls[1,2], R. J. Haug[1], and K. Pierz[3] — [1]Institut für Festkörperphysik, Universität Hannover, Appelstraße 2, 30167 Hannover — [2]Cavendish Laboratory, University of Cambridge Madingley Road, Cambridge CB3 0HE, UK — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We investigate the noise properties of vertically coupled self-assembled InAs quantum dots (QDs) and find a surprising enhancement of shot noise.

The two layers of InAs QDs are surrounded by AlAs tunneling barriers. GaAs acts as a 3-dimensional emitter and collector. Depending on the external bias voltage we find peaks in the I/V-characteristic that correspond to electron transport through a stack of two vertically coupled QDs. We find enhanced shot noise at these peaks. For the noise measurements we focus on one peak in the I/V-characteristic. The so-called Fano factor α is introduced to compare the measured shot noise S with the full-Poissonian noise $S_{full} = 2eI$ that is expected for a single tunneling barrier: $\alpha := S/2eI$. At both sides of the peak the Fano factor α rises to values of $\alpha = 1.4$, while the noise is reduced on the top of the peak ($\alpha < 1$). The Fano factor α shows a significant temperature dependence while the peak in the I/V-characteristic changes only slightly. We discuss the different coupling mechanisms which can lead to such an enhanced shot noise.

HL 6.5 Mon 11:15 BEY 118

Resonances in the transport through one-dimensional constrictions in silicon based MOS field effect transistors — •Carsten Kentsch, Wolfgang Henschel, and Dieter Kern — Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen

Recently silicon has attracted attention towards the realization of spin based qubits as its main isotope has no nuclear spin and therefore a reduced probability of scattering with the base material can be expected. Spin-polarized electrons exist in the edge-states of two-dimensional electron gases at high magnetic fields. They are individually accessible by suitable constrictions and therefore can be useful to study the scattering between the spin-states by measuring electric current.

Hall-bar devices consisting of a silicon MOS field effect transistor with embedded split-gates below the top gate have been fabricated and characterized at. 1.5 Kelvin and magnetic fields of up to 8 Tesla. Transport through constrictions induced by the split gates shows fluctuations which can be interpreted as the effect of transmission resonances in a one-dimensional channel of a length comparable with the split-gate dimensions.

HL 6.6 Mon 11:30 BEY 118

Probing a Kondo correlated quantum dot with spin spectroscopy — •M. C. Rogge[1], D. Kupidura[1], M. Reinwald[2], W. Wegscheider[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We investigate Kondo effect and spin blockade observed on a many-electron quantum dot and study the magnetic field dependence. The quantum dot is built using local anodic oxidation. In a 3He/4He dilution refrigerator the magnetic field dependence of the differential conductance is measured. At lower fields a pronounced Kondo chessboard pattern is found which is replaced by spin blockade at higher fields. In an intermediate regime both effects are visible and the spin of the tunneling electron in the Kondo regime is detected. We make use of this combined effect to gain information about the internal spin configuration of our quantum dot. We find that the data cannot be explained assuming regular filling of electronic orbitals. Instead spin polarized filling seems to be probable. We compare our results with other publications of chessboard patterns and find a correlation with the electron number.

HL 6.7 Mon 11:45 BEY 118

Conductance and frequency dependent noise of a quantum dot spin valve — •Matthias Braun[1], Jürgen König[1], and Jan Martinek[2] — [1]Theoretische Physik III, Ruhr-Universit"at Bochum, D-44780 Bochum — [2]Institute of Molecular Physics, Polish Academy of Science, 60-179 Poznań, Poland

We discuss the transport properties of a single-level quantum dot weakly coupled to ferromagnetic leads with non-collinear magnetizations. The conductance of such a device directly depends on the non-equilibrium spin on the quantum dot [1]. The dot spin undergoes an interaction induced intrinsic spin precession [2], which can suppress magnetoresistance and can lead to a negative differential conductance. Spin relaxation can be addressed by an all electrical Hanle setup [3]. While the conductance is sensitive to the time average dot spin only, the time dependent spin dynamics can be observed in the current-current correlation function.

[1] M. Braun, J. König, and J. Martinek, PRB **70**, 195345 (2004)
[2] J. König and J. Martinek, PRL **90**, 166602 (2003)
[3] M. Braun, J. König, and J. Martinek, EPL **72**, 294 (2005)

HL 6.8 Mon 12:00 BEY 118

Freely Suspended Quantum Dots — •Clemens Rössler[1], Stefan Ludwig[1], Jörg P. Kotthaus[1], Dieter Schuh[2], and Werner Wegscheider[2] — [1]Center for NanoScience and Sektion Physik, Ludwig-Maximilians-Universität, Geschwister Scholl Platz 1, 80539 München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, 93040 Regensburg, Germany

Electrons in quantum dots are confined in all three spatial directions. The confinement leads to a quantisation of the eigenenergy of the electron states. Semiconductor quantum dots are promising candidates for the realisation of quantum bits (qubits). Similar to a classical bit a qubit is based on two states, e.g. the charge state of a single electron in a tunnel coupled double quantum dot. In such a system the interaction with phonons is a major source of decoherence.

In order to investigate the electron-phonon coupling we employ phonon cavities that are nanoscale bridges excavated from an AlGaAs/GaAs heterostructure. The latter contains a two-dimensional electron system (2DES). By use of top gates we locally deplete the 2DEG and, thus, define a freely suspended quantum dot on the bridge. In this way we couple a phonon cavity with a charge cavity.

This setup allows the observation of coupled electro-mechanical modes [1]. The tunability of the modified phonon spectrum of the nanobridge will allow to investigate the electron-phonon interaction by means of transport experiments.

[1] E. M. Höhberger et al., PRL 92, 046804 (2004).

HL 6.9 Mon 12:15 BEY 118

Tunneling resonances in quantum dots: Coulomb interaction modifies the width — •Björn Kubala[1], Jens Könemann[2], Jürgen König[1], and Rolf J. Haug[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Institut für Festkörperphysik, Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Single-electron tunneling through a zero-dimensional state in an asymmetric double-barrier resonant-tunneling structure is studied [1]. The broadening of steps in the I–V characteristics is found to strongly depend on the polarity of the applied bias voltage. Based on a qualitative picture for the finite-life-time broadening of the quantum dot states and a quantitative comparison of the experimental data with a non-equilibrium transport theory, we identify this polarity dependence as a clear signature of Coulomb interaction.

[1] J. Könemann, B. Kubala, J. König, and R. J. Haug, cond-mat/0506505 (unpublished).

HL 6.10 Mon 12:30 BEY 118

Quantum dot system in high magnetic field: From weak to strong tunnel coupling — •Eleonora Storace, Jürgen Weis, and Klaus von Klitzing — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

Electrical transport measurements are performed on a quantum dot (QD) system defined as an in-plane structure via etching through a GaAs/AlGaAs heterostructure. Applying a perpendicular magnetic field and increasing afterwards the coupling between the leads and the QD, peaks and valleys of the conductance traces show a smooth transition from the Coulomb blockade oscillations regime to a constant value that is a multiple of e^2/h, suggesting the formation of a direct channel between source and drain leads. This behavior is explained considering that, since the geometrical extension of the QD itself is rather large, compressible and incompressible strips are formed along the whole structure and, in the case of strong coupling, the electron wavefunctions in the outer compressible strips in the leads can overlap with the ones in the QD. Tuning the magnetic field through different values of Landau levels filling factor, several electron configurations can be studied; in particular, it is possible to define a situation in which a compressible droplet is present inside the dot region in co-existence with the direct channel, giving rise to an interfering phenomenon known as Fano effect.

HL 6.11 Mon 12:45 BEY 118

Carrier storage time of milliseconds at room temperature in self-organized quantum dots — •A. Marent[1], M. Geller[1], A. P. Vasiev[2], E. S. Semenova[2], A. E. Zhukov[2], V. M. Ustinov[2], and D. Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]A. F. Ioffe Physico-Technical Institute, Russian Academy of Sience, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia

Self-organized quantum dots (QDs) are promising building blocks for future memory devices. The first milestone is a carrier retention time in the order of milliseconds at room temperature, the typical refresh time of a dynamic random access memory (DRAM). We showed previously, that holes in InAs/GaAs QDs exhibit a ground state localization energy of about 200 meV. This leads to a storage time at room temperature in the order of nanoseconds, which is not sufficient for a memory device. Here, we studied the carrier storage and emission from InAs/GaAs QDs with an additional AlGaAs barrier with deep level transient spectroscopy (DLTS). The thermal emission from the hole ground states over the entire AlGaAs barrier shows a pronounced peak at 300 K for a reference time of 5 ms. That means, we measure a storage time in the order of milliseconds at room temperature, the crucial DRAM refresh time. In addition, we determined the thermal activation energy for hole emission from the ground states over the entire AlGaAs barrier to ~580 meV.

The work was partly funded by the SANDiE Network of Excellence of the European Commission, contract number NMP4-CT-2004-500101 and SFB296 of DFG.

HL 6.12 Mon 13:00 BEY 118

Acoustoelectric current transport through a double quantum dot — •Jens Ebbecke[1], Nick Fletcher[2], and JT Janssen[2] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg — [2]National Physical Laboratory, Queens Road, Teddington TW11 0LW, United Kingdom

We present acoustoelectric current measurements through a double quantum dot. Due to background impurity potential fluctuations an unintentional quantum dot is situated next to an intentionally induced single dot. By changing the top gate voltages, each of the two dots alone can be addressed separately but also a situation can be realized where both dots are coupled and form a double quantum dot system. In the regime that is dominated by the conduction through the intentional quantum dot quantized charge transport has been realized mediated by surface acoustic waves. Based on the measurements on this device we propose a mechanism for a parallel double quantum dot turnstile that can be used as a spin entangler.

HL 7 Quantum dots and wires: Optical properties I

Time: Monday 10:15–13:00 Room: POT 151

HL 7.1 Mon 10:15 POT 151

Spectral jitter in cathodo- versus photoluminescence of single InGaAs quantum dots — •Erik Stock, Till Warming, Robert Seguin, Sven Rodt, Konstantin Pötschke, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

Spectral jitter in the lumiscence of single quantum dots (QD) has been regulary observed. This jitter is attributed to the quantum confined Stark effect, induced by local electrical fields near the QDs. For future single QD devices this jitter might be harmfull (for example for coupling to a microcavity) Here we present a comparison of the jitter of the same single QD using cathodoluminescence (CL) and micro-photoluminescence (PL). In CL the primary electrons have larger energy, then the exciting photons in PL. We observe that the amplitude of the jitter in CL is much larger then in PL experiments. We conclude that it is impossible to extract information about the structural quality of QD heterostructures by comparison of the jitter in single dot luminescence measurements, done with different excitation sources.

This work was partly funded by the SANDiE Network of Excellence of the European Commission, contract number NMP4-CT-2004-500101 and SFB296 of DFG.

HL 7.2 Mon 10:30 POT 151

Impact of Piezoelectricity on Shape and Order of Wavefunctions in Uncapped InAs/GaAs Quantum Dots — •Andrei Schliwa[1], Theophilos Maltezopoulos[2], Markus Morgenstern[3], Roland Wiesendanger[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität*Berlin — [2]Institute of Applied Physics, University of Hamburg — [3]II. Inst. of Physics B, RWTH Aachen University

Recently it became possible to map the shape of electron wavefunctions in uncapped InAs/GaAs quantum dots (QDs) by using scanning tunneling spectroscopy (STS) [1]. These measurement revealed an anomalous order of the single particle states in most of the investigated QDs which triggered the here presented theoretical investigations based on the eight-band-$\mathbf{k}\cdot\mathbf{p}$ model.
The outer shape of the model-QD is specified by using the morphological data, recorded as a byproduct of the STS-method, whilst the composition profile has been treated as variable. All of the measured QDs are elongated in [1$\bar{1}$0] direction with a larger in-plane anisotropy-ratio at the QD-apex than at the bottom. This alone however is not sufficient to explain the observed wavefunction order. It requires the inclusion of the strain induced piezoelectric field to amplify the already present confinement anisotropy to finally obtain the anomalous order of the electron orbitals in the simulation.

[1] Maltezopoulos T., Bolz A., Meyer C., Heyn C., Hansen W., Morgenstern M., Wiesendanger R., Phys. Rev. Lett. 91, p.196804 (2003)

HL 7.3 Mon 10:45 POT 151

Noise properties of ultrabroadband Quantum Dot Superluminescent Light Emitting Diodes — •Martin Blazek, Joachim Kaiser, Tobias Gensty, and Wolfgang Elsässer — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, D-64289 Darmstadt

Incoherent light applications, for example, Optical Coherence Tomography (OCT), require high power, low noise, and broad bandwidth light sources. We experimentally investigate the intensity noise properties of ultrabroadband Superluminescent Light Emitting Diodes (SLEDs), which are based on Quantum Dot structures. The spectral emission bandwidth of more than 50 nm (FWHM) is associated with a short coherence length guaranteeing a high axial resolution in OCT operation. The examined SLEDs emit more than 30 mW centered around 1300 nm. In a direct noise detection setup, we use a large area InGaAs photodiode to detect the emitted light. The amplified photocurrent noise is measured with an Electrical Spectrum Analyzer and normalized to the shot noise level. Spatially, spectrally and polarization resolved measurements are performed to reveal relations between the noise behavior and the SLEDs specific spatial and spectral emission properties. The results will be discussed with respect to device characteristics and OCT applications.

HL 7.4 Mon 11:00 POT 151

Optical Nearfield Spectroscopy of Individual InAs/GaAsQuantum Dots at Low Temperatures — •Omar Al-Khatib, Kai Hodeck, and Mario Dähne — Technische Universität Berlin, Institut fürFestkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

Semiconductor quantum dots attract considerable interest for future technical purposes. In particular the possibility to realise discrete energy levels in solid-state matter promises to provide a basis for innovations like new laser sources or quantum information technology. We report on photoluminescence spectroscopy of individual MOCVD-grown InAs/GaAs-dots. For that purpose we use Scanning Nearfield Optical Microscopy (SNOM) in the range from 10 K up to 300 K [1]. We focus on the investigation of relatively large quantum-dots, which are grown with low dot density and display ground-state emission of 1300 nm wavelength at room-temperature, thus matching telecommunication fiberoptic requirements. By taking single-dot spectra under varying excitation intensity, we observe photoluminescence emissions from different recombination processes, in particular biexciton and trion recombination, and discuss the data with theoretical models of multiexciton complexes. We would like to thank Konstantin Pötschke and Prof. Dr. D. Bimberg for providing the samples.

[1] K. Hodeck et al., phys. stat. sol. (c)No.4, 1209 (2003)

HL 7.5 Mon 11:15 POT 151

InP-Quantum Dots in AlGaInP — •Wolfgang-Michael Schulz[1,2], Robert Rossbach[1,2], Michael Jetter[1,2], and Peter Michler[2] — [1]4th Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]5th Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

In recent years low dimensional structures have attracted great interest in research and device fabrication because of the strong change in the density of states and the associated effects. One major issue of the quantum dots (QDs) is the emission at elevated temperatures, especially for further applications towards single-photon devices in the visible spectral range. The InP-material system can fulfill these requirements. Therefore, to achieve a high electron confinement we grew InP-QDs embedded in high band gap AlGaInP. The samples were structurally investigated by atomic force microscopy as well as optically by power-, temperature-dependent and time-resolved photoluminescence. By analysing the temperature behaviour we found that even at high aluminum containing barriers the carriers can only escape to the direct Γ-band of the AlGaInP. We could also observe single-photon emission in the wavelength range from 670 nm up to 565 nm.

HL 7.6 Mon 11:30 POT 151

Diamagnetic shift of disorder-localized excitons in narrow quantum wells — •M. Erdmann[1], M. Wenderoth[1], R. G. Ulbrich[1], S. Malzer[2], and G. Döhler[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Universität Erlangen-Nürnberg, Institut für technische Physik, Germany

Magneto-μ-photoluminescence (μPL) experiments on narrow GaAs/$Al_{0.3}Ga_{0.7}As$ quantum wells reveal an increase in diamagnetic shift of localized exciton states with emission energy. In a narrow GaAs/AlAs double quantum well, even negative diamagnetic shift is observed. μPL spectra were obtained in a confocal setup with a magnetic field applied perpendicular to the quantum well plane. This is the first experimental evidence that the diamagnetic shift of disorder-localized excitons is a sum of two contributions: A positive shift from the relative motion, and a negative center-of-mass shift resulting from disorder. [1]

[1] M. Grochol, F. Grosse, and R. Zimmermann, PRB 71, 125339 (2005)

HL 7.7 Mon 11:45 POT 151

Resonant Rayleigh scattering from single excitons in disordered GaAs/AlGaAs quantum wells — •Daniel Schwedt[1], Rico Schwartz[1], Heinrich Stolz[1], Dirk Reuter[2], Andreas Wieck[2], Galina Khitrova[3], and Hyatt M. Gibbs[3] — [1]Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock — [2]Ruhr-Universität Bochum — [3]College of Optical Sciences, Tucson, Az.

We report on experiments performed on MBE-grown quantum well samples exhibiting different kinds of disorder such that the excitons be-

come localized either in the nano-roughness of the interfaces or in slightly larger islands of monolayer steps, i.e. interface fluctuation quantum dots. The excitons have been excited resonantly in Brewster geometry and the elastically scattered signal, i.e. resonant Rayleigh scattering (RRS), has been observed in normal direction with microscopic resolution. The limitation of spatial resolution by diffraction is counterbalanced with high spectral resolution limited only by the linewidth of the exciting cw laser (less than 20 μeV in this case) so that the determined RRS spectra break up into single exciton lines. Thus, important sample parameters like the homogeneous exciton linewidth or relative oscillator strengths are directly measureable by a straight forward resonance scan of the excitation energy. Moreover, microscopically resolved RRS may become a tool for determination of the extension of the exciton's center-of-mass wave functions as well as local energy distribution of the exciton states and such giving insight to the underlying disorder potential.

HL 7.8 Mon 12:00 POT 151

Strong and weak coupling of quantum dot excitons in pillar microcavities — •Stephan Reitzenstein[1], Carolin Hofmann[1], Andreas Löffler[1], Alexander Kubanek[1], Johann Peter Reithmaier[1,2], Martin Kamp[1], Vladimir Kulakovskii[3], Leonid Keldysh[4], Thomas Reinecke[5], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Würzburg, Germany — [2]Technische Physik, Universität Kassel, Kassel, Germany — [3]Institute of Solid State Physics, RAS, Chernogolovka, Russia — [4]Lebedev Physical Institute, RAS, Moscow, Russia — [5]Naval Research Laboratory, Washington DC, USA

We report on strong as well as weak coupling of self assembled InGaAs quantum dots in high-Q semiconductor micropillar cavities. The micropillar cavities are based on a planar microcavity structure grown by molecular beam epitaxy. The planar structure consists of a GaAs λ-cavity centered between a lower and an upper distributed GaAs/AlAs Bragg reflector. In the center of the GaAs λ-cavity a low density layer of InGaAs QDs is introduced. By means of electron beam lithography and deep plasma etching we realized micropillars with Q-factors of about 5.000 to 35.000. The low quantum dot density allows us to investigate the interaction of single QD excitons and the vacuum field of the microcavity by temperature tuning. In addition to simple cases of strong coupling with a vacuum Rabi splitting of up to 140 μeV we will present examples of sequential coupling where QD excitons with different emission energies show strong or weak coupling with the optical mode of the same micropillar at different resonance temperatures.

HL 7.9 Mon 12:15 POT 151

Micro-photoluminescence investigations on single InGaN quantum dots up to 150 K — •K. Sebald, H. Lohmeyer, J. Gutowski, T. Yamaguchi, and D. Hommel — Institute of Solid State Physics, University of Bremen, Germany

To fully utilize the potential of InGaN quantum dot (QD) samples for future device applications their optical properties must be studied thoroughly. We will present micro-photoluminescence (μ-PL) measurements on single InGaN QDs. The QD samples were grown by MOVPE on sapphire (0001) substrates. The InGaN is deposited on a GaN buffer at a temperature of 700°C. The InGaN QD layer is stabilized by a novel kind of capping layer. For the final GaN capping the growth temperature is increased up to 820°C. Mesa structures with diameters down to 200 nm have been fabricated by focused-ion-beam etching after evaporation of an Al_2O_3 protection layer. Due to the low spatial surface density of the QDs one gets access to the optical properties of isolated QDs already at mesa diameters of 600 nm. The emission peaks possess linewidths down to 0.2 meV which is in the order of the spectral resolution of the experimental setup. μ-PL measurements on single InGaN QDs were carried out in dependence on the excitation density. We report on the observation of binding and antibinding multiexcitonic states. Furthermore, we were able to analyse the emission of single QDs up to 150 K and to quantify their activation energy.

HL 7.10 Mon 12:30 POT 151

Excited state emission and carrier dynamics of single InP/GaInP quantum dots — •Matthias Reischle[1], Gareth J. Beirne[1], Robert Rossbach[2], Michael Jetter[2], and Peter Michler[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

InP quantum dots (QDs) are promising candidates for lasers and single photon sources in the visible spectral range. To proceed towards a room temperature operating device first the complex carrier dynamics have to be understood. Therefore we have performed power dependent-, temperature dependent-, and time-resolved measurements on single QDs. Approximately 50% of the dots exhibit a number of additional recombination-lines which emerge at high power-densities and are thought to originate from excited states. In general we have observed up to four distinct excited states from these dots. Furthermore, we have observed a strong correlation between the level spacings and the activation energies obtained from fitting the temperature dependence of the emission intensity using an Arrhenius model. This indicates, that at elevated temperatures carriers can occupy succesively higher excited states and thereby eventually escape from the dot.

HL 7.11 Mon 12:45 POT 151

Spin coherence in spherical CdS quantum dots — •P. Nahalkova[1,2], D. Sprinzl[1], P. Nemec[1], P. Maly[1], V. N. Gladilin[2], and J. T. Devreese[2] — [1]Charles University in Prague, Ke Karlovu 3, 121 16 Prague 2, Czech Republic — [2]Universiteit Antwerpen, Universiteitsplein 1, B-2610 Antwerpen, Belgium

Spin coherence in quasi-spherical CdS quantum dots (QDs) in a glass matrix has been investigated. Time-resolved differential transmission experiments were performed to measure the decay of the degree of circular (linear) polarization DCP (DLP). We show that due to the nearly spherical shape of our QDs, the properties of DCP and DLP differ considerably from those of the most often investigated pyramidal self-assembled QDs. Namely, the electron spin relaxation time of $\sim$ 10 ns can be deduced from the DCP decay. The DCP dynamics measured on ns timescale can be explained well by intralevel exciton transitions with electron spin flip, driven by the electron-hole exchange interaction and assisted by two LO phonons. Two-phonon processes contribute significantly also to exciton transitions without electron spin flip, which are manifested in DCP and DLP dynamics on ps timescale. We also discuss the influence of attractive interaction between electron-hole pairs on DCP and DLP. This work was supported by the Ministry of Education of the Czech Republic in the framework of the research plan MSM 0021620834 and the research centre LC510, as well as by the Bijzonder Onderzoeksfonds of the Universiteit Antwerpen, BOF NOI UA 2004, IUAP (Belgium), and the European Commission SANDiE Network of Excellence, contract No. NMP4-CT-2004-500101.

HL 8 Invited Talk Leturcq

Time: Monday 14:30–15:15 Room: HSZ 01

Invited Talk

HL 8.1 Mon 14:30 HSZ 01

Counting statistics of single electron transport in a quantum dot — •Renaud Leturcq[1], Simon Gustavsson[1], Barbara Simovic[1], Roland Schleser[1], Thomas Ihn[1], Paul Studerus[1], Klaus Ensslin[1], Dan C. Driscoll[2], and Art C. Gossard[2] — [1]Solid State Physics Laboratory, ETH Zürich, CH-8093 Zürich, Switzerland — [2]Materials Department, University of California, Santa Barbara, CA-93106, USA

We demonstrate the measurement of current fluctuations in a semiconductor quantum dot by using a quantum point contact as a charge detector. Electrons traveling through the quantum dot are counted one by one. In addition to the shot noise, this method gives access to the full distribution of current fluctuations, known as full counting statistics. We demonstrate experimentally the suppression of the second moment (variance, related to the shot noise) and the third moment (asymmetry) in a tunable semiconductor quantum dot, in agreement with theoretical predictions.

Current fluctuations in a conductor give additional information compared to average current measurements, in particular for interacting systems. In semiconductor quantum dot systems it is envisioned that shot noise measurement provide a way to demonstrate entanglement of electrons. However, this measurement is difficult with conventional methods,

due to the very low current levels in quantum dots of the order of 10 fA. Our experimental technique allows to measure currents in the aA regime. Also the experimental resolution of the noise signal is 5-6 order of magnitude better than in previous experiments.

HL 9 Poster I

Time: Monday 15:15–17:45 Room: P3

HL 9.1 Mon 15:15 P3

Systematische Untersuchung zum Strahlprofil von fokussierten Ionenstrahlen — •andre uhlemann, Alexander Melnikov, Rolf Wernhardt, and Andreas Wieck — Angewandte Festkörperphysik Ruhr-Universität Bochum, Universitätstr.150,44801 Bochum

Systematische Untersuchung zum Strahlprofil von fokussierten Ionenstrahlen Andre Uhlemann, Alexander Melnikov, Rolf Wernhardt und A.D.Wieck Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum,Universitätsstr.150, Bochum 44780 Techniken zur Anwendung fokussierter Ionenstrahlen (FIB) finden an vielen Stellen Einzug in die Nanotechnologie. Die Verbesserung der Funktionalität vieler Anwendungen macht eine systematische Untersuchung von Strahlprofilen und deren unerwünschte Seitendosis erforderlich. Mit Hilfe von Ionenstrahllithographie und durch das Sputtern dünner Goldfilme wird das Strahlprofil eines Zwei-Linsen- FIB Systems untersucht .Im Vordergrund dieser Untersuchung steht die Einflussnahme von Abbildungsparametern wie z.B Blenden, Strahlstrom, Stigmatoren und Strahlengang auf das Strahlprofil. Es wird darüber hinaus die Frage diskutiert , unter welchen Konditionen eine Strahlaufweitung aufgrund des statistischen Coulomb-Effekts vorliegt, und in wie weit eine Holtsmarkverteilung das Strahlprofil besser als eine einfache Gaussverteilung beschreiben kann.

HL 9.2 Mon 15:15 P3

MOVPE of InN on nitridated sapphire and GaN templates — •M. Drago[1], C. Werner[1], P. Vogt[1], G. Manolis[2], M. Pristovsek[1], U. W. Pohl[1], M. Kneissl[1], and W. Richter[3] — [1]Techn. Univ. Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Nat. Techn. University of Athens, Dept. of Physics, GR-15780 Athens, Greece — [3]Univ. di Roma Torvergata, Dipart. di Fisica, Via della ricerca scientifica 1, I-00133 Rome, Italy

Optimum crystalline quality and defect analysis are still critical issues for InN research. For MOVPE growth on sapphire, substrate nitridation is the key step in order to obtain single crystal InN layers. Here we report studies on sapphire nitridation with ammonia by in-situ spectroscopic ellipsometry (SE). At 1050°C, 100 mbar and an ammonia flow of 1 L/min the sapphire surface reacts completely within 45 s, forming an AlN layer about 0.8 nm thick. The influence of sapphire nitridation on the quality of InN layers was assessed ex-situ investigating a set of InN layers grown on sapphire after different nitridation duration. For a 45 s nitridation InN displayed the best morphology, electronic properties and narrowest (00.2) X-Ray reflections. For a duration of 180 s sapphire nitridation (~1.0 nm AlN calculated by SE), the InN (10.2) reflections became narrower. Longer nitridation times led to deterioration of the quality of the InN layers. These results are compared to the growth of InN on GaN templates. SXPS measurements on the InN layers demonstrate no contamination by carbon, but show some traces of oxygen, which influence electronic and optical properties of InN.

HL 9.3 Mon 15:15 P3

Spin noise spectroscopy in GaAs — •M. Roemer, M. Oestreich, R.J. Haug, and D. Haegele — Institut für Festkörperphysik, Universität

We observe the thermal noise of electron spins in bulk GaAs by Faraday-rotation noise spectroscopy. This new experimental technique allows for nearly perturbation free measurements of the spin dynamics in semiconductors. Faraday-rotation is measured in the spectral region below the band gap, which avoids common problems like carrier heating and electron spin relaxation by spin interaction with optically created holes. We measure exemplarily the electron spin relaxation time and the electron Landé g–factor in n–doped GaAs at low temperatures and discuss the noise power in dependence on the probe wavelength. The measured noise power is compared to a theory based on Poisson distribution probability which yields good agreement.

HL 9.4 Mon 15:15 P3

Electrical Characterization of AlInN / GaN heterostructures grown by MOVPE — •C. Baer, H. Witte, A. Krtschil, C. Hums, J. Blaesing, A. Dadgar, and A. Krost — Otto-von-Guericke-University Magdeburg, Postfach 4120, 39016 Magdeburg

AlInN/GaN-junctions are of special interest due to its possible application as p-type FETs for In concentrations above 32%. However, there is only rare information on the electrical properties of AlInN and AlInN/GaN heterostructures up to now. We have investigated AlInN/GaN grown on different buffer layer structures on sapphire or Si substrates by metal organic vapour phase epitaxy.

At first we investigated the influence of the different junctions on the electrical measurements. For instance, in Hall-effect and CV-measurements the properties of the GaN buffer layer were found to be dominant. In samples with thick and thin AlInN layers we found both n-type and p-type conductivity regions by Halleffect and CV-measurements as well as by scanning capacitance microscopy (SCM). The origin for the different conductivity types will be discussed in terms of the layer structure and various defects. Furthermore, the AlInN/GaN structures were characterized by photo-conductivity spectroscopy, optical and thermal admittance spectroscopy and by deep level transient spectroscopy with respect to the defects.

HL 9.5 Mon 15:15 P3

Optical Investigation of AlN Layers and AlN Single Crystals — •Günther M. Prinz[1], Martin Feneberg[1], Christoph Kirchner[2], Sarad B. Thapa[2], Matthias Bickermann[3], Boris Epelbaum[3], Ferdinand Scholz[2], Klaus Thonke[1], and Rolf Sauer[1] — [1]Abt. Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Abt. Optoelektronik, Universität Ulm, D-89069 Ulm — [3]Institut für Werkstoffwissenschaften 6, Universität Erlangen, D-91058 Erlangen

Aluminum nitride (AlN) has an ultra-wide direct bandgap of approximately 6.2eV at LHe temperature. This fact and the full miscibility with gallium nitride make AlN a very promising material for optoelectronic applications.

We investigate both AlN layers grown by MOCVD on sapphire and AlN single crystals using cathodoluminescence and photoluminescence spectroscopy. In both cases the light is dispersed by a monochromator with a focal length of 1m (yielding a spectral resolution better than 1meV) and detected by a LN2-cooled CCD-camera.

The measurements are carried out from LHe to room temperature. For both sample types, we observe strong near band-edge emission at around 6eV. The spectral shift of the near band-edge luminescence as a function of temperature is fitted using different models.

HL 9.6 Mon 15:15 P3

Spatial fluctuations of the local potential in Silicon doped GaAs — •K. Teichmann[1], S. Loth[1], M. Wenderoth[1], R. G. Ulbrich[1], and U. Kretzer[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Freiberger Compound Materials GmbH, Freiberg, Germany

We investigated highly Silicon doped GaAs (10^{+19} cm^{-3}). Silicon is typically incorporated as a shallow donor, and is known to show strong autocompensation at high doping concentrations [1]. In our measurement we used UHV scanning tunneling microscopy at 8K. We prepared our sample as {110} cleavage plane. In particular we investigated distribution of dopants. In addition constant current topographies reveal a large amount of dopant induced defects. Both are not statistically distributed and show significant clustering on a length scale of several nanometers. By scanning the same region of the sample with different voltages (multibias spectroscopy) and by performing dI/dz spectroscopy we studied the correlation between the local dopant distribution and the electrostatic potential ($\phi_{el.stat.}(x, y)$) as well as the local apparent barrier height.

[1] C. Domke et al., Phys. Rev. B **54**, 10288 (1996).

HL 9.7 Mon 15:15 P3

To handicraft material systems with magnetic and semiconducting properties — •Safak Gök, Alexander Melnikov, Jun Ling Yang, and Andreas D. Wieck — Ruhr-Universität Bochum, Universitätstr. 150, D-44780 Bochum

We have tried to fabricate a material system, which owns semiconducting and magnetic properties at the same time. Therefore we have utilized the advantages of our combined molecular beam epitaxy - focused ion beam (MBE-FIB) -System, to deposite Mn atoms into GaAs in a soft landing mode. This technique offers the possibility to integrate the magnetic atoms into the semiconductor lattice with very low crystal defects. Magneto - transport measurements show an anomalous Hall effect which reveals clearly that our MBE-FIB-System makes possible an important progress the research towards convenient material for spintronics.

HL 9.8 Mon 15:15 P3

Magnetotransport of $Ga_{1-x}Mn_xAs$ on (001) and (311)A GaAs — •Ursula Wurstbauer, Matthias Reinwald, Matthias Döppe, Dieter Schuh, Dieter Weiss, and Werner Wegscheider — Universität Regensburg, 93040 Regensburg, Germany

We have studied $Ga_{1-x}Mn_xAs$ grown by low-temperature molecular beam epitaxy (LT-MBE) on GaAs (001) and (311)A substrates. In-plane and out-of-plane magnetotransport measurements clearly reveal an anomalous Hall effect (AHE) and a giant planar Hall effect (GPHE). Rotating the samples in the field, the magnetic anisotropy relative to the crystal orientation can be deduced. The (001) samples show for in-plane measurements a cubic anisotropy with the hard axis aligned along the [1-10] and [110] directions and an easy axis along [100] and [0-10]. Additional an uniaxial anisotropy with the hard axis along the [001] direction and the easy axis parallel to the surface was observed by out-of-plane measurements.
Unlike these, the (311)A samples exhibit for both in-plane and out-of-plane measurements a complex superposition of the AHE and the GPHE. In addition, we compared post growth annealing with an in-situ annealing method using an As capping layer. In both cases we found an increase of T_c.

HL 9.9 Mon 15:15 P3

Temperature Dependence of the Electron g Factor in GaAs — •Stefanie Döhrmann[1], Roland Winkler[1,2], Daniel Hägele[1], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, 30167 Hannover — [2]Northern Illinois University, Department of Physics, De Kalb, IL 60115, USA

We present detailed high precision measurements of the electron Landé factor g^* in weakly n-doped GaAs. Using time- and polarization resolved spin quantum beat spectroscopy in an external magnetic field, we determine g^* in a temperature range from 2 K to 300 K. At low temperatures, we find a strong interaction between the electron and nuclear spin system. The resulting dynamic nuclear polarization (DNP) acts as an additional magnetic field which drastically affects the measured g^*. The value of the bare g^* can be determined accurately by monitoring the time dependent DNP. We systematically investigate the dependence of g^* on excitation polarization, excitation energy, excitation density, external magnetic field and temperature. The measured temperature dependence of g^* shows the opposite trend compared to $\mathbf{k} \cdot \mathbf{p}$ calculations.

HL 9.10 Mon 15:15 P3

Self-built molecular beam epitaxy system for III - V semiconductors — •K. Trounov, I. Kamphausen, D. Reuter, and A. D. Wieck — Lehrstuhl fuer Angewandte Festkoerperphysik, Ruhr-Universitaet Bochum, Universitaetsstr. 150, D-44780 Bochum

We are setting up an MBE system for the growth of III-V semiconductor heterostructures. The system is completely in-house designed and fabricated. It consists of three chambers: a load lock, a buffer chamber, and the main chamber. We will discuss design considerations as e.g. the shutter mechanism and the materials choice for the individual components. The present status of the system will also be discussed.

HL 9.11 Mon 15:15 P3

Influence of the structural transition from $Ga_{1-x}Mn_xAs$ alloys to granular GaAs:Mn/MnAs hybrids probed by magneto-transport — •M. Elm[1], J. Teubert[1], P.J. Klar[1], W. Heimbrodt[1], M. Reinwald[2], and W. Wegscheider[2] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]Institute of Applied and Experimental Physics II, University of Regensburg, Germany

The magneto-resistance properties of $Ga_{0.98}Mn_{0.02}As$ alloys on (311)A substrate grown by molecular beam epitaxy and corresponding GaAs:Mn/MnAs hybrid samples obtained by controlled thermal annealing at different temperatures were studied. Thermal annealing leads to the formation of MnAs clusters. The size of the clusters increases with increasing annealing temperature whereas the cluster density decreases accordingly. The magneto-resistance measurements were performed on Hall-bars with a length of $650\,\mu$m and a width of $200\,\mu$m in fields up to 10 T and in the temperature range from 2 to 280 K. Clear differences are observed in the transport behaviour of the alloy sample and the hybrid samples. The results are compared with measurements of GaMnAs/MnAs hybrid structures grown by MOVPE on (100) substrates.

HL 9.12 Mon 15:15 P3

Why does the level-repulsion model fail in the vicinity of the GaN_xP_{1-x} indirect gap? — •M. Güngerich[1], P.J. Klar[1], W. Heimbrodt[1], G. Weiser[1], J.F. Geisz[2], C. Harris[3], A. Lindsay[3], and E.P. O Reilly[3] — [1]Dept. of Physics and Material Sciences Center, Philipps-University, Renthof 5, D-35032 Marburg, Germany — [2]National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401, USA — [3]Tyndall National Institute, Lee Maltings, Prospect Row, Cork, Ireland

The character of the fundamental band gap of P-rich GaN_xP_{1-x} has been under controversial discussion during the last few years. By electromodulated absorption studies of MOVPE-grown GaN_xP_{1-x} with $0.0 \leq x \leq 0.029$, we prove that a simple parametrization of the electronic structure in the energy range of the N localized levels according to a two-level repulsion-model fails in this material. The Γ character of electronic transitions in the range of the N levels is shown to be spread over several sharp transitions rather than concentrated in a single E_- transition. Pressure-dependent photoluminescence indicates a purely impurity-like character of these transitions. For ordered structures containing well separated N atoms the applicability of the level-repulsion model is confirmed by tight-binding calculations. As soon as, due to statistical spatial N-distribution, N pairs and clusters are formed the model breaks down and needs to be replaced by the Linear Combination of Isolated Nitrogen States (LCINS) approach. Photocurrent measurements confirm the widely observed blue shift of the GaP-like E_+ band gap.

HL 9.13 Mon 15:15 P3

Low-temperature scanning tunneling microscopy on semiconductor samples grown by molecular beam epitaxy — •Selina Olthof, Oguzhan Gürlü, Giovanni Costantini, Armando Rastelli, Oliver G. Schmidt, M. Alexander Schneider, and Klaus Kern — Max-Planck-Institut für Festkörperforschung, Heisenbergstr.1, D-70569, Stuttgart

The Scanning Tunneling Microscope (STM) is a powerful tool to analyze surfaces with atomic resolution as well as to perform local spectroscopy. Especially for the latter investigation, an instrument working at liquid helium temperatures gives superior access to the electronic structure of e.g. heterostructures and quantum dots. To be able to investigate semiconductor samples that are grown by Molecular Beam Epitaxy (MBE) in a home build low temperature UHV-STM, a battery operated vacuum system was build that allows sample transfer between separate chambers. As sample sizes in the STM are smaller than the 2” wafer standard used in semiconductor MBE, an adapter was designed that interferes as little as possible with the MBE growth procedure. First results of topographic and spectroscopic studies performed at 6 Kelvin on MBE-grown III-V heterostructures will be presented.

HL 9.14 Mon 15:15 P3

Carrier relaxation dynamics in annealed and hydrogenated (GaIn)(NAs)/GaAs quantum wells — •Torben Grunwald[1], Kristian Hantke[1], Jörg D. Heber[1], Sangam Chatterjee[1], Peter J. Klar[1], Kerstin Volz[1], Wolfgang Stolz[1], Antonio Polimeni[2], Mario Capizzi[2], and Wolfgang Rühle[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]CNISM-Dipartimento di Fisica, Universitá di Roma, Piazzale A. Moro 2, I-00182 Roma, Italy

We measured time-resolved photoluminescence on as-grown, annealed, as well as annealed and hydrogenated $(Ga_{0.7}In_{0.3})(N_{0.006}As_{0.994})$/GaAs quantum well structures. The post-growth treatment changes not only the photoluminescence decay time but also the intensity of photoluminescence directly after excitation. This initial luminescence intensity is determined by a competition between relaxation of electrons into nitrogen related potential fluctuations in the conduction band and their capture by deep traps. In contrast, the decay of the photoluminescence is mainly determined by the competition between radiative and nonradiative recombination, which are both influenced by localization. Annealing decreases localization effects and nonradiative recombination. Hydrogenation also reduces localization effects but increases nonradiative recombination.

HL 9.15 Mon 15:15 P3

(InGa)As Oberflächenemitter mit horizontaler Kavität (HC-SEL) — •Volker Gottschalch[1], Helmut Herrnberger[2], Tobias Gühne[1], Jaroslav Kovac jr.[3], Gunnar Leibiger[1], Jaroslav Kovac[3], Rüdiger Schmidt-Grund[1], Joachim Zajadacz[2], Jens Dienelt[2], and Axel Schindler[2] — [1]Universität Leipzig, Fakultäten für Chemie und Physik, Linnéstrasse 3, D-04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoser Str. 15, D-04318 Leipzig — [3]Slowakische Technische Universität, Fakultät für Mikroelektronik, Ilkovicova 3, SK-81219 Bratislava

Oberflächenemittierende Laserdioden mit horizontaler Kavität sind infolge ihrer hohen Lichtleistungen im Vergleich zu VCSEL-Strukturen von speziellem Applikationsinteresse. $In_{0.37}Ga_{0.63}As$-Doppel-QW-Laserstrukturen mit Emissionswellenlängen bis zu 1180 nm wurden mit der MOVPE im Standardsystem bei Abscheidungstemperaturen von 550℃ gezüchtet. Die Schwellstromdichten der Oxidstreifenlaser lagen bei 250 Acm^{-2}. Mittels der PECVD wurden die Laserriegel auf den Spaltflächen mit dielektrischen Spiegeln aus SiO_x/Si-Schichtfolgen vergütet. Die Auswirkungen auf den differentiellen Quantenwirkungsgrad, die Schwellstromdichte und die Strahlgüte wurden untersucht. Mikrospiegel von 45° wurden durch reaktives Ionenstrahlätzen (Cl_2 CAIBE) erzeugt und nach der Charakterisierung der Einzeldioden ebenfalls zur Auskopplung des Laserstrahls durch das GaAs-Substrat mit einem Bragg-Spiegel versehen. Die elektrooptischen Kennlinien der Dioden werden diskutiert.

HL 9.16 Mon 15:15 P3

MOVPE-Wachstum von GaN Nadeln — •Matthias Shirnow[1], Volker Gottschalch[1], Gerald Wagner[2], Jens Bauer[1], Hendrik Paetzelt[1], and Jörg Lenzner[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannesallee 29, D-04103 Leipzig — [2]Institut für Kristallographie und Mineralogie, Universität Leipzig, Linnéstrasse 3, D-04103 Leipzig — [3]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstrasse 3, D-04103 Leipzig

Das MOVPE-Wachstum von GaN-Nadeln wurde für die Quellenkombination Trimethylgallium und Dimethylhydrazin untersucht. Als Substratmaterial kamen (001), $(111)_{Ga}$, $(\bar{1}11)_{As}$ GaAs-, (111) Si- und (0001), $(01\bar{1}2)$ Al_2O_3-Substrate zum Einsatz. Bei der Niederdruck-MOVPE in einem kommerziellen Reaktor wurde der DMHy-Partialdruck von 0.07 bis 1 mbar und die Wachstumstemperatur von 550 bis 750℃ variiert. Die Charakterisierung erfolgte mittels TEM, HRTEM, SAD, Röntgendiffraktometrie und CL. GaN-Nadeln entstanden im Temperaturgebiet von 550 bis 650℃. In allen Fällen wurde unter den GaN-Nadeln eine GaN-Schicht detektiert. Der anisotrope Wachstumsprozess ("'catalyst-free"'), der zu nadelförmigen Kristallen im nm- bis μm-Bereich führt, steht offensichtlich mit Zinkblende-Wurtzit-Übergangen in dieser Übergangsschicht im Zusammenhang.

HL 9.17 Mon 15:15 P3

$A^{III}B^{V}$ Nano- und Mikroröhren verschiedener Orientierung und Struktur — •Hendrik Paetzelt[1], Volker Gottschalch[1], Jens Bauer[1], Helmut Herrnberger[2], and Gerald Wagner[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannesallee 29, D-04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoser Str. 15, D-04318 Leipzig — [3]Institut für Kristallographie und Mineralogie, Universität Leipzig, Linnéstrasse 3, D-04103 Leipzig

Aus stark verzerrten MOVPE-Heterostrukturen wurden mittels materialselektiver Ätztechnik $A^{III}B^{V}$ Nano- und Mikroröhren definierter Geometrie und Orientierung erzeugt. Die Schichtfolgen (BGa)As/GaInAs und (BGa)P/(GaIn)P wurden mit Opferschichten aus AlAs und AlGaP kombiniert, um Röhren mit Durchmessern zwischen 140 nm und 2 μm herzustellen. Der Einfluss der Materialparameter: Zusammensetzung, Schichtdicke, Grenzflächengüte, sowie der Substratorientierung bzw. Fehlorientierung auf Durchmesser und Struktur der Röhren, wurden untersucht und mittels linearer Elastizitätstheorie modelliert. TEM Aufnahmen von Querschnittsflächen und AFM Aufnahmen der Oberflächen bzw. der Grenzflächen werden vorgestellt und diskutiert. Die Auswirkungen einer nachträglichen epitaktischen Abscheidung von pseudomorphen GaAs-Schichten auf die gekrümmte Oberfläche der Röhren, und deren Einfluss auf Stabilität und Röhrendurchmesser wurden untersucht, und damit die Möglichkeit der nachträglichen Veränderung der Spannungsverteilung in der Nanoröhre aufgezeigt.

HL 9.18 Mon 15:15 P3

Oberflächenpassivierung von GaAs-Nanodrähten und Ladungsträgerconfinement durch Mantelstrukturen — •Jens Bauer[1], Volker Gottschalch[1], Hendrik Paetzelt[1], Gabriele Benndorf[2], and Gerald Wagner[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannesallee 29, D-04103 Leipzig — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstrasse 3, D-04103 Leipzig — [3]Institut für Kristallographie und Mineralogie, Universität Leipzig, Linnéstrasse 3, D-04103 Leipzig

Eine Kombination von MOVPE (metallorganische Gasphasenepitaxie) und VLS ("'vapor-liquid-solid"')-Wachstumsmechanismus erlaubt die Darstellung von Halbleiternanodrähten. Durch gezielte Variation der Züchtungsbedingungen können sowohl eine säulenförmige als auch eine spitz zulaufende Morphologie erreicht werden. Die geringen lateralen Ausdehnungen führen zu einem hohen Einfluss von Oberflächeneffekten auf die optischen Eigenschaften dieser Nanodrähte. Durch geeignete Passivierungsmethoden reduzieren sich derartige Einflüsse deutlich. Unter Ausnutzung von normalem epitaktischen Schichtwachstum lassen sich Mantelstrukturen auf den Nanodrähten realisieren ("'core-shell"'-Strukturen), welche bei geeigneter Materialwahl ein Ladungsträgerconfinement im Nanodraht ermöglichen. Im Beitrag werden die Passivierung von GaAs-Nanodrähten durch in-situ-Stickstoffbehandlung bzw. ex-situ-SiO_x-Abscheidung und der Aufbau von GaAs/(AlGa)As bzw. GaAs/Ga(AsN) "'core-shell"'-Strukturen vorgestellt und die Einflüsse auf die Photolumineszenzausbeute diskutiert.

HL 9.19 Mon 15:15 P3

Optical orientation of electron spins by in-plane excitation of GaAs quantum wells — •Niels Ubbelohde[1], Stefan Pfalz[1], Roland Winkler[1,2], Daniel Hägele[1], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Appelstr. 2, D-30167 Hannover — [2]Department of Physics, Northern Illinois University, De Kalb, IL 60115, USA

We study the optical orientation of electron spins in GaAs quantum wells using a light beam propagating *parallel* to the plane of the two-dimensional (2D) system. A circularly polarized laser pulse is focussed on the cleaved edge of the quantum wells thus creating spin-polarized electrons in the wells. Application of an in-plane magnetic field perpendicular to the excitation direction leads to spin precession which we observe in the emission along the growth direction of the 2D system. From the polarization- and time-resolved photoluminescence, we obtain the initial degree of electron spin polarization P_0 which is studied as a function of the excitation energy. In comparison with the optical orientation for excitation in growth direction [1], we observe a qualitatively different behaviour of the energy dependence of P_0. While the former geometry yields a high degree of initial spin polarization for excitation of the lowest heavy-hole exciton, we now measure $P_0 = 0$. Furthermore, we find that the sign of P_0 is independent of the excitation energy.

[1] S. Pfalz, R. Winkler, T. Nowitzki, D. Reuter, A. D. Wieck, D. Hägele and M. Oestreich, Phys. Rev. B **71**, 165305 (2005)

HL 9.20 Mon 15:15 P3

Slow, focused ion beam (FIB) meet high-purity layers: combined MBE-low-energy-FIB facility to creat shallow, overgrown doped layers — •Sinan Ünlübayir, Dirk Reuter, Alexander Melnikov, and Andreas D. Wieck — Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

We have modified a commercial focused ion beam (FIB) to allow usage in a variable energy range between only 10 eV to 30 keV. To slow down the ions, a retarding field between the sample stage and a FIB column is applied. In case of slow ion implantation it is common to speak about deposition, because the depth of penetration is few nanometer, or around one monolayer. The FIB is connected with a ultra high vacuum lock to a III/V molecular beam epitaxy system. This enable us to overgrow the implanted regions after transferring into the MBE chamber. With this technique we have embeded lateral, shallow doped regions into GaAs or AlGaAs. The present work discussed about Si- and Be-doped layers in GaAs, which are produced by ion energy between 10 eV to 1000 eV. Furthermore we doped GaAs/$Al_xGa_{1-x}As$-Heterostructures (so-called HEMTs) with this Si deposition technique. It will be showed that, production of two dimensional electron gases (2DEG) is achieved. The samples have been examined by means of Hall and magneto transport measurements at low temperatures. The smallest lateral size of the doped layer obtained by us was 5 μm. To the best of the authors knowledge, this is the smallest size reported elsewhere.

HL 9.21 Mon 15:15 P3

Magnetotransport of p-type and n-type (B,Ga,In)As — •J. Teubert[1], P. J. Klar[1], W. Heimbrodt[1], and V. Gottschalch[2] — [1]Dept. Physics and WZMW, Philipps-University, Germany — [2]Faculty of Chemistry and Mineralogy, University of Leipzig, Germany

We present magnetoresistance (MR) measurements on p-type and n-type (B,Ga,In)As in fields up to 10 T and at temperatures down to 2 K. The samples were grown by MOVPE with B and In contents of 2,7% and 6%, respectively, and with different carrier concentrations. The MR results will be compared with those of (Ga,In)(N,As). Both, the incorporation of N and B forms highly localized energy levels resonant with the conduction band leading to an interaction of these localized levels with the extended conduction band states. In the case of N, one observes strong level-repulsion effects and thus a strong red-shift of the fundamental band gap. B seems to have much less influence on the conduction band structure compared to N, e.g. no significant reduction of the band gap was observed and only an increase of effective electron mass was found. Despite the difference in band-structure modification due to B and N, it is surprising that the MR results of (B,Ga,In)As show many similarities to those of (Ga,In)(N,As) e.g. strong Anderson localization effects for n-type samples.

HL 9.22 Mon 15:15 P3

Thermopower measurements on n-type (Ga,In)(N,As) — •J. Teubert, P. J. Klar, W. Heimbrodt, K. Volz, W. Stolz, and P. Thomas — Dept. Physics and WZMW, Philipps-University of Marburg, Germany

We present first thermopower measurements on n-type-(Ga,In)(N,As) semiconductor alloys. N in (Ga,In)(N,As) forms a highly localized energy level resonant with the conduction band that strongly perturbs the conduction band structure of the crystal. The interaction between the localized N-related levels and the extended conduction band states leads to a strong dependence of the local band gap on nitrogen concentration. Together with the variation of the local N-environment this results in significant spatial and energetic disorder. For example, these effects manifest themselves in the magnetotransport behaviour of n-type (Ga,In)(N,As), which is dominated by weak Anderson localization effects. Combined thermopower and resistivity measurements can be analysed using models established for amorphous semiconductors. This analysis yields further insight into the nature (i.e. lengthscale, width) of the disorder potential fluctuations.

HL 9.23 Mon 15:15 P3

Pulsed Laser Deposition growth and characterization of laterally arranged uniform ZnO nanowires — •Andreas Rahm[1], Thomas Nobis[1], Michael Lorenz[1], Gregor Zimmermann[1], Marius Grundmann[1], Bodo Fuhrmann[2], and Frank Syrowatka[2] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstr. 5, D-04103 Leipzig, Germany — [2]Universität Halle, Zentrum für Materialwissenschaften, Hoher Weg 8, D-06120 Halle, Germany

A regular lateral alignment of Zinc Oxide nanostructures which have very promising optical properties is necessary for practical device applications. We report on the Pulsed Laser Deposition [1] growth of free standing nanowire arrays with uniform hexagonal arrangement. In order to achieve this we prepared an ordered array of catalytic gold particles by nanosphere lithography [2] using monodisperse spherical polystyrol nanoparticles. These templates were investigated by Scanning Electron Microscopy and Atomic Force Microscopy prior to growth. Using XRD we determined the crystallographic relations between the ZnO wires and the a-plane sapphire substrates. Furthermore we present Cathodoluminescence measurements.

[1] M. Lorenz, E.M. Kaidashev, A. Rahm, T. Nobis, J. Lenzner, G. Wagner, D. Spemann, H. Hochmuth, M. Grundmann, Appl. Phys. Lett. 86 (2005), 143113

[2] J.C. Hulteen, R.P. van Duyne, J. Vac. Sci. Technol. A 13(3) (1995), 1553

HL 9.24 Mon 15:15 P3

Cathodoluminescence Study of Zinc Oxide Nanopillars in a Field Emitter-SEM — •Martin Schirra, Anton Reiser, Andreas Ladenburger, Rolf Sauer, and Klaus Thonke — Abt. Halbleiterphysik, Universität Ulm, D-89069 Ulm

Investigation of semiconductor nanostructures in a scanning electron microscope (SEM) requires a field-emitter (FE) type cathode for high spatial resolution. When apart from SEM images also cathodoluminescence (CL) shall be measured, one has to know and control the excited sample volume which limits the spatial CL resolution and, due to electron scattering, is mainly determined by the energy of the primary electron beam. We present a simple model to estimate the size of the excitation volume. Small excitation volumes require low acceleration voltages, which in turn demand short working distances in the FE-SEM. This is problematic, if the CL-signal is coupled out via mirror optics. Therefore we have developed a setup which uses UV transparent glas fiber optics. The system was tested by recording CL spectra of single ZnO nanopillars. A spatial resolution of 80nm at a spectral resolution better than 0.5meV was achieved. Recording extrinsic and intrinsic near bandedge CL features the crystalline quality, strain, defects, shallow dopant species and doping gradients along the pillar axis are assessed and the results are discussed.

HL 9.25 Mon 15:15 P3

Investigation of ZnO layers obtained by RBQE method — •Lia Trapaidze, Tamaz Butkhuzi, Tamar Khulordava, Lia Aptsiauri, Eka Kekelidze, Maia Sharvashidze, and Giorgi Natsvlishvili — Tbilisi State University, Dep. of Physics, 3 Chavchavadze Ave, 0128, Tbilisi, Georgia

Wide band semiconductors are interesting materials for obtaining of the light-emitting diodes in the violet and ultraviolet area, solid-state lasers and other electro optic systems. We elaborated non-equilibrium method Radical Beam Epitaxy (RBE), which gives us a possibility to regulate effectively electro-optical characteristics of the wide band semiconductors. Using RBQE method it is possible to get p-type, n-type and isolate layers of ZnO and p-n junction of the basis of ZnO/ZnO. By means of RBE method ZnO layers were grown on the basis of ZnO. The temperature of treatment was 400 C, duration was 4 hours. We measured I-V characterization, after them we obtained p-n junction. In the ultraviolet part of the PL spectra of ZnO epitaxial layers we observed intense peaks and the visible part were reduced. Observation of acceptor bound exciton in ZnO layers obtained by RBQE are characterized by high purity and perfection structure and significantly reduced number of point defect, what is one of the most important problems. For structural characterization of ZnO, new layers were checked with a Siemens D5000 XRD (X-Ray diffraction) spectrometer.

HL 9.26 Mon 15:15 P3

Confined optical modes in monolithic ZnSe-based pillar microcavities — •H. Lohmeyer[1], K. Sebald[1], C. Kruse[1], J. Gutowski[1], D. Hommel[1], J. Wiersig[2], N. Baer[2], and F. Jahnke[2] — [1]Institute of Solid State Physics, University of Bremen, P.O.Box 330 440, 28359 Bremen, Germany — [2]Institute of Theoretical Physics, University of Bremen, P.O.Box 330 440, 28359 Bremen, Germany

We report on the successful realization and optical characterization of monolithic II-VI pillar microcavities (MCs) which are very promising for future applications such as single photon emitters at elevated temperatures or quantum-dot based vertical-cavity surface-emitting lasers in the blue-green spectral region.

VCSEL structures made of ZnCdSSe/ZnSSe λ-cavities and Bragg mirrors composed of ZnSSe and MgS/ZnCdSe superlattices have been fabricated by molecular-beam epitaxy. Airpost pillar MCs with diameters between 500 nm and 4 μm were fabricated by focused ion-beam etching. The discrete mode spectra of the pillars are studied by photoluminescence measurements.

The measured data show full agreement with calculations of the transmission spectra of the three-dimensional pillars based on a vectorial transfer-matrix method. Achievable Purcell factors well above 10 can be estimated from the measured quality factors and calculated mode volumes. First investigations of the coupling of quantum-dot like emitters to the pillar modes show a strong enhancement in the detected photoluminescence signal of the latter in resonance with modes of the cavity.

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HL 9.27 Mon 15:15 P3

Growth and characterization of Mn- and Co- doped ZnO nanowires — •Andreas Rahm, Evgeni M. Kaidashev, Heidemarie Schmidt, Mariana Diaconu, Andreas Pöppl, Rolf Böttcher, Christoph Meinecke, Tilman Butz, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstr. 5, D-04103 Leipzig, Germany

ZnO based nanostructures have attracted increasing interest in recent years due to their structural diversity. Furthermore, transition metal doping (e.g. by Co or Mn) of ZnO has been predicted [1] and shown [2] to create a promising ferromagnetic material for spintronics. We report on the high-pressure pulsed laser deposition growth of zinc oxide nanowires [3] containing about 0.2 at-% Co and 0.5 at-% Mn by NiO and Au catalyst. Scanning electron microscopy and X-ray diffraction measurements revealed arrays of parallel-standing nanowires with hexagonal cross section and uniform in-plane epitaxial relations without rotational domains. Elemental analysis was carried out using particle induced X-ray emission and Q-band electron spin resonance. The valence of the incorporated Mn was determined to be 2+. Atomic and magnetic force microscopy measurements indicate that Mn is incorporated preferentially at the nanowire boundaries. [1] T. Dietl , H. Ohno, F. Matsukura, J. Cibert, D. Ferrand, Sciene 287, 1019 (2000) [2] K. Ueda, H. Tabata, T. Kawai, Appl. Phys. Lett. 79, 988 (2001) [3] M. Lorenz, E.M. Kaidashev, A. Rahm, T. Nobis, J. Lenzner, G. Wagner, D. Spemann, H. Hochmuth, M. Grundmann, Appl. Phys. Lett. 86 (2005), 143113

HL 9.28 Mon 15:15 P3

Synthesis and Characterisation of CdSe:Mn-nanoparticles — •Andreas Hofmann[1], Christina Graf[1], Reinhard Neder[2], Georg Schmidt[3], and Eckart Rühl[1] — [1]Institut für Physikalische Chemie, Universität, , Am Hubland, D-97074 — [2]Institut für Mineralogie und Kristallstrukturlehre, Universität Würzburg, Am Hubland, D-97074 — [3]Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074

We present a new preparation method for dilute magnetic II-VI-semiconductor nanoparticles by a high temperature synthesis. On the basis of a Green Chemistry approach we use CdO and different Mn-precursors to build up nearly monodisperse CdSe:Mn-nanocrystals (NC) without a size-selection process. The NC have a manganese content of about 1%, which was measured by ICP. SQUID-measurements also show a paramagnetic coupling, which indicates that there is no interaction between Mn-atoms. The size of the NC (3 to 7 nm) was determined by transmission electron microscopy and photoluminescence-measurements. We use EPR-spectroscopy to determine the location of Mn in the particles. It is shown that Mn is embedded in the CdSe-core. It is crucial for integrating Mn in the core of the NC that it has a zinc-blende lattice [1]. This is accomplished by growing CdSe on zinc-blende ZnSe NC. However, we use a novel synthesis [2] to produce zinc-blende CdSe-cores, where Mn can incorporate easily. Further, we try to coat the particles with a thin ZnS-shell and discuss resulting changes in fluorescence quantum yield.

[1] S. C. Erwin et al., Nature, **91**, 436, (2005).
[2] M. B. Mohamed et al., J. Phys. Chem. B, **10533**, 109, (2005).

HL 9.29 Mon 15:15 P3

The influence of native and impurity defects on the formation of radiative centres in ZnSe crystals — •Vadim Sirkeli, Galina Ivanova, Dmitrii Nedeoglo, and Natalia Nedeoglo — Moldova State University, Department of Physics, A. Mateevici str. 60, Chisinau, MD-2009 Moldova

Photoluminescence spectra of both as-grown ZnSe crystals and the crystals doped with Au from Zn+Au or Se+Au melt have been investigated. It is established that gold-doping from Zn+Au melt leads to the formation of both simple Au_i donor and Au_{Zn} acceptor defects. Associative radiative centres (Au_{Zn}-Au_i) and (Au_{Zn}-D) are also formed. The edge luminescence of the crystals is attributed to radiative annihilation of Au_i and V_{Se} donor-bound excitons. The luminescence spectra of ZnSe crystals doped with Au from Se+Au melt contain only one narrow line, which is ascribed to radiative annihilation of Au_{Zn} acceptor-bound excitons. It is shown that the process of the formation of Au_i donor or Au_{Zn} acceptor defects and their complexes with native defects can be controlled by changing the composition of annealing medium. The observed variations of radiative properties for gold-doped ZnSe crystals are explained by amphoteric properties of gold impurity and its ability to form the complexes with native defects.

HL 9.30 Mon 15:15 P3

Optical and vibrational properties of p-doped $Zn_{1-x}Mn_xTe$-bulk material — •C. Kehl[1], M. Eyring[1], M. Lentze[1], T. Kiessling[1], Le Van Khoi[2], J. Geurts[1], and W. Ossau[1] — [1]Universität Würzburg, Physikalisches Institut, Experimentelle Physik III, Am Hubland, 97074 Würzburg — [2]Institut of Physics, Polish Academy of Science, AL. Lotnikow 32/46, 02-668 Warsaw

Using magneto-optic photoluminescence, reflectivity and Raman measurements, p-doped $Zn_{1-x}Mn_xTe$-bulk material was investigated in order to study its optical properties at the fundamental band gap and its lattice dynamics. The samples used for this study were grown via Bridgman technique with a Mn concentration from 0 up to 30% and doping levels from p = $1{\cdot}10^{16}$ to $5{\cdot}10^{19}$ cm^{-3}.
The photoluminescence and reflectivity respectively was measured both *without magnetic field* and *with B-fields up to* 4 *Tesla* in Faraday configuration. It was applied for the exact determination of the Mn concentration in several samples, as well as for the investigation of the internal electronic Mn transition, the donor-acceptor-transition and the excitonic excitations. Furthermore the phonon behaviour was investigated via resonant Raman experiments, close to the fundamental gap resonance. The experiments were performed both without B-field and with B-field in Voigt configuration. An obvious dependence of the phonon eigenfrequencies on the Mn concentration of the sample could be demonstrated.

HL 9.31 Mon 15:15 P3

Growth and Doping of ZnO Nanostructures on Different Substrate Materials — •Anton Reiser, Günther M. Prinz, Martin Schirra, Andreas Ladenburger, Martin Feneberg, Rolf Sauer, and Klaus Thonke — Abt. Halbleiterphysik, Universität Ulm, 89069 Ulm

Growth of ZnO nanostructures either by vapor-liquid-solid epitaxy (VLSE) or by modified chemical vapor deposition (CVD) is investigated. Variation of the growth parameters such as temperature of the sample, temperature and composition of the source materials, flow of the transport gas, oxygen supply etc. allows to control preferential growth of specific ZnO nanostructures. Different substrates, as e.g. a-, r-, c-plane sapphire, silicon, and gallium nitride, affect the structure and the optical properties of the resulting nanostructures. We study the doping of such nanostructures, either directly in the growth process, by adding suitable materials to the sources, by using different catalyst materials, or by ion implantation of the as-grown structures. The crystalline quality and the optical properties of the nanostructures as grown and after subsequent process steps are monitored by SEM images and x-ray analysis, by micro-Raman measurements, by photoluminescence, and by field emitter type SEM cathodoluminescence spectroscopy.

HL 9.32 Mon 15:15 P3

Impact of As-doping on the optical properties of ZnO — •Martin Noltemeyer, Frank Bertram, Thomas Hempel, Silke Petzold, Jürgen Christen, Sören Giemsch, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

We present results from the optical and structural characterization of heteroepitaxial grown ZnO which was doped with arsenic. The samples were grown by metal organic vapor phase epitaxy (MOVPE) on GaN/sapphire templates. For doping experiments the layers were doped with arsenic using different AsH_3-flows ranging from 0.0005-0.5 sccm. An un-doped reference samples is grown for comparison. In the low temper-

ature (T = 4.2K) photoluminescence spectrum the free exciton X, the bound exciton lines I_0/I_1, I_2/I_3, and I_8, as well as the 1st and 2nd LO phonon replica from I_8 can be easily identified. In addition, the TES-I_8 line can be observed. With increasing the AsH_3-flow all excitonic lines broaden and significantly decrease in intensity. In particular I_2/I_3 completely disappears. As a more prominent feature, a distinguished donor acceptor pair recombination band (DAP) shows up with As-doping at 3.23 eV exhibiting up to 6 well resolved LO phonon replicas. Spatially and spectrally resolved cathodoluminescence measurements give a direct correlation of structural and optical properties of these layers.

HL 9.33 Mon 15:15 P3

Doping of ZnS monocrystals by P ions — •Aptsiauri Lia, Kekelidze Eka, Trapaidze Lia, and Butkhuzi Tamaz — Tbilisi State University, Chavchavadze ave.3, 0128, Tbilisi Georgia

. ZnS belongs to a class of materials that can be easily doped only n-type, but to obtain samples with low ohmic is considered to be difficult mainly because of intense compensating processes, which are widely investigated. In the present work in order to obtain hole conductivity in ZnS by phosphorus doping and to identify the centers that are responsible for the increase of hole concentration as well as the centers compensating the conductivity we carried out implantation of ZnS mono-crystals by P ions. Initial mono-crystals were of electric conductivity. After implantation the samples were annealed under preliminary deposited gold layers in nitrogen atmosphere. The lowest resistivity was obtained We carried out Thermodynamic analysis for ZnS-P. We defined defects and carriers as a function of zinc vacancies concentration. Thermodynamic analysis showed that difficulty of doping is conditioned by the fact that area of hole conductivity is too narrow and at high temperatures it may even disappear.

HL 9.34 Mon 15:15 P3

Energy transfer processes between extended band states and Te-related localized states in $ZnS_{1-x}Te_x$ — •T. Niebling, P.J. Klar, and W. Heimbrodt — Dept. Physics and WZMW, Philipps-Univerisity of Marburg, Germany

Various wurtzite $ZnS_{1-x}Te_x$ bulk samples of low x have been studied by time-resolved photoluminescence (PL). The dependence on concentration, on temperature, and on excitation density as well as the temporal behaviour indicate that the dynamics of the PL is influenced by excitation transfer processes between band states and the isoelectronic impurity levels located above the top of the valence band. These states can be related to Te_n complexes where $n = 1, 2, 3$ is the number of Te impurities forming the complex. For higher Te concentrations or immediately after the excitation pulse, the PL spectrum is dominated by a UV band whose intensity shifts towards a blue band either with increasing concentration or with increasing time delay after the excitation pulse. The observed concentration dependence is a manifestation of the statistics of the different complexes where preferably higher Te clusters occur with increasing x. The time evolution of the PL is caused by excitation transfer processes towards smaller energies. The energy transfer from the isolated centres to the pair states will be discussed in detail.

HL 9.35 Mon 15:15 P3

Hydrogen-related shallow donors in zinc oxide studied by infrared absorption and photoconductivity — •F. Börrnert, E. V. Lavrov, and J. Weber — Technische Universität Dresden, 01062 Dresden, Germany

Zinc oxide samples grown from vapor phase and treated with hydrogen and/or deuterium plasma were studied by means of infrared absorption spectroscopy and photoconductivity. Two electronic transitions were found in infrared absorption at 1430 and 1480 cm^{-1}. These lines belong to the H-I defect which was tentatively associated with bond-centered hydrogen. The energies of these transitions rule out H-I as a candidate for the hydrogen-related shallow donor in zinc oxide. Electronic transitions of three independent hydrogen-related shallow donors were observed in the photoconductivity spectra at 180, 240, and 310 cm^{-1}.

HL 9.36 Mon 15:15 P3

Pseudopotential investigations of electronic and optical properties of wurtzite ZnO and GaN — •Daniel Fritsch, Heidemarie Schmidt, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften

We have investigated the electronic properties of two important UV materials by means of the empirical pseudopotential method (EPM) including spin-orbit coupling. The transferable model potential parameters of the ionic model potential used in this work were fitted to experimentally well-known low-temperature transition energies of wurtzite ZnO and GaN to obtain a reliable description of the band dispersion throughout the Brillouin zone.

We determined the transition matrix elements in the electric dipole approximation at special points in the Brillouin zone following the scheme proposed by Chadi and Cohen [1]. A summation of these matrix elements yields the dielectric function and can be related to experimental data obtained by spectroscopic ellipsometry [2].

[1] D. J. Chadi and M. L. Cohen, Phys. Rev. B 8, 5747 (1973).
[2] D. Fritsch et al., Proceedings of NUSOD '05, 69 (2005).

HL 9.37 Mon 15:15 P3

Influence of confinement effects and carrier concentration on spin relaxation rates studied by spin-flip Raman spectroscopy on heavily doped (Zn,Mn)Se and (Cd,Mn)Te — •M. Lentze[1], L. C. Smith[2], D. Wolverson[2], P. Grabs[1], and J. Geurts[1] — [1]Universität Würzburg, Experimentelle Physik III, Am Hubland, 97074 Würzburg — [2]University of Bath, Department of Physics, Bath BA2 7AY, United Kingdom

Spin-flip Raman spectroscopy (SFRS) is a convenient way to study optical properties of diluted magnetic semiconductors (DMS). Especially useful features of the technique are optical material selectivity (important for heterostructures) as well as high sensitivity. We studied II-VI semiconductors like $Zn_{(1-x)}Mn_xSe$ and $Cd_{(1-x)}Mn_xTe$ which are promising components for the new spin based information technology (spintronics).

Our investigations are focused on n-doped heterostructures, containing quantum wells with 2DEG (($Zn, Mn)Se$ and $(Cd, Mn)Te$) embedded in $(Zn, Be)Se$ and $(Cd, Mg)Te$ respectively. Analysing the Raman signal we obtain the effective Manganese content, the g-values of the electrons and their exchange parameter $N_0\alpha$. A non-ambiguous influence of confinement and electron concentration in the quantum wells on the SFRS linewidth occurs for both material systems.

Besides backward scattering experiments, also spin-flip Raman spectra in forward scattering were taken, after selective substrate etching. By the comparison of half width of the SFRS signals we could determine spin relaxation times T_2 as well as spin diffusion constants D_s. An obvious decrease of T_2 with increasing n-doping level could be demonstrated.

HL 9.38 Mon 15:15 P3

Cathodoluminescence of PLD grown ZnO thin films: A comparison of experiment and simulation — •Robert Johne, Michael Lorenz, Holger Hochmuth, Jörg Lenzner, Holger von Wenckstern, Gabriele Benndorf, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, 04103 Leipzig, Germany

We have investigated ZnO thin films on sapphire, which are intended to serve as scintillators. Cathodoluminescence (CL) spectra were excited on the ZnO side of the thin film samples and the emitted light was detected in two geometries: (a) on the ZnO side (reflection geometry) and (b) on the sapphire substrate side (transmission geometry). The excitonic CL peak in reflection geometry red-shifts with increasing CL excitation energy. This redshift and the peak shift of reflection relative to transmission geometry spectra can be explained by a model of photon propagation including the effect of self-absorption of the near band edge luminescence in the ZnO film. In addition, different surface morphologies, slopes and positions of the intrinsic absorption edge and effects to due detection in a limited solid angle were included in the simulation and compared with experimental results. These influences may explain the occasionally observed double peak structure of experimental CL spectra in reflection geometry.

HL 9.39 Mon 15:15 P3

Ferromagnetism in Zn(Mn,Sn)O and Zn(Mn,P)O films — •M. Diaconu[1], H. Schmidt[1], M. Fecioru-Morariu[2], G. Güntherodt[2], D. Spemann[1], H. Hochmuth[1], M. Lorenz[1], and M. Grundmann[1] — [1]Inst. für Exp. Physik II, Fakultät für Physik, Uni. Leipzig, Linnestrasse 3-5, 04103 Leipzig — [2]II. Physikalisches Institut, RWTH Aachen, Physikzentrum Melaten, Huyskensweg Turm 28B, 52074 Aachen

Ferromagnetic behavior was observed in Zn(Mn,Sn)O films below 250 K and in Zn(Mn,P)O films above 300 K, with a maximum magnetic moment of 0.045 μ_B per Mn ion at room temperature. The films have a Mn content around 5 at% and P content around 0.1 and 0.5 at%

or Sn content around 0.05 at% and were grown by pulsed laser deposition on *a*-plane sapphire. The film composition was determined by Rutherford backscattering and particle induced X-ray emission. The presence of secondary phases was investigated by X-ray diffraction. We also investigated the effect of annealing at 800°C in N_2 atmosphere and we observed that after 2 hours annealing the films became paramagnetic at all temperatures and electrically insulating.

HL 9.40 Mon 15:15 P3

Integral electrical and micro-electrical investigations of ZnO thin films — •H. von Wenckstern, M. Brandt, H. Schmidt, G. Zimmermann, R. Johne, J. Lenzner, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

ZnO thin films grown by pulsed-laser deposition on sapphire substrates are investigated by integral electrical and micro-electrical methods. Temperature dependent Hall measurements yield the dominant scattering mechanisms and the thermal activation energy of dominant donors. The results obtained from this integral method are compared to surface properties investigated on the nanometer scale. For that, atomic force microscopy, scanning capacitance microscopy, scanning surface potential microscopy, and scanning electron microscopy measurements are used. Further, the influence of a degenerate layer at the sapphire/ZnO interface on the determination of transport properties is discussed thoroughly in this contribution.

HL 9.41 Mon 15:15 P3

Electrical characterization of ZnO grown by MOCVD on a multi-layer template — •Stephan Tiefenau, H. Witte, A. Krtschil, A. Dadgar, S. Giemsch, and A. Krost — Otto-von-Guericke Universität Magdeburg, FNW/IEP/AHE, Postfach 4120, 39016 Magdeburg

Currently, ZnO layers are in the focus of interest due to its possible applications in future optoelectronic devices, for instance in highly efficient LED and laser diodes. However, there are still some problems in the growth of high quality ZnO and especially in an effective p-type doping. For the latter topic, electrical measurements are important to understand transport and compensation mechanisms and properties of deep defects. The ZnO layers were grown by metal organic vapor phase epitaxy on a GaN/AlN template either on silicon or sapphire substrates. The heterostructures cause space charge regions which influence the electrical characteristics and have to be considered. We compare Hall effect and C-V measurements and show the different information depths of these methods. Furthermore, the impact of layer defects such as holes and surface roughness is investigated systematically with C-V measurements and scanning surface potential microscopy. On the basic of these investigations, properties of ZnO related deep defects and of interface states are characterized using photoconductivity spectroscopy, thermal and optical admittance spectroscopy and deep level transient spectroscopy.

HL 9.42 Mon 15:15 P3

Photoluminescence studies of VPE-grown *ZnO* nanorods — •H. Gafsi[1], C. Bekeny[1], T. Voss[1], I. Rückmann[1], J. Gutowski[1], A. Che Mofor[2], A. Bakin[2], and A. Waag[2] — [1]Institute of Solid State Physics, University of Bremen, P.O.Box 330 440, 28359 Bremen, Germany — [2]IHT, TU Braunschweig, P.O Box 3329,38023 Braunschweig

Capable of emitting UV light *ZnO* is a promising semiconductor for realizing fully integrated optoelectronic nanodevices. It has a wurtzite crystal structure with a large band gap of $3.37\,eV$ $(300\,K)$ and an exciton binding energy of $60\,meV$, which assures excitonic emission processes still being important at room temperature.

Here, we present temperature dependent PL measurements on *ZnO* nanorods grown by vapor-phase epitaxy (VPE) on two different substrates, $6H$-SiC and *a*-plane Al_2O_3.

The PL reveals well resolved near-band-gap features, in particular excitonic peaks. Also, it shows phonon-assisted excitonic transitions at temperatures up to about $200\,K$. On the high energy side of the free exciton at around $3.42\,eV$ an emission band with several fine structure lines is observed whose origin is discussed. Comparing the PL spectra on different substrates, a-Al_2O_3 provides a narrower donor-bound-exciton emission peak than $6H$-SiC. Though nominally undoped the rods on $6H$-SiC show signatures, which can be attributed to band-to-acceptor transitions. These results demonstrate that by using VPE it is possible to produce nanorods of high quality without using a catalyst.

HL 9.43 Mon 15:15 P3

Composition Dependent Properties of Structured II-VI Semiconductor Nanoparticles — •Sofia Dembski[1], Christina Graf[1], Reinhard Neder[2], and Eckart Rühl[1] — [1]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]Institut für Mineralogie und Kristallstrukturlehre, Universität Würzburg, Am Hubland, D-97074 Würzburg

II-VI-Semiconductor nanoparticles (quantum dots, QD) have unique size-dependent optical and electronic properties. Especially, small nanoparticles have a large surface-to-bulk ratio. Therefore, it is expected that the particle surface dominates their properties so that the local environment near the surface strongly influences their properties. We present a systematic study on optical, electronic, and structural properties of QD in selected environments. CdSe-ZnS core-shell nanoparticles are obtained from the high temperature thermolysis of organometallic precursors in coordinative solvents. These particles are subsequently functionalized either by an exchange of their ligands or by the reversible coating with an amphiphilic polymer. As a result, the particles can be studied in various environments. The crystal structure of the QD is characterized by transmission electron microscopy (TEM) and x-ray diffraction (XRD). The influence of the local environment on the optical properties of the QD is studied by optical absorption and photoluminescence spectroscopy.

HL 9.44 Mon 15:15 P3

Phonon properties in $Zn_{1-x}Mn_xSe$ bulk epilayers and thickness effect on the shape of reststrahlen band — •K. C. Agarwal, B. Daniel, D. Kälblein, C. Klingshirn, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

Recently, diluted magnetic semiconducts (DMS) like $Zn_{1-x}Mn_xSe$ attract a lot of attention due to their potential for the realization of spin devices. In this contribution, we present the results of our temperature dependent far infrared (FIR) investigations performed on MBE grown $Zn_{1-x}Mn_xSe$ epilayers. Our results reveal the phonon properties of this mixed crystal alloy. For the $Zn_{1-x}Mn_xSe$ samples with low Mn contents ($x = 0,8$ %), the anharmonic interactions are small resulting in equal values of the transverse optical (TO)- and longitudinal optical (LO)-broadenings (γ). However, for the samples with larger Mn contents a significant difference between LO and TO broadenings is found. In addition to the known ZnSe-like and MnSe-like phonon resonances, we observe a weak feature below the MnSe-like phonon band. The frequency of this feature shows a temperature and Mn dependent shift. We suggest that this feature observed in our measurements is a “weak-mode”, which has its origin in the disorder resulting from the Mn incorporation in the samples. Additionally, the shape of the reststrahlen band is found to change significantly with layer thickness. This effect is studied in some detail for pure ZnSe epilayers by comparing our experimental data with theoretical simulations.

HL 9.45 Mon 15:15 P3

PAC-measurements in GaN on alternative Si(111)-based substrates — •J. Penner[1], R. Vianden[1], A. Dadgar[2], and A. Krost[2] — [1]Helmholtz - Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn, Germany — [2]Institut für Experimentelle Physik, Otto-von-Guericke-Universität, PO-Box 4120, 39016 Magdeburg, Germany

Si(111) substrates are an interesting alternative for growing GaN epilayers. However, since lattice parameters and thermal behaviour of Si differ from GaN, high defect densities and hydrostatic expansion is produced during the growth of epilayers. Thin AlN buffer layers can help to build up compressive strain and to reduce the defect density [1]. The AlN layers also passivate the silicon surface and inhibit the so-called melt-back etching. We used the Perturbed-Angular-Correlation (PAC) method to study the electric field gradient at the site of ^{111}In implanted into GaN/AlN/Si(111). Subsequently, an annealing programme was carried out. A similar behaviour as seen in GaN grown on sapphire is found.However, the interaction frequency observed for probes on regular sites and the frequency for probes sitting in an disturbed environment are significantly higher than the corresponding values for GaN/sapphire. We discuss possible reasons for this behaviour.

[1] A. Dadgar et. al.; Appl. Phys. Lett. 82 (2003), 28-30

HL 9.46 Mon 15:15 P3

Formation of Antimony rich double layer structures at InP/GaAsSb Interfaces — •Stefan Weeke[1], Martin Leyer[1], Markus Pristovsek[1], and Wolfgang Richter[2] — [1]Institut für Festkörperphysik, Hardenbergstraße 36, TU Berlin, 10623 Berlin — [2]Dipartimento di Fisica, Roma II (Tor Vergata), Via della Ricerca Scientifica 1, I-00133 Rome, Italy

The GaAsSb/InP material system is promising for InP based DHBTs. However, segregation of antimony into InP is a serious problem, affecting the quality of the interface and hence the device performance. To investigate the segregation behaviour of antimony, we exposed InP surfaces with antimony by TMSb covering the typical InP/GaAsSb growth temperature range in MOVPE.We have observed the unexpected formation of an antimony rich double layer structure with one layer occuring at the interface and the other 50 to 100nm deep in the InP overlayer after subsequent overgrowth with InP. It was observed that the spacing between the layers depends on growth temperature, growth rate and the amount of antimony deposited on the surface.During MOVPE growth of GaAsSb only the antimony rich surface reconstruction is observed by RAS. During overgrowth with InP the antimony slowly vanishes, until at a certain point all remaining Sb is incorporated into a second antimony rich layer. This transition is most easily seen in first derivative of the RAS transients. As an explanation of this unusual segregation behaviour a model of strain induced surface melting is proposed.

HL 9.47 Mon 15:15 P3

Characterization of thin sol-gel-deposited high-k zirconia (ZrO_2) layers — •Peter Iskra[1], Michel Kazempoor[2], Gerhard Lilienkamp[1], and Winfried Daum[1] — [1]Institut für Physik und Physikalische Technologien, TU Clausthal — [2]Institut für Schichten und Grenzflächen (ISG3), Forschungszentrum Jülich GmbH

Thin ZrO_2 films have been deposited on silicon (100) with and without native oxide layers using the sol-gel process. The oxide thickness and surface morphology was determined by ellipsometry and AFM measurements. Auger depth profiles were used to characterize composition and interface reactions. We applied tunneling-AFM to evaluate the local thickness and electrical properties of the oxides. AFM measurements showed a roughness of the oxide layers which is comparable to the roughness of the substrates. By means of the depth profiles we found appropriate parameters for the sol-gel process such as composition of the sol, annealing temperature, and oxygen partial pressures which made the deposition of stoichiometric, carbon-free layers possible. The Auger depth profiles revealed that a thin interface layer of complex composition is formed and how the thickness of this layer depends on the annealing process. First attempts have been made to evaluate film characteristics such as thickness and homogeneity from tunneling-AFM images and tunneling I-V curves.

HL 9.48 Mon 15:15 P3

Spontaneous 2D accumulation of charged Be dopants in GaAs p-n superlattices — •Sebastian Landrock, Knut Urban, and Philipp Ebert — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

In a classical view abrupt dopant profiles in semiconductors tend to be smoothed out by diffusion due to concentration gradients and repulsive screened Coulomb interactions between the charged dopants. We demonstrate, however, using scanning tunneling microscopy and secondary ion mass spectroscopy, that charged Be dopant atoms in GaAs p-n superlattices spontaneously accumulate and form two-dimensional dopant layers. These are stabilized by reduced repulsive screened Coulomb interactions between the charged dopants arising from the two-dimensional quantum mechanical confinement of charge carriers.

HL 9.49 Mon 15:15 P3

Structural study of Cyclopentene on InP(001)(2x4) — •Miron Kropp[1], Regina Passmann[1,2], Patrick Vogt[1], Norbert Esser[2], and Wolfgang Richter[3] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]ISAS - Institute for Analytical Sciences - Department Berlin, Albert-Einstein-Str. 9, 12489 Berlin, Germany — [3]Università degli Studi di Roma "Tor Vergata", Via della Ricerca Scientifica 1, 00133 Roma, Italy

Organic molecules could be the ideal building blocks for functionalization of semiconductor surfaces. Up to now most of the experimental work has been concerned with Si surfaces. Almost no results exist for the technologically important III-V(001) surfaces such as InP(001) and GaAs(001). Here we report on the modification of the optical anisotropy during absorption of Cyclopentene(C_5H_8) on the InP(001)(2x4) surface as measured by Reflectance Anisotropy Spectroscopy (RAS). Surfaces are also characterized by LEED and Auger Electron Spectroscopy (AES). Upon Cyclopentene deposition, the InP(001)(2x4) LEED pattern disappears until only the (1x1) bulk symmetry remains. Auger spectra show that a carbon peak emerges. The surface related RAS features around 1,8 eV are reduced in intensity depending on the amount of molecules deposited. By annealing the sample at 400°C the whole process can be reversed and the (2x4) can be restored. Comparison to calculations of the InP(001)(2x4) RAS signal hint towards an interactions between Cyclopentene and the Indium dangling bonds. In addition the atomic structure of the C_5H_8/InP(001) surface is studied by SXPS and STM.

HL 9.50 Mon 15:15 P3

Improving the interface between silicon and La_2O_3 high-k dielectric — •Sandra Seidel, Christian Wolff, Andreas Assmuth, Tanja Stimpel-Lindner, Hermann Baumgärtner, and Ignaz Eisele — Institut für Physik, Fakultät für Elektrotechnik, Universität der Bundeswehr München, 85577 München-Neubiberg, Deutschland

The traditional scaling of CMOS devices is reaching the fundamental limits of the standard materials. Therefore, new materials have to be introduced. The most critical point for the shrinking is the introduction of a high dielectric constant (high-k) material as alternative gate material. In general materials having dielectric constant around 10 are suggested for short term and materials having k > 20 for long term solution. Furthermore, the dielectric constant is not the only parameter to be taken into consideration. Other important parameters are band gap, band alignment and interface-state density. In this work, molecular-beam deposited La_2O_3 was studied as a possible high-k candidate. In direct contact with silicon, this binary oxide is unstable and interfacial SiO_2 and silicate layers are formed. Therefore, an engineered interfacial layer was required in order to take advantage of the potential high-k characteristics. This interface can be achieved by growing an ultrathin nitride layer between substrate and high-k material. Electrical characteristics and XPS results will be shown.

HL 9.51 Mon 15:15 P3

Band Bending of Sulfur Passivated GaAs: A Raman Investigation — •Steve Pittner[1], Gianina Nicoleta Gavrila[2], Georgeta Salvan[1], Axel Fechner[1], Marion Friedrich [1], and Dietrich R. T. Zahn[1] — [1]Chemnitz University of Technology, Semiconductor Physics, D-09107 Chemnitz, Germany — [2]BESSY GmbH, Albert-Einstein-Straße 15, D-12489 Berlin, Germany

In this work the influence of a wet chemical treatment using a solution of S_2Cl_2 + CCl_4 (1:3) on GaAs(100) on the depletion layer thickness and band bending was investigated. Various excitation wavelengths were employed for taking Raman spectra under UHV conditions. The depletion layer thickness and band bending was calculated from the ratio of the coupled plasmon- LO phonon (PLP) mode and LO mode in the Raman spectra. The dependence on the information depth of different laser lines will be shown. N - and p-type doped GaAs are compared. The results are discussed in comparison to previous measurements [1,2] and it is illustrated that the improved treatment used leads to reduction of the depletion layer thickness and the band bending by approximately 60% for n-type GaAs. The importance of annealing steps in UHV are pointed out.

[1] Vasily N Bessolov, Mikhail V Lebedev, Nguyen Minh Binh, Marion Friedrich and Dietrich R T Zahn, Semicond. Sci. Technol. 13 (1998)
[2] L.A.Farrow, C.J. Sandroff, M.C. Tamargo, Appl. Phys. Lett., Vol. 51, No.23, 1931

HL 9.52 Mon 15:15 P3

Charge trapping at Si(100)-ZrO_2 interfaces studied by second-harmonic generation — •Bastian Manschwetus, Armin Rumpel, Peter Iskra, Gerhard Lilienkamp, and Winfried Daum — Institut für Physik und Physikalische Technologien, TU Clausthal, Leibnizstrasse 4, D-38678 Clausthal-Zellerfeld

Thin ZrO_2 layers deposited on Si(100) substrates by a sol-gel technique have been studied by second-harmonic generation (SHG) spectroscopy using femtosecond laser pulses. SHG spectra in the two-photon energy range between 3.1 eV and 4.2 eV are dominated by interband transitions at the main bulk critical-points of silicon (E_1 at 3.3 eV and E_2 at 4.4 eV) and by a specific interface transition at 3.6 eV. Fixed-frequency measurements at 730 nm and 700 nm laser wavelength (1.70 eV and 1.77 eV, re-

spectively) show a pronounced time dependence of the SHG signal. This time dependence on the scale of seconds to several minutes describable by two exponentials varies as the intensity of the exciting laser beam is increased. In analogy to previous results of other groups obtained for Si-SiO_2 systems we relate the time dependence of the SHG signal to a quasi-static electric field giving rise to electric-field-induced SHG at the silicon side of the interface. This field is caused by multi-photon excitation of electrons and holes in the ZrO_2 layer and subsequent trapping of a part of these charges in defects of the ZrO_2 layer. At lower laser intensities electron excitation into the ZrO_2 conduction band is the dominant mechanism as it requires only two-photon excitation. Hole excitation into the ZrO_2 valence band requires three-photon excitation and becomes important only at higher intensities.

HL 9.53 Mon 15:15 P3

Diluted magnetic semiconductors Sb(2-x)V(x)Te(3) — •Cestmir Drasar[1], Petr Lostak[1], Zhenhua Zhou[2], and Ctirad Uher[2] — [1]University of Pardubice, Studentska 95, 53210, Pardubice, Czech Republic — [2]Unversity of Michigan,Ann Arbor, Michigan 48109, USA

Recently, a new type of diluted magnetic semiconductors based on the tetradymite-type structure was described [1,2]. In this contribution, we compare the transport and magnetic properties of Sb(2-x)V(x)Te(3) in the single crystalline form (x = 0.0-0.03) with the properties of thin films grown by MBE in which the content of vanadium is much higher (x = 0.0-0.35). It was found that the vanadium-doping in single crystals of Sb(2)Te(3) does not change the concentration of holes yet it gives rise to ferromagnetism at low temperatures. The Curie temperature T(C) increases with the vanadium content and reaches 22 K for a single crystal of Sb(1.97)V(0.03)Te(3). In the case of thin films of Sb(2-x)V(x)Te(3), the concentration of holes determined from the Hall effect increases with the increasing concentration of vanadium and the Curie temperature T(C)of a film with x = 0.35 reaches at least 177 K, the temperature comparable or higher than that obtained with Mn-doped GaAs.

1. J. S. Dyck, P. Hájek, P. Lošťák, and C. Uher, Phys. Rev. B 65, 115212 (2002). 2. Z. Zhou, Y.-J. Chien, and C. Uher, Appl. Phys. Lett. 87, 112503 (2005).

HL 9.54 Mon 15:15 P3

Molecular Beam Deposition of La_2O_3 as high-k gate dielectric — •Christian Wolff, Sandra Seidel, Andreas Assmuth, Oliver S. Senftleben, Tanja Stimpel-Lindner, Hermann Baumgärtner, and Ignaz Eisele — Institut für Physik, Fakultät für Elektrotechnik, Universität der Bundeswehr München, 85577 München-Neubiberg, Deutschland

One of the big challenges in the shrinking of CMOS devices approach is the gate insulator. To be able to follow the dimension shrinking according to the ITRS, the SiO_2 film thickness should drop below 1nm within the next few years. This means that the direct tunnel leakage current through the insulator will increase to an extent where a replacement for SiO_2 will be needed. The evolving near-term solutions for the gate dielectric problem are materials like silicon oxynitride or aluminium oxide. As a long-term solution with a dielectric constant between 20 and 30, we have studied the rare earth metal oxide La_2O_3. Lanthanum oxide thin films were grown on silicon substrate by molecular beam deposition. The deposition process in UHV was optimised investigating the influence of substrate temperature, the partial pressures of oxygen and ozone, respectively, and post-growth annealing. The La_2O_3 thin films grown with the developed processes have been electrically and physically characterised by I(U), C(U), XPS, AES and SEM measurements.

HL 9.55 Mon 15:15 P3

In-situ characterization of the electronic properties of Si-nanoparticles — •Ingo Plümel[1,2], Hartmut Wiggers[2], and Axel Lorke[1] — [1]Experimental Physics, University of Duisburg-Essen, Lotharstraße 1, 47048 — [2]Institute of Combustion and Gas Dynamics, University of Duisburg-Essen, Lotharstraße 1, 47048

The compaction behavior of nano- and microcrystalline silicon powder under the application of an uniaxial force was characterized in the 37 MPa to 750 MPa range using DC measurements and impedance spectroscopy.

Changes in conductance and impedance are caused by pressure dependent rearrangement of particles within the powder, and deformation of the particle and electrode interfaces. Time dependent measurements at a constant force show three regions which are dominated by different effects. Analysis of this behavior with impedance spectroscopy enables a more precise characterization of the ongoing relaxation processes. With the help of a laser interferometer, the influence of mechanical changes during compaction on the impedance can be taken into account. The different contributions to the total impedance can be separated by designing and applying an equivalent circuit diagram.

Finally, by analyzing the time dependent change of the separated capacity contributions, the powder can be characterized using an effective medium model.

HL 9.56 Mon 15:15 P3

Quantum coherence and transport in mesoscopic (Ga,Mn)As wires and rings — •Daniel Neumaier, Konrad Wagner, Matthias Reinwald, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

We investigated the coherence length of holes in (Ga,Mn)As mesoscopic wires and rings at mK temperatures. The structures were fabricated using negative elecrton beam lithography and chemical assisted dry etching techniques. Phase coherence is significantly reduced in ferromagnetic conductors, due to magnetism related scattering effects, and coherence phenomena in electronic transport like universal conductance fluctuations (UCF), or the Aharonov-Bohm effect are expected only in samples with very small dimensions. Here we investigate UCFs in (Ga,Mn)As wires with length between 100 and 600 nm and a width of 25 nm as well as in rings with diameters ranging from 100 nm to 200 nm with the same width. We also tried to improve the coherent transport by post-growth low temperature annealing, which significantly reduces the concentration of Mn interstitials. First results will be reported.

HL 9.57 Mon 15:15 P3

Hydrodynamic Effects in a two dimensional Jet of Interacting Electrons — •Xaver Vögele — Center for NanoScience und Sektion Physik, Ludwig-Maximilians-Universität,Geschwister Scholl Platz 1, D-80539 München, Germany

We discuss hydrodynamic effects in a 2dim jet of electrons in a GaAs/AlGaAs heterostructure. According to a prediction by A. Govorov and J. Heremans (Phys. Rev. Lett. 92, 26803 (2004)) an electron beam traversing an aperture creates a pumping effect attracting carriers. Due to electron-electron collisions the injected electrons leave positively charged holes thus generating an attractive potential for the charge carriers. This phenomenon may be compared to classical hydrodynamic effects described by the quadratic Bernoulli equation (e.g. the pumping power of a water pump is proportional to the square of the pressure applied along the tube.) However the predicted quantum pumping effect in a Fermi liquid depends linearly on the source drain voltage applied across the aperture. Our experimental setup to confirm this effect consists of a GaAs/AlGaAs heterostructure with a high mobility two dimensional electron gas. Topgates are used to shape an aperture and define a 3 ym wide and 5 ym long channel along which the characteristic potential of the jet is measured by quantum point contacts. Potential measurements along the channel at different distances from the aperture will be used to extract the electron-electron collision length. We present the planed experiment and discuss first results.

HL 9.58 Mon 15:15 P3

Magnetic focusing phenomena in mesoscopic Hall-bar geometries — •Tobias Feil[1], Kai Bröking[2], Ragnar Fleischmann[2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Universität Regensburg, 93040 Regensburg — [2]Max-Planck-Institut für Dynamik und Selbstorganisation, 37073 Göttingen

We investigate low field magnetotransport in ballistic Hall-bar geometries with dimensions much smaller than the electron mean free path at low temperatures. For the experiments we use GaAs/AlGaAs heterojunctions with mobilities up to $1000 m^2/Vs$ and a corresponding mean free path of $50\mu m$. Our Hall-bars are manufactured by means of electron beam lithography and dry etching with typical potential probe separations between 2 and $10\mu m$ and potential probe width of $\approx$500nm.

Driving a constant current along the Hall-bar, we observe pronounced oscillations of the longitudinal resistance as a function of a perpendicular magnetic field. The oscillations, reminiscent of magnetic focusing, show minima with resistance values often below the Drude resistance. The experimental findings are compared to Landauer-Büttiker-type simulations, aiming at the transition from Drude resistance to ballistic transport in such mesoscopic Hall-bars.

HL 9.59 Mon 15:15 P3

Parallel implementation of the recursive Green's function method — •Panagiotis Drouvelis[1,2], Peter Schmelcher[1,3], and Peter Bastian[2] — [1]Theoretische Chemie, Universität Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany — [2]Interdisziplin´ares Zentrum für Wissenschaftliches Rechnen, Im Neuenheimer Feld 368, D-69120 Heidelberg, Germany — [3]Physikalisches Institut, Philosophenweg 12, Universität Heidelberg, D-69120 Heidelberg, Germany

A parallel algorithm for the implementation of the recursive Green's function technique, which is extensively applied in the coherent scattering formalism, will be presented. The algorithm performs a domain decomposition of the scattering region among the processors participating in the computation and calculates the Schur's complement block in the form of distributed blocks among the processors. If the method is applied recursively, thereby eliminating the processors cyclically, it is possible to arrive at a Schur's complement block of small size and compute the desired block of the Green's function matrix directly. The numerical complexity due to the longitudinal dimension of the scatterer scales linearly with the number of processors, though, the computational cost due to the processors' cyclic reduction, establishes a bottleneck to achieve efficiency 100%. The proposed algorithm is accompanied by a performance analysis for two numerical benchmarks, in which the dominant sources of computational load and parallel overhead as well as their competitive role in the efficiency of the algorithm will be demonstrated.

HL 9.60 Mon 15:15 P3

Hall effect measurements at high temperatures in highly resistive materials (CaF_2) — •Thomas Geruschke[1], Peter Blaum[2], and Reiner Vianden[1] — [1]Helmholtz-Institut für Strahlen und Kernphysik Universität Bonn, Nußallee 14-16, 53115 Bonn — [2]Schott AG, Dept.: "Research and Technology Development/Materials Development-Glass Ceramics", 55122 Mainz

In photolithography for integrated circuit fabrication narrower printed linewidths is achieved by moving to shorter wavelengths. For 157 nm lithography fluorine excimer lasers are used. In process the high energetic laser photons damage the crystallattice of the calcium fluoride lenses. This leads to a change of the optical properties of the material. With Hall effect techniques we try to investigate these defects. Therefore a Hall apparatus for measurements at high temperatures is under construction. The results will be presented and discussed.

HL 9.61 Mon 15:15 P3

Ballistic and mode-controlled rectification in high-mobility Si/SiGe cross junctions — •Egmont Fritz[1], Gang Qiao[1], Ulrich Wieser[1], Ulrich Kunze[1], and Thomas Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerCrysler Forschungszentrum Ulm, Wilhelm-Runge-Straße 11, D-89081 Ulm

Mesoscopic multi-terminal junctions prepared from high-mobility semiconductor field-effect heterostructures have attracted much attention in order to study ballistic electron transport. Here we report on the observation of ballistic rectification found in four-terminal Si/SiGe cross junctions. The Ψ-shaped junctions are composed of a central voltage stem and two current-injecting branches. The branches are directed towards the lower voltage probe of the stem and oppositely merge under zero injection angle into the stem. Electrical characterization of the rectifiers is performed at $T = 4.2$ K. The configuration of leads and voltage probes enables to separate between different mechanisms of rectification. The potential at the upper voltage probe displays a mode-controlled signal while the potential difference between both ends of the stem indicates a pure ballistic voltage. Nonlocal effects are studied in a modified cross junction with orthogonal current leads.

HL 9.62 Mon 15:15 P3

Spectral function of externally confined electrons in a strong time-dependent field — •Andrea Fromm[1], Michael Bonitz[1], and James Dufty[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15, 24098 Kiel — [2]Physics Department, University of Florida, Gainesville

Charged particles which are spatially confined in traps or quantum dots are of growing interest in many fields, including semiconductor transport, clusters or ultracold ions. Of special relevance is the particle response to strong AC electromagnetic fields where interesting collective effects (plasmons) and nonlinear phenomena such as high-harmonics generation and multi-photon absorption are expected. A self-consistent gauge-invariant nonequilibrium Green's functions treatment of these phenomena has been developed recently [1,2] for spatially homogeneous systems and was extended to weakly inhomogeneous spatially confined systems [3]. Here we extend this approach to a detailed analysis of the electron spectral function which selfconsistently includes strong fields and confinement effects and present results for the effective quantum potential for various external fields.

[1] D. Kremp, Th. Bornath, M. Bonitz, and M. Schlanges, Phys. Rev. E 60, 4725 (1999). [2] M. Bonitz, Th. Bornath, D. Kremp, M. Schlanges, and W.D. Kraeft, Contrib. Plasma Phys. 39, 329 (1999). [3] M. Bonitz, and J.W. Dufty, Cond. Matt. Phys. 7, 483 (2004)

HL 9.63 Mon 15:15 P3

Transient photocurrents of porous semiconductor electrodes permeated with electrolyte — •Sven Rühle[1], Ivan Ivanov[2], Valery Skryshevskyy[2], Jörg Rappich[3], and Thomas Dittrich[3] — [1]Condensed Matter & Interfaces, Debye Institute, University Utrecht, 3508 TA Utrecht, The Netherlands — [2]Taras Shevchenko University, Department of Radiophysics, Volodymyrska st. 64, 01033 Kyiv, Ukraine — [3]Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany

Photocurrent transients were used to investigate electron transport in mesoporous, nanocrystalline TiO_2 and Si films immersed into aqueous electrolyte. The pH and the conductivity of the electrolyte were changed systematically. It is shown that both trapping and recombination depend strongly on the pH. For porous Si, addition of fluoride into the acidic solution lead to an increase of the diffusion coefficients. Values for the effective diffusion constants are evaluated. A numerical model was used to decouple the impact of recombination and trapping on the transient response.

HL 9.64 Mon 15:15 P3

Inertial ballistic rectification in a top-contact metal-oxide-InAs nanostructure — •Markus Wahle, Thorsten Last, Saskia F. Fischer, and Ulrich Kunze — Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, 44780 Bochum

Ballistic motion of charge carriers in semiconductors brings about new phenomena which can be explained by a classical billiardlike model. One prominent effect of this kind is the negative bend resistance in cross-shaped devices associated with the current passing around the corner of the junction [1,2]. Here we report on the effect of ballistic rectification in a lateral metal-semiconductor nanostructure. The non-local voltage-current characteristic of a four-probe metal-oxide-InAs structure exhibits a kink centered at zero bias current at low temperatures [3]. At forward current a nearly linear characteristic with an excess resistance of about 2 Ohm can be observed, which gradually decreases with temperature increasing from 2 K up to 20 K. We explain this rectification effect by polarity-dependent ballistic injection of hot electrons from the drift region between the current leads into the adjacent collector region. The experiments indicate a low-temperature ballistic mean free path larger than the distance of 1.8 μm between the nanoscale contacts for current injection and voltage probe.

[1] G. Timp *et al.*, Phys. Rev. Lett. **60**, 2081 (1988).
[2] Y. Hirayama *et al.*, Phys. Rev. B **45**, 13465 (1992).
[3] T. Last *et al.*, J. Supercond., in press.

HL 9.65 Mon 15:15 P3

Drift velocity of electrons and Existence of the pinch effect in the Ge-n — •Mehdi Vaezzadeh, Majid Vaezzadeh, Mahmoud Jafari, and Ehsan Noroozifar — Dept. of Physics K.N.Toosi University of technology, P.O. Box: 15875-4416 Tehran Iran

A theoretical model has been proposed. Based on this model we have calculated analytically the increasing of longitudinal resistance by applying magnetic field on the Ge-n. Our work is based on decreasing the cross section of conduction electrons which leads to determination of the drift velocity of itinerant electrons. The repulsion of electrons in a direction (Hall Effect) decreases the cross section of the itinerant electrons which causes the longitudinal resistance of the sample increases. With increasing the external magnetic field the longitudinal resistance of the sample increases. By fitting the calculated results with the experimental results of the Ge-n in the range of $0<B<350$ mT we have determined the drift velocity of itinerant electrons. We have also calculated the main cross section of transmitted current in the absence of the magnetic field. The results indicate the existence of the pinch effect in this system.

HL 9.66 Mon 15:15 P3

Indirect transitions and direct current in semiconductor superlattices generated by application of half-cycle pulses — •Andrey Moskalenko, Alex Matos-Abiague, and Jamal Berakdar — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

We investigate the action of a single half-cycle pulse (HCP) on a semiconductor superlattice. As a model system we choose a superlattice consisting of a lattice of delta function peaks. We calculate matrix elements for transitions between eigenstates of the superlattice and use them to calculate populations in minibands and charge current induced by the HCP having a duration that is short enough. The current consists of an intraminiband part, which is constant in time (neglecting the relaxation), and an oscillating interminiband part. We investigate the dependence of the intraminiband current on the strength of the HCP for different fillings of the lowest miniband at zero temperatures. We show that for a low filling of the lowest miniband the dependence of the intraminiband current on the strength of the HCP has minima when the wave vector transferred by the pulse to the carriers matches an integer of the half of the reciprocal lattice constant. In the case of the filled lowest miniband the dependence of the intraminiband current on the pulse strength has a threshold since for the generation of the intraminiband current the population in the second or higher minibands must be created.

HL 9.67 Mon 15:15 P3

Control of occupations and coherences in semiconductor quantum dots induced by traveling wave packets — •Doris Reiter, Vollrath Martin Axt, and Tilmann Kuhn — Institut für Festkörpertheorie, Westfälische Wihelms-Universität Münster, Wilhelm-Klemm-Str.10, 48145 Münster, Germany

The capture of a traveling electronic wave packet by carrier-phonon interaction from a semiconductor quantum wire into a quantum dot can result in a superpostion of the discrete dot states. We show that we can control not only the resulting occupations but also the coherences between the discrete dot states by suitably creating two wave packets. By varying the starting time, starting position or the mean excess energy of the wave packets we achieve different control mechanism. While usually coherences are controlled directly by optical methods, in our case a decisive element of control is the arrival time of the wave packets at the dot. When we place two wave packets at each side of the dot the two packets cannot interfere, so we can easily control the time difference of the arrival by the starting time or starting position of the wave packets. If we generate two packets at the same side of the dot interference leads to spectral shaping of the pulses, which has great influence on both occupations and coherences. Another interesting case is the excitation with multicolor pulses, where we can address selectively the discrete dot states. More interestingly, we can gain control over the coherences in this case.

HL 9.68 Mon 15:15 P3

Optimized ultrafast optical pumping of a vertical-cavity surface-emitting laser — •Christoph Lange[1], Wendel Wohlleben[2,3], Sangam Chatterjee[1], Wolfgang Stolz[1], Marcus Motzkus[2], and Wolfgang Rühle[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Faculty of Chemistry, Philipps-Universität Marburg, Hans-Meerwein-Strasse, D-35032 Marburg, Germany — [3]Present Address: Polymer Physics Research, BASF AG, D-67056 Ludwigshafen, Germany

The emission characteristics of an optically pumped vertical-cavity surface-emitting laser (VCSEL)[1] are optimized by specifically shaping the pump pulse. The temporal variation of amplitude and phase of the excitation are adapted using a genetic algorithm in a learning-loop [2]. Both, the excitation and emission pulses, are live monitored using a spectrometer-streak camera system. The performance of the VCSEL with respect to its emission intensity, pulse width, decay time, or delay after excitation is thus strongly improved.

[1] C. Ellmers et al., Appl. Phys. Lett. **74**, 1367 (1999).
[2] H. Rabitz et al., Science **288**, 824 (2000).

HL 9.69 Mon 15:15 P3

Persistent vs. photoinduced currents in semiconductor mesoscopic rings. — •A. Matos-Abiague, A. S. Moskalenko, and J. Berakdar — Max-Planck Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany.

The dynamics of semiconductor mesoscopic rings driven by ultrashort electromagnetic pulses is theoretically investigated. It is shown that by subjecting the ring to a sequence of shaped pulses a charge current can be generated in the ring in absence of any external magnetic field. The dependence of the photoinduced currents (and the associated magnetization of the ring) on the electromagnetic field parameters is studied in details. We also demonstrate that predefined magnetic states of an array of rings can be optically generated and manipulated. Furthermore, when the ring is pierced by a magnetic flux there exist persistent currents that are dynamically modified by the action of the pulses. The influence of the electromagnetic field on the persistent current as well as its coexistence and competition with the photoinduced current are discussed.

HL 9.70 Mon 15:15 P3

Profile of a photoconductive THz Emitter excited by an amplified laser system — •Falk Peter, Stephan Winnerl, Andre Dreyhaupt, Harald Schneider, and Manfred Helm — Forschungszentrum Rossendorf, Institute of Ion Beam Physics and Materials Research, P.O. Box 510119, D-01314 Dresden, Germany

We present a large photoconductive THz emitter[1] consisting of two interdigitated metallization layers on a semi-insulating GaAs substrate. The photoexcited carriers are unidirectional accelerated by a bias voltage providing an electric field. This leads to a subsequent emission of THz radiation. The second metallization inhibits the optical excitation in every second period of the electrode structure in order to prevent destructive interference. We analyse the spatial profile of such an emitter excited with unfocused fs optical pulses from an Ti:sapphire amplifier with an average power of 60mW at a 1kHz repetition rate. The resulting THz beam has a bandwidth from 0.1 THz to 4 THz and a field amplitude of up to 6kV/cm (Ubias = 30V). The focussed THz spot was mapped out and analyzed with respect to the frequency. A strong increase of the beam diameter with decreasing frequency was found.Saturation behavior was observed by changing the excitation density.

[1] A. Dreyhaupt, S.Winnerl, T.Dekorsy, and M.Helm, Appl. Phys 86, 121114 (2005)

HL 9.71 Mon 15:15 P3

Charge carrier dynamics in graphite and carbon nanotubes observed by time-resolved THz spectroscopy — •Tobias Kampfrath, Luca Perfetti, Christian Frischkorn, and Martin Wolf — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Ultrafast charge carrier dynamics in graphite and carbon nanotubes have been investigated by time-resolved THz spectroscopy. In graphite, analysis of the transient dielectric function between 10 and 30 THz and model calculations show that more than 90 % of the initially deposited excitation energy is transferred to few strongly coupled lattice vibrations within 500 fs. These hot optical phonons also substantially contribute to the striking increase of the Drude relaxation rate observed during the first ps after photoexcitation. The subsequent cooling of the hot phonons yields a lifetime estimate of 7 ps for these modes [1].

The response of the nantoube sample lacks a distinct free-carrier response which is attributed to the photogeneration of strongly bound excitons in the tubes with large energy gaps. We find a feature of enhanced transmission caused by the blocking of optical transitions in small-gap tubes. The rapid decay of a featureless background with pronounced dichroism is associated with the increased hopping rate of spatially localized charge carriers before thermalization is completed.

[1] Phys. Rev. Lett. **95**, 187403 (2005)

HL 9.72 Mon 15:15 P3

Cotunneling through quantum dots with phonon-assisted spin-flip processes — •Jörg Lehmann and Daniel Loss — Departement für Physik und Astronomie, Universität Basel, CH-4056 Basel, Switzerland

For applications in spintronics and quantum computing a detailed knowledge about relaxation and coherence properties of the considered systems is crucial. Here, we investigate to what extent measurements of the cotunneling current through semiconductor quantum dots can provide information about a major source of decoherence in these systems, namely spin-flip processes induced by the coupling to acoustic phonons of the environment. An expression for the phonon-assisted cotunneling current is derived by means of a generalised Schrieffer-Wolff transformation, which allows one to eliminate to lowest order the dot-lead coupling. Explicit expressions for the elastic and inelastic contributions to the co-

tunneling current are given and the influence of the spin-phonon coupling on the heating of the dot is considered. The general results are evaluated for the case of a parabolic semiconductor quantum dot with Rashba and Dresselhaus spin-orbit coupling and a method for the determination of the spin-phonon relaxation rate is proposed. [1]

[1] J. Lehmann and D. Loss, `arXiv:cond-mat/0509420`.

HL 9.73 Mon 15:15 P3

Non-invasive detection of charge-rearrangement in a quantum dot — •C. Fricke[1], M. C. Rogge[1], B. Harke[2], F. Hohls[3], M. Reinwald[4], W. Wegscheider[4], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Max-Planck-Institut für biophysikalische Chemie, Göttingen — [3]Cavendish Laboratory, Cambridge, Great Britain — [4]Angewandte und Experimentelle Physik, Universität Regensburg

We show transport measurements in high magnetic field on a coupled system including a quantum dot and a quantum point contact. We use a GaAs/AlGaAs heterostructure containing a two-dimensional electron system (2DES) 34 nm below the surface. The lateral quantum dot and the quantum point contact (QPC) are defined by the atomic force microscope (AFM) using local anodic oxidation (LAO). We demonstrate electron redistribution on the quantum dot caused by the magnetic field [1]. The dot's charge configuration is measured by means of a quantum point contact as non-invasive detector. Our device allows to control independently the quantum point contact and all tunnelling barriers of the quantum dot. Thus we are able to measure both the change of the quantum dot charge and also changes of the electron configuration at constant number of electrons on the quantum dot. We use these features to exploit the quantum dot in a high magnetic field where transport through the quantum dot displays the effects of Landau shells and spin blockade. We confirm the internal rearrangement of electrons as function of the magnetic field for a fixed number of electrons on the quantum dot.

[1] C. Fricke et al., Phys. Rev. B **72**, 193302 (2005)

HL 9.74 Mon 15:15 P3

Coherent single electron spins manipulation in a quantum dot — •Dawid Kupidura, Stefan Ludwig, and Jörg Kotthaus — Department für Physik der LMU München, Lehrstuhl Prof. Kotthaus, Geschwister-Scholl-Platz 1, 80539 München

Recent progress in solid state quantum dots allowed measurement of the energy relaxation times as well as the phase coherence times of charge and spin qubits. Maybe the most impressive experiment employs the singlet-triplet splitting in a two-electron double quantum dot [1]. The latter measurements indicate the coherence time T_2 ¿ 1.2 μs [1]. This time may be limited due to the Overhauser magnetic field (caused by hyperfine interactions) varying in space and in time. Another origin of decoherence in this experiment might be electrostatic potential fluctuations in time that modify the exchange interaction [1].

In our approach we plan to use the two Zeeman-split spin states of an electron in a single quantum dot as originally proposed by Loss and DiVincenzo [2]. An advantage of this design is its robustness against local potential fluctuations as well as against the fluctuating Overhauser field ($B_{ext} >> B_{nuclear}$). We aim towards a single electron spin resonance experiment by additionally to B_{ext} applying a pulsed RF-magnetic field. Single spin read-out for such an experiment was demonstrated elsewhere [3].

[1] J. R. Petta et. al. Science 309, 2180 (2004) [2] D. Loss and D. P. DiVincenzo PRA 57, 120 (1998) [3] J. M. Elzerman et. al. Nature 430, 431 (2004)

HL 9.75 Mon 15:15 P3

Signatures of Mixed Phase Space in Open Quantum Dot Arrays — •Roland Brunner[1], Ronald Meisels[1], Friedemar Kuchar[1], Jonathan P. Bird[2], Richard Akis[3], and David K. Ferry[3] — [1]Institute of Physics, University of Leoben, Austria — [2]Dept. of Electrical Engineering, University at Buffalo, USA — [3]Dept. of Electrical Engineering, Arizona State University, USA

An interesting aspect of *open quantum dots* is the interplay of regular, quasi-regular and chaotic behavior of the electron transport, where one is concerned with the correspondence of classical and quantum mechanical behavior [1].

In this work we focus on the transport in open quantum-dot arrays regarding the correspondence of classical and quantum-mechanical treatments. We analyze, in particular, a prominent peak that was recently reported in the low-field magneto-resistance, MR, (B ∼0.2 T) of a single dot and arrays with different numbers of dots [2,3]. Certain details of the behavior of this MR peak can be interpreted in the classical treatment only by additionally assuming phase-space tunneling. In the quantum-mechanical interpretation an important result is the opening of gaps in the (complex) band structure and the decay of the wave function along the dot array and its dependence on the energetic position in the gap.

[1] L. E. Reichl, The Transition to Chaos, Springer Verlag (2004).
[2] M. Elhassan et al., Phys. Rev. B 70, 205341 (2004).
[3] R. Brunner et al.,Physica E 21, 491 (2004).

HL 9.76 Mon 15:15 P3

Miscellaneous current measurements through carbon nanotubes — •Christoph Würstle, Jens Ebbecke, and Achim Wixforth — Institut für Physik der Universität Augsburg, Experimentalphysik I, Universitätsstr. 1, 86159 Augsburg

We present measurements where we align carbon nanotubes (CNT) with surface acoustic waves (SAW) over predefined contacts. When the contacts are close enough a contacted CNT behaves like a quantum dot (QD). At low temperatures of around 4.2 K we investigate the effect of a finite Shottky-Barrier and also Coulomb blockade in such a system. Instead of applying a finite source drain voltage, we also use a SAW to induce a current (in dependence of the gate voltage) through the QD. With this method our aim is to measure quantized current through a CNT.

HL 9.77 Mon 15:15 P3

Detection of impurities in a Coulmb blockade device — •D. Tutuc[1], M. C. Rogge[1], M. Reinwald[2], W. Wegscheider[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Abteilung Nanostrukturen, Universität Hannover, Appelstrasse 2, 30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

In this work we report results on electrical transport in zero and non-zero magnetic field in a multi-terminal quantum dot fabricated by Local Anodic Oxidation (LAO) with an Atomic Force Microscope (AFM). The measurements were performed at low temperatures (approximately 17mK) in a 3He/4He dilution cryostat with magnetic field ranging from 0T to 5T with. In the Coulomb blockade regime we observe charged impurities suppressing the transport through the dot. The measurements are fully reproducible and the effect is also present in the measurements in magnetic field at 1T and 2T. The reproducibility of this effect lets us assume that the impurities are stable and not induced by random telegraph noise. Since magnetic field has almost no detectable effect the impurities seem to be of non-magnetic origin and seem to be situated near the barriers.

HL 9.78 Mon 15:15 P3

Shot noise at a Fermi edge singularity — •N. Maire[1], T. Lüdtke[1], F. Hohls[1,2], R. J. Haug[1], and K. Pierz[3] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We investigate self-assembled InAs quantum dots embedded in a GaAs-AlAs-GaAs heterostructure. We see steps in the I-V characteristic which can be directly linked to resonant tunneling through individual quantum dots. At one of these steps we notice a peak like current overshoot at a magnetic field of 14.9 T. We find that this current overshoot stems from an electron-electron interaction effect, a so-called Fermi edge singularity (FES) effect.

We measure the noise spectra of this step and observe a 1/f noise and a frequency independent noise, the shot noise. We observe a suppressed shot noise compared to the theoretical value $S = 2eI$ of a single tunneling barrier. This suppression is indeed expected for a double barrier resonant tunneling structure (DBRTS). This suppression is characterized by the dimensionless Fano factor $\alpha = S/2eI$; S being the average noise power density. We find that the shot noise is even more suppressed at the voltage position of the current peak induced by the FES. Temperature dependent measurements down to ≈ 300 mK show that this additional suppression decreases with increasing temperature. We find that these effects can be attributed to the varying tunneling rate of the emitter electrons near the FES.

HL 9.79 Mon 15:15 P3

Magnetotransportmeasurements and electron counting on GaAs/AlGaAs quantum rings — •A. Mühle[1], R. J. Haug[1], W. Wegscheider[2], and M. Bichler[3] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-92040 Regensburg — [3]Walter Schottky Institut, TU München, D-85748 Garching

We present transport measurements done in dependence of an external magnetic field on quantum rings on the surface of GaAs/AlGaAs heterostructures. These rings were fabricated by atomic force microscope lithography utilising local anodic oxidation [1]. Using in-plane gates, the energy of the electrons in the arms of the rings as well as the coupling of the structures to the leads can be controlled.

While sweeping the magnetic field in the regime with only few electrons on the ring, it is possible to determine their exact number if certain features in the transport spectrum can be observed namely Kondo effect and spin-flips.

Additionally, a setup with a quantum point contact next to a quantum ring can be used to count the electrons on the ring by utilizing the influence of the ring's charge on the conductance of the point contact.

[1] U. F. Keyser et al., Phys. Rev. Lett. **90**, 196601-1 (2003)

HL 9.80 Mon 15:15 P3

The role of quantum capacitance in coupled low-dimensional electron systems — •Bastian Marquardt[1], Marco Russ[1], Cedrik Meier[1], Axel Lorke[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Experimental Physics, University of Duisburg-Essen, Lotharstr. 1, D-47048 Duisburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44799 Bochum, Germany

We have investigated the charging behavior of a layer of self-assembled InAs quantum dots placed in close vicinity to a two-dimensional electron gas (2DEG). As the gate bias is changed, the charging states of both systems are altered simultaneously. Based on the quantum capacitance of the involved layers we develop a general model to determine the charging state of coupled low-dimensional electron systems from capacitance-voltage (CV) spectroscopy. The model is then applied to the special case of a layer of self-assembled quantum dots, coupled to a 2DEG. As a complementary method to detect the carrier densities we have employed Hall voltage measurements. We find that the measurement of the two-dimensional carrier density through lateral transport provides a direct insight into the vertical charging process of the quantum dot system. In agreement with results from CV spectroscopy Coulomb blockade and quantization energies can be extracted. Moreover, the Hall measurement offers a higher peak to valley ratio and a better estimate for the number of simultaneously charged dots than the capacitance data. This novel DC transport spectroscopy is particularly promising for structures with very slow tunneling times, such as single electron memory devices.

HL 9.81 Mon 15:15 P3

Magneto-capacitance Spectroscopy of Self-assembled InAs Quantum Dots — •R. Roescu, P. Kailuweit, D. Reuter, and A. D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, Germany

We have investigated self-assembled InAs quantum dots (QDs) by magneto-capacitance-voltage (C-V) spectroscopy to obtain insight into their energy band structure.

The dispersion of the charging peaks with perpendicular field (i.e. field direction perpendicular to the growth plane) gives information of the orbital angular momentum of the individual charging peaks [1]. Monitoring the height of the capacitance signal as a function of an in-plane field allows mapping the wave functions of the QDs in momentum space [2].

We will discuss the results for electrons as well as for holes and point out the significant differences.

[1] R. J. Warburton et all, Phys. Rev. B 58 no. 24 (1998) 16221-16231

[2] O. Wibbelhoff et all, Physica E21 (2004) 516-520

Financial support from the DFG GRK384 is gratefully acknowledged.

HL 9.82 Mon 15:15 P3

Photoelectronic Transport Imaging (PETI) of Individual Carbon Nanotubes — •Eduardo Lee, Kannan Balasubramanian, Marko Burghard, and Klaus Kern — Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, Stuttgart, 70569

Carbon nanotubes (CNTs) display a range of interesting properties, which make them attractive as components of nanoscale electronic devices. However, the operation mechanism of CNT-based devices is still not thoroughly understood. To overcome this limitation, local probe techniques have proven as highly valuable tools. Photoelectronic transport imaging (PETI) is one such methods which involves the acquisition of photo-generated current images while scanning the sample through a diffraction-limited laser spot. The resulting PET images contain signatures of local charge transport barriers that may arise from charge transfer at the interface to attached electrodes or defects along the nanotubes such as intramolecular junctions. In fact, previous PETI studies of both semiconducting and metallic single-wall carbon nanotubes (SWCNTs) revealed strong photocurrent responses at the contacts due to the local Schottky-like barriers. In the present contribution, gate voltage-dependent PETI is applied to investigate these contact barriers in more detail. For the semiconducting tubes, it was observed that the photocurrent signal at the contacts is suppressed upon band flattening through the applied gate potential. This behavior is distinguished from the metallic tubes, for which no significant changes could be detected upon gate potential variation.

HL 9.83 Mon 15:15 P3

Low-temperature electrical transport in semiconducting nanowires — •Marc Scheffler, Jorden van Dam, Floris Zwanenburg, and Leo Kouwenhoven — Kavli Institute of NanoScience, Delft University of Technology, POB 5046, 2600GA Delft, The Netherlands

Semiconductor nanowires offer a new route to the study of electronic transport on mesoscopic length scales, as their diameter sets an intrinsic constriction to the range of 100 nm and below. Additional structures along the longitudinal direction can be defined during growth (heterostructures) as well as by metallic contacts and gates.

We study the electronic transport in InP and InAs nanowires at low temperatures. Here the choice of appropriate metallic contacts can induce new electronic phases, e.g. superconductivity. Even more tunability is given by different gate geometries that we use to deplete the nanowire either as a whole or locally. Local gating can then lead to controllable separation of different sections of a nanowire as required for devices like point contacts or quantum dots.

HL 9.84 Mon 15:15 P3

Acoustoelectric current in single GaN-whiskers — •Simone Maisch[1], Jens Ebbecke[1], Achim Wixforth[1], Raffaela Calarco[2], Ralph Meijers[2], Michel Marso[2], and Hans Lüth[2] — [1]Universität Augsburg, Experimentalphysik I, Universitätsstr. 1, 86159 Augsburg — [2]Institute of Thin Films and Interfaces (ISG1) and CNI-Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich, 52425 Jülich

Selforganization is a powerful tool for information technology. Different kinds of semiconductor wires have already been grown by this technique but their applications to nanostructured electronic devices is still in the beginning. We have contacted single GaN-whiskers by Ti-contacts fabricated by ebeam-lithography. Measurements of acoustoelectric current transport through these selforganized quantum wires will be presented. There a surface acoustic wave is launched on a piezoelectric substrate and the goal is to transport single electrons one by one through the three-terminal device.

HL 9.85 Mon 15:15 P3

Electromigration Forces on Ions in Carbon Nanotube Transistors — •Neng-Ping Wang[1], Stefan Heinze[1], and Jerry Tersoff[2] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]IBM Research Division, T.J. Watson Research Center, Yorktown Heights, New York, 10598 USA

Due to their unique structural and electronic properties carbon nanotubes (CNs) are promising candidates for future nanoelectronics. Recently, field-effect transistors (FETs) from single-wall CNs have been a research focus. In particular, ballistic transport has been demonstrated and key transport parameters compare well with state-of-the-art silicon FETs. Doping with alkali metals has been a main route to improve transistor performance. However, current-induced, electromigration, forces on such alkali ions may lead to ion diffusion and alter the device properties.

Here, we report calculations of ballistic transport in carbon nanotube transistors using the non-equilibrium Greens function formalism within

a tight-binding approximation. We use a cylindrically device setup [for details, see S. Heinze, N.-P. Wang, and J. Tersoff, Phys. Rev. Lett. 95, 186802 (2005)] and calculate the current-induced forces on ions located either inside or outside the CN. The forces are largest in the turn-on regime of the transistor, and much smaller in the on- and off-state. The electromigration forces are mainly due to momentum transfer from the charge carriers, i.e., due to the "wind"force. The sign of the "effective valence"Z^* is independent of the actual charge sign, but can be reversed with gate voltage.

HL 9.86 Mon 15:15 P3

Spin Injection into Nonmagnetic Semiconductors: Application of a Unified Transport Theory — •U. Wille and R. Lipperheide — Abteilung Theoretische Physik, Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin, Germany

In a recent paper [PRB **72**, 165322 (2005)], we have developed a theory unifying ballistic and diffusive spin-polarized electron transport in ferromagnet/semiconductor heterostructures. It is based on our previously formulated "thermoballistic" description of (spinless) electron transport in parallel-plane semiconductor structures [PRB **68**, 115315 (2003)].

In the present contribution, we apply the unified transport theory in the study of the injection of spin-polarized electrons into nonmagnetic semiconductors, emphasizing the transition from the purely diffusive to the purely ballistic transport regime. We consider various examples: (i) For heterostructures involving ferromagnetic contacts and a homogeneous semiconducting sample without space charge, we study spin injection driven by an external electric field over a broad range of system and material parameters. (ii) The effect of a Schottky barrier piling up at the interface between a metallic ferromagnet and a semiconductor is analyzed. (iii) Within an extended formulation of the unified theory, we consider spin injection out of a (nondegenerate) dilute magnetic semiconductor.

Our results are discussed in comparison with previously obtained theoretical results.

HL 9.87 Mon 15:15 P3

Anisotropic magnetoresistance and planar Hall effect in (100) and (311)A GaMnAs — •Thomas Hummel, Michael Glunk, Joachim Däubler, Wladimir Schoch, Wolfgang Limmer, and Rolf Sauer — Abteilung Halbleiterphysik, Universität Ulm, D-89069 Ulm, Germany

The in-plane longitudinal and Hall resistance (planar Hall effect) of GaMnAs is studied for epitaxial GaMnAs layers grown on (100) and (311)A GaAs substrates. The measurements are carried out at T=4.2K on photolithographically prepared Hall bars with an external magnetic field continuously adjustable in magnitude and orientation. Sweeping the strength of the magnetic field for fixed orientations or stepping its orientation at fixed field strengths results in pronounced jumps of both the longitudinal and Hall resistance due to the magnetic anisotropy of the GaMnAs epilayers. A quantitative analysis of the data within a single domain model reveals that the direction of the magnetization can be significantly deflected from the magnetic easy axes by the external magnetic field even for low field strengths below 50 mT. Specific differences between the (100) and (311)A GaMnAs layers are discussed.

HL 9.88 Mon 15:15 P3

Lattice parameter and hole density of GaMnAs on GaAs(311)A — •Joachim Däubler, Michael Glunk, Wladimir Schoch, Wolfgang Limmer, and Rolf Sauer — Abteilung Halbleiterphysik, Universität Ulm, D-89069 Ulm, Germany

We discuss the structural and electrical properties of GaMnAs layers with Mn concentrations up to 5%, grown on GaAs(311)A substrates by low-temperature molecular-beam epitaxy. High resolution x-ray diffraction studies reveal a higher concentration of As antisites and a weaker linear increase of the relaxed lattice constant with Mn content in the (311)A layers compared to (100) reference layers. The hole densities and Curie temperatures, determined from magnetotransport measurements, are drastically reduced in the (311)A layers. The findings are explained by an enhanced incorporation of Mn atoms on non-substitutional and non-interstitial sites, probably as Mn-Mn or As-Mn complexes, caused by the larger amount of excess As in the (311)A layers.

HL 9.89 Mon 15:15 P3

Magneto-Optical Investigation of InGaAs Quantum Dot Spin-LEDs — •J. Fallert[1], W. Löffler[1,2], D. Tröndle[1,2], C. Mauser[1], M. Hetterich[1,2], and H. Kalt[1,2] — [1]Universität Karlsruhe (TH), Karlsruhe, Germany — [2]DFG Center for Functional Nanostructures (CFN), Karlsruhe, Germany

We investigate p-i-n diode structures in which electrons are spin-polarized using a semimagnetic n-ZnMnSe layer and then injected into InGaAs / GaAs quantum dots. Magneto-optical measurements show efficient electrical spin injection as indicated by a total circular polarization degree (CPD) of up to 30% in the electroluminescence signal. We observe that depending on the emitted photon energy of the quantum dots the spectrally resolved CPD varies from 0% to 75%. HRTEM micrographs have been used to determine the present quantum dot geometries. Numerical calculations of electron and hole states in these quantum dots give quantitative results for the distribution in number and energy of bound states, depending on size and indium concentration.

HL 9.90 Mon 15:15 P3

Electrical Properties of Fe/GaAs-Heterostructures in Cleaved-Edge-Overgrowth Geometry — •Fang-Yuh Lo[1], E. Schuster[2], C. Urban[3], D. Reuter[1], W. Keune[2], U. Köhler[3], and A. D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum — [2]Laboratorium für Angewandte Physik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [3]Experimentalphysik IV/Oberflächenphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

In order to have clean interfaces, thin Fe layers were grown on the UHV-cleaved edge of GaAs-based heterostructures. Then the thin Fe films were patterned into spin-valve structure via the focused ion beam technique. The Fe/heterostructure contact revealed Schottky character, which could act as a tunnel junction for injecting spins from Fe into semiconductors. Magnetoresistances between 0.01% and 0.07% were observed for different heterostructures, and the possible mechanisms will be discussed. We gratefully acknowledge financial support from the DFG SFB491 and DFG GRK384.

HL 9.91 Mon 15:15 P3

Magnetic Anisotropies in (Ga,Mn)As-Hallbars — •S. Hümpfner, K. Pappert, O. Rival, T. Borzenko, J. Wenisch, C. Gould, G. Schmidt, and L.W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The ferromagnetic semiconductor (Ga,Mn)As has become a widely used material in semiconductor spintronics. For device design and the understanding of its transport behaviour it is crucial to understand the rich anisotropy landscape of this material.

We investigate the magnetic anisotropy of structures made from thin LT-(Ga,Mn)As layers grown on a GaAs buffer. The anisotropic magnetoresistance (AMR) enables us to map the magnetic anisotropy landscape through careful transport studies. We show how non-local longitudinal (R_{xx})and in-plane Hall (R_{xy}) resistance measurements on Hall bars complement each other in this analysis. We then discuss the influence that different parameters such as the Hall bar design, its orientation with respect to the (Ga,Mn)As crystal, and annealing have on the measured (R_{xx}) and (R_{xy})patterns and deduce the underlying magnetic anisotropies at 4.2 K. Conclusions on the possible origin of different (Ga,Mn)As anisotropy terms are drawn, which will help to controllably create or avoid certain magnetic configurations in future device designs.

HL 9.92 Mon 15:15 P3

Magnetotransport properties and dynamics of domain wall in magnetic nanowires — •Jamal Berakdar[1], V. K. Dugaev[2], V. R. Vieira[2], P. D. Sacramento[2], J. Barnas[3], and M. A. N. Araujo[4] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [2]Departamento de Física and CFIF, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisbon, Portugal — [3]Department of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland — [4]Departamento de Física, Universidade de Évora, P-7000 Évora, Portugal

We investigate theoretically the magnetoresistance of semiconducting ferromagnetic nanowires with a laterally constrained domain wall . The wall is assumed to be sharp on the scale of the Fermi wavelength of the

charge carriers. The role of the spin-orbit interaction of the Rashba type as well as the influence of impurity scattering are discussed. In addition, we discuss the current-induced dynamics of a magnetic domain wall and calculate the spin torque exterted by an electric current. We find the torque has two components: one component results in a translational motion of the domain wall while the other leads to a deformation of the domain-wall shape, forcing thus the magnetic moments to deviate from the easy plane.

HL 9.93 Mon 15:15 P3

Spin-polarized injection from ferromagnetic semiconductor (Ga,Mn)As into GaAs. — •Andreas Einwanger, Mariusz Ciorga, Janusz Sadowski, Werner Wegscheider, and Dieter Weiss — Universität Regensburg, Experimentelle und Angewandte Physik, D-93040 Regensburg

We have fabricated devices to investigate spin-polarized injection of electrons from ferromagnetic semiconductor (Ga,Mn)As into n and n+ GaAs epilayers. The measurements are performed in lateral spin valve configuration. Two spin-aligning contacts with different coercive fields are employed: one to inject spin-polarized carriers and the other to detect obtained spin-polarization through changes in the in-plane magnetoresistance occuring when magnetization of each of the two contacts is separately switched by in-plane magnetic field. To obtain the efficient spin-polarized injection of electrons from a p-type (Ga,Mn)As into a n-type active layer we employ a spin Esaki diode structure p+(Ga,Mn)As/n+GaAs under reverse bias as spin-aligning contacts. This way we avoid problems related to short spin-relaxation times of holes. The distance between spin injector and detector can be varied to investigate spin relaxation length in the material. We report on first results of our experiments on this all-electrical spin-polarized injection and detection scheme.

HL 9.94 Mon 15:15 P3

Acoustically induced spin transport in (110) GaAs quantum wells — •Odilon D. D. Couto[1], Jörg Rudolph[1], Yang Guang[1], Fernando Iikawa[2], Rudolf Hey[1], Paulo V. Santos[1], and Klaus H. Ploog[1] — [1]Paul-Drude-Institut, 10117 Berlin — [2]Universidade Estadual de Campinas, Campinas, Brazil

GaAs quantum well (QW) structures grown along the [110] direction exhibit due to their symmetry much longer relaxation times for spins polarized along the growth direction than conventional (100) QWs. The electronic quality of the (110) structures, in contrast, is substantially lower than for (100) structures, as judged from the efficiency of the transport of carriers by surface acoustic waves (SAWs). In this contribution, we address this limitation for long-range spin transport by SAWs by (i) improving the sample growth process and (ii) increasing the intensity of the acoustic fields. The latter was achieved by coating the samples with a piezoelectric ZnO layer. The steady-state polarization of photogenerated spins increases substantially under a SAW due to the quenching of excitonic spin relaxation mechanisms as the electrons and holes are spatially separated by the piezoelectric field. Optically detected transport measurements under a magnetic field B in the sample plane and perpendicular to the SAW propagation direction show that the coherent transport length reduces from $l_s = 30$ μm for $B = 0$ (corresponding to $T_2 = l_s/v_{SAW} \sim 10$ ns, where v_{SAW} is the SAW velocity) to less than 10 μm for $B = 18$ mT. Mechanisms for this drastic reduction in l_s will be discussed.

HL 9.95 Mon 15:15 P3

Theory of relaxation oscillations in semiconductor quantum dot lasers — •Ermin Malic, Moritz Jan Philip Bormann, Eckehard Schöll, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenberg Str. 36, 10623 Berlin, Germany

The dynamics of relaxation oscillations in semiconductor quantum dot lasers is investigated theoretically. Our microscopic approach combines rate equations for photon and electron occupations with kinetic equations for the scattering rates between Coulomb coupled localized states and continuum wetting layer states in an InAs/GaAs quantum dot structure. The relaxation oscillations emerging during turn-on processes are on a nanosecond time scale.

HL 9.96 Mon 15:15 P3

Study of vertical-cavity surface-emitting laser structures in the strong coupling regime by modulation spectroscopy — •B. Metzger, G. Blume, P.J. Klar, and W. Heimbrodt — Dept. Physics and WZMW, Philipps-University of Marburg, Germany

In recent years, various modulation spectroscopic methods have been successfully applied for characterizing vertical-cavity surface-emitting laser (VCSEL) structures. Most VCSEL structures employed in devices show only a weak coupling between the cavity mode and the lowest quantum well exciton in the active region. The spectral line shapes of the corresponding $\Delta R/R$ signals in and off resonance are well understood. However, so far there are no reports of modulation spectroscopic studies of VCSEL structures in the strong coupling regime. Here we present first contactless electroreflectance (CER) results on a VCSEL structure with 12 strain-compensated (Ga,In)As/Ga(P,As) quantum wells in the active region of a 2λ-cavity exhibiting a large Rabi splitting. The degree of cavity detuning was varied by changing the sample temperature. The CER spectra obtained will be analysed and compared with those of VCSEL in the weak coupling regime.

HL 9.97 Mon 15:15 P3

Characterisation of Ga(N,As,P)/GaP QW structures for III-V lasers on Si substrates by modulation spectroscopy — •C. Karcher, G. Blume, P.J. Klar, B. Kunert, K. Volz, W. Stolz, and W. Heimbrodt — Dept. Physics and WZMW, Philipps-University of Marburg, Germany

Recently lasing was achieved at 100 K in GaP based laser structures employing highly strained Ga(N,As)/GaP and Ga(N,As,P)/GaP single quantum well structures in the active region. This opens the field for achieving III-V lasers on Si substrate as the lattice-mismatch between GaP and Si is rather small. We study these lasers and related quantum well structures of different well width and varying composition grown on (100) GaP substrates by photomodulated reflectance, electroreflectance, and photocurrent spectroscopy. The obtained modulation spectra and photocurrent characteristics are analysed in terms of the band alignment of the quantum well structures. These results yield additional knowledge about the band structure essential for achieving room-temperature lasing in the near future.

HL 9.98 Mon 15:15 P3

Collective Excitations and Composite Fermions — •G. Meissner and U. Schmitt — Theoretische Physik, Universitaet des Saarlandes, Postfach 15 11 50, D-66041 Saarbruecken

Strong correlations are of significance in incompressible quantun liquid phases of interacting 2D electrons in high perpendicular magnetic fields exhibiting the fractional quantum Hall effect at certain fractional filling factors of the lowest Landau level. Therefore, dispersion relations of resulting collective excitations as magneto-rotons are reexamined and shown to be obtained in a non-perturbative many-body approach using intensively sum-rule techniques. Employing a Chern-Simons gauge theory in the Zeeman low-energy limit, finite wave-vector spin-flip excitations of integer quantum Hall states of Composite Fermions with corresponding integer filling factors are then investigate by summing up diagrams for their Coulomb interaction in shielded potential approximation. Compelling similarities found in the dispersion of these intra-Landau level and inter-Landau level excitations are finally discussed in view of a comparison with inelastic light-scattering experiments in such quantum Hall systems.

HL 9.99 Mon 15:15 P3

Magnetotransport measurement set-up in pulsed magnetic fields up to 60 T — •N. Kozlova, M. Kozlov, D. Eckert, K.-H. Mueller, and L. Schultz — IFW Dresden

In the present work, the magnetotransport measurement technique is presented and various materials, exhibiting resistances from 1 mOhm up to several tens of kOhm, are investigated in pulsed magnetic fields of up to 60 T. For example, these are semimetals, high-temperature superconductors and ferromagnetic manganites. The developed technique allows performing the magnetoresistance and the Hall-effect measurements simultaneously.

[1] N. Kozlova et al. Phys. Rev. Lett. 95 (2005) 086403.
[2] Y. Skourski et al. Physica B 346-347 (2004) 325-328.
[3] N. Kozlova et al. Physica B 346-347 (2004) 74-78.

HL 9.100 Mon 15:15 P3

Experimental and Numerical Investigations of the Terahertz Photoconductivity of QH-Systems — •Gabriel Vasile[1,2], Christian Stellmach[1], Yuri Vasilyev[3], Alexander Hirsch[1], Günter Hein[4], Rolf Gerhardts[5], and Georg Nachtwei[1] — [1]Institut für Angewandte Physik, TU-Braunschweig, D-38106 Braunschweig, Deutschland — [2]National Institute of Research-Development for Cryogenics and Isotopic Technologies, Ro-1000 Rm. Valcea, Romania — [3]A.F. Ioffe Physical Technical Institute, Ru-194021 St. Petersburg, Russia — [4]Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Deutschland — [5]Max Planck Institut für Festkörperforschung, D-70569 Stuttgart, Deutschland

We present measurements of the Terahertz (THz) photoconductivity of quantum-Hall systems in GaAs/AlGaAs heterostructures with meander and Corbino geometries by using a pulsed p-Ge laser as the THz source (1.7 to 2.5 THz). The photoconductivity versus the magnetic field shows a two-fold structure: one peak at the cyclotron frequency and the others near the minima of the conductivity around the filling factor 2. In order to understand the features revealed by our measurements we perform calculations of the absorption (Joule heating) for different magnetic fields and laser frequencies. To do so we first calculate the dynamic and static conductivities within the Drude and self-consistent Born approximations. The quantum effect seems to be smeared out at high frequencies. This work shows important conclusions for the development of tunable THz detectors.

HL 9.101 Mon 15:15 P3

Photoconductivity measurements on Terahertz-HgTe/HgCdTe-Quantum-Hall-detectors — •R. Bonk[1], C. Stellmach[1], C. Becker[2], V. Hock[2], G. Hein[3], and G. Nachtwei[1] — [1]Institut für Angewandte Physik, TU-Braunschweig, Mendelssohnstr.2, D-38106 Braunschweig — [2]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Am Hubland, D-97074 Würzburg — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Many Terahertz-(THz) applications from material research to biological systems have stimulated an intense research in the field of THz wave detection. Two- dimensional electron systems under quantum hall-(QH) conditions develop energy gaps of the order of 10 meV between the Landau levels. Therefore, these systems can interact effectively with far-infrared radiation with wavelengths of the order of 100 μm. Hence, it was found that QH-systems can be used for fast THz detectors with spectral selectivity. In this work we present THz- photoconductivity-(PR) measurements on MCT-(HgCdTe/HgTe)-quantum wells. A pulsed p-Ge laser (120-180 μm) and a glow bar were used as THz sources. With the pulsed monochromatic laser radiation quasi-time resolved PR is measured. The results are relaxation times-(RT) (dissipative to QH state) limited by the experimental setup in the μm range. Additionally, we are interested in the spectral resolution and in the sensitivity of THz-QH-detectors. MCT samples show a sensitivity of the irradiated FIR power, but no visible reaction in the strong bolometric signal to different laser energies.

HL 9.102 Mon 15:15 P3

Characterization of AlGaN/GaN - heterostructures by means of magnetotransport measurements in high magnetic fields — •K. Knese[1], F. Vogt[1], N. Riedel[1], U. Rossow[1], E. Sagol[2], Ch. Stellmach[1], and G. Nachtwei[1] — [1]Institut für Angewandte Physik, Technische Universität Braunschweig, Mendelsohnstr. 2, D-38106 Braunschweig — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

The group-III-nitrides are very promising materials in terms of high power, high temperature and high frequency electronic applications. In this work, we investigate the electronic properties of a two dimensional electron gas (2DEG) in AlGaN/GaN heterostructures grown on sapphire substrates in order to obtain a better understanding of scattering mechanisms and transport properties. Therefore, Shubnikov-de Haas (SdH)- and Hall-measurements were performed on several samples (in Hall bar- and Van der Pauw- geometry) with different Al-content of the AlGaN-barrier in high magnetic fields up to 18 T. From SdH- and Hall- measurements the sheet carrier concentration was determined to be $4{\cdot}10^{12}$ - $1{\cdot}10^{13}$ cm^{-2}. The analysis of temperature-dependent SdH-oscillations yields an electronic effective mass of 0.23 - 0.26 m_0. In addition, the quantum scattering lifetime τ_t, which is related to the Landau level broadening, and the classical lifetime τ_D can be calculated from such measurements, whereas the ratio τ_t/τ_D is an indicator of the type of scattering mechanism present in the sample. Finally, the effective Landé-factor g^* was determined from angular dependent SdH-measurements.

HL 9.103 Mon 15:15 P3

Anisotropic magnetization and magnetotransport studies of two- and three-dimensional electron systems in GaAs — •A. Krohn, J. I. Springborn, Ch. Heyn, and D. Grundler — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

The low-temperature magnetization M of quasi-free electrons in conducting metals and semiconductors exhibits the well-known de Haas-van Alphen (dHvA) oscillations which originate from the Landau quantization of the electronic spectrum in a magnetic field B. While the dHvA effect is isotropic for a three-dimensional system (3DES) of free electrons, it is anisotropic for a two-dimensional electron system (2DES). In our experiment we have examined different electron systems realized in Si-doped epitaxial GaAs layers where the thickness was varied from 20 nm (2DES) to several μm (3DES). The carrier density was adjusted to be similar and about 10^{18} cm^{-3}. The mobility was about 2×10^3 cm^2/Vs. We measured the dHvA oscillations by detecting the torque $\tau = M \times B$ acting on a highly sensitive cantilever magnetometer. This technique was in particular sensitive to anisotropic magnetization. At the same time we evaluated the Shubnikov-de Haas oscillations from magnetotransport measurements. All data were taken at B up to 14 T and temperatures $T < 5$ K. We found that also the thick samples exhibited a surprisingly anisotropic magnetization, even for a layer thickness as large as several hundred nm. We thank D. Heitmann for continous support and acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508 and via GR1640/1-3.

HL 9.104 Mon 15:15 P3

Magnetization of a tunneling coupled double-layer electronsystem and double-layer quantum dots — •O. Rösler[1], J. Topp[1], D. Reuter[2], A.D. Wieck[2], and D. Grundler[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, D-20355 Hamburg — [2]Ruhr-Universität Bochum, Lehrstuhl für Angewandte Festkörperphysik, Universitätsstraße 150, D-44780 Bochum

We have experimentally investigated the magnetization of a double-layered two dimensional electron system and of double-layered quantum dots. The heterostructure was grown by molecular-beam epitaxy. It consisted of two 15 nm wide GaAs quantum wells. These were separated by a narrow tunneling barrier consisting of $Al_{0.33}Ga_{0.66}As$ with a thickness of 1 nm. Delta-doping layers on both sides of the double-quantum well was integrated to provide electrons. The doping layers were optimized to get an approximately symmetric conduction band profile i.e., a balanced electron system. The magnetization shows sawtooth like quantum oscillations at even and odd total filling factors in magnetic fields B up to 33 T. With increasing angle between double-layer normal and B specific filling factors appear and disappear. This unexpected behaviour will be studied in further detail in a mixing chamber cryostat providing a temperature down to 10 mK. Here, we will also investigate quantum dots prepared from the same wafer. We report on our last results.

The authors thank D. Heitmann for continuous support and the Deutsche Forschungsgemeinschaft for financial support via SFB 508.

HL 9.105 Mon 15:15 P3

De Haas-van Alphen effect in a two-dimensional electron system with variable carrier density and mobility — •N. Ruhe, J. I. Springborn, M. A. Wilde, Ch. Heyn, and D. Grundler — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung der Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

We have studied simultaneously the de Haas-van Alphen (dHvA) and the quantum Hall effect in a gated two-dimensional electron system (2DES) at temperatures down to 300 mK. The 2DES was formed in a modulation-doped GaAs/AlGaAs heterostructure and integrated into a micromechanical cantilever. Using a fiber-optics interferometer we measured the quantum oscillatory behavior of the magnetization in a magnetic field B up to 14.5 T. The high sensitivity of $4.5 \cdot 10^{-16}$ J/T at $B = 10$ T allowed us to measure the dHvA oscillations for carrier densities n_S ranging from 5 to $33 \cdot 10^{10}$ cm^{-2}. Leads were integrated to measure simultaneously the zero-field mobility μ_e. It was found to vary by a factor of five between 1 and $5 \cdot 10^5$ cm^2/Vs. Unexpectedly we observed that the sawtooth like dHvA amplitude per electron did not depend on n_S and μ_e

for even integer filling factors ν at fixed B. The behavior is consistent within a density-independent quantum scattering time of $7 \cdot 10^{-13}$ s. For the dHvA amplitude at $\nu = 1$ we find a characteristic dependence on B and n_S which we explain by exchange enhancement.

The authors thank D. Heitmann and A. Schwarz for continuous support and the Deutsche Forschungsgemeinschaft for financial support via SFB 508 and GR 1640/1.

HL 9.106 Mon 15:15 P3

Magneto-resistance studies on evenly curved Hall bars — •Olrik Schumacher, Miriam Stampe, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg, Germany

We present transport measurements on evenly curved two-dimensional electron systems in InGaAs-microtubes. The method of self-rolling strained semiconductor double layers enables us to build tubes with tuneable radii [1][2]. Using an optimized epitaxial layer design combined with a special lithographic procedure we fabricate GaAs/InGaAs-microtubes with Hall bars containing a two-dimensional electron system (2-DES). When brought into a magnetic field the field component perpendicular to the 2-DES plane is strongly modulated. Transport measurements on such curved Hall bars with current direction along the axis of the microtube will be shown. By rotating the curved Hall bar in the magnetic field one can tune the perpendicular field component such that there is a zero-crossing on the Hall bar. In that case, this field component has opposite sign at the edges of the bar and new electron trajectories like snake orbits are predicted [3]. We discuss ac- as well as dc-measurements in view of the signatures of such orbits.

[1] V. Ya. Prinz et al., Physica E 6 (2000) 828-831
[2] O. Schumacher et al., Appl. Phys. Lett. 86 (2005) 143109
[3] J. E. Müller, Phys. Rev. Lett. 68 (1992) 385-388

HL 9.107 Mon 15:15 P3

Local properties of disordered fractional quantum hall systems — •Christian Mueller and Daniela Pfannkuche — Jungiusstrasse 9 20355 Hamburg

We propose a new method to study the local properties of highly correlated FQH states when disorder is present. The method is based on the correlations between electrons and wavefunction vortices which characterizes different fractional quantum Hall states. We calculate the conditional electron-vortex correlation function $g^{r_0}_{x,y}$ for finite size systems at different filling factors and disorder potentials. Monte-Carlo-techniques are used to evaluate the multidimensional integrals involving few-electron-wavefunctions obtained from an exact diagonalization of the Hamiltonian. Usage of the method is demonstrated in a fully spin polarized $\nu = \frac{1}{3}$ state with up to 6 electrons. The system is disturbed by several disorder potential types. Regions of different filling factors can de distinguished by comparison of the conditional correlation functions.

HL 10 Invited Talk Santos

Time: Tuesday 09:30–10:15 Room: HSZ 01

Invited Talk

HL 10.1 Tue 09:30 HSZ 01

Coherent spin transport by acoustic fields in GaAs quantum wells — •Paulo Santos, James Stotz, Odilon Couto, Fernando Iikawa, Rudolph Hey, and Klaus Ploog — Paul-Drude-Institut, Berlin

Spintronic applications require processes for the storage, manipulation, and coherent transport of spins. Here, we show that these tasks can be realized in undoped GaAs quantum wells (QWs) by mobile potential dots (dynamic quantum dots, DQDs) induced by surface acoustic waves (SAWs). The type-II piezoelectric potential induces spatially separated negative and positive DQDs, which store and transport photogenerated electrons and holes. The spatial separation prevents recombination and quenches excitonic spin relaxation mechanisms. Measurements of the spin transport length ℓ_s on QWs grown along different orientations demonstrate that ℓ_s is limited by the Dyakonov-Perel mechanism. Here, the carriers experience an effective magnetic field B_{int} associated with spin-orbit coupling, which leads to spin precession angles that depend on the individual carrier trajectory and velocity. Variations in B_{int} can be minimized by confining all spins within a small DQD during transport. In fact, we demonstrate ℓ_s approaching 100 μm when the DQD dimensions are reduced below 1 μm. The spins precess coherently around B_{int} during transport. The spin precession frequency can be controlled by an external magnetic field, thus opening the way for the realization of spin control gates based on SAWs.(Work supported by the NanoQuit/BMBF, Germany.)

HL 11 Invited Talk Bauer

Time: Tuesday 10:15–11:00 Room: HSZ 01

Invited Talk

HL 11.1 Tue 10:15 HSZ 01

Spin accumulation dynamics in semiconductors close to ferromagnetic contacts — •Gerrit E.W. Bauer — TU Delft

In recent experiments the spin accumulation electrically injected into semiconductors has been spatially imaged by Faraday or Kerr rotation spectroscopy [1,2]. Here I will review a theory for the spin accumulation that acquires a time-dependence through proximity of ferromagnets and applied magnetic fields [3]. It is shown that the experiments provide important insights into the nature of the spin injection and the semiconductor-ferromagnet interface.

[1] J. Stephens, J. Berezovsky, J.P. McGuire, L.J. Sham, A.C. Gossard, D.D. Awschalom, Phys. Rev. Lett. 93, 097602 (2004)} [2] S.A. Crooker, M. Furis, X. Lou, C. Adelmann, D.L. Smith, C.J. Palmstrom, P.A. Crowell, Science 309, 2191 (2005)} [3] G.E.W. Bauer, Y. Tserkovnyak, A. Brataas, J. Ren, K. Xia, M. Zwierzycki, and P. J. Kelly, Phys. Rev. B 72,155304 (2005)}

HL 12 Symposium Quantum optics in semiconductors I

Time: Tuesday 11:15–13:15 Room: HSZ 01

Keynote Talk

HL 12.1 Tue 11:15 HSZ 01

Single Photon Nanotechnology based on Semiconductor Quantum Dots — •A. J. Shields — Quantum Information Group, Toshiba Research Europe Ltd, 260 Cambridge Science Park, Milton Road, Cambridge CB4 0WE UK

The potential application of quantum optics in areas such as secure optical communications and ultra-fine imaging has stimulated research on novel components for the generation and detection of single photons. We summarise here progress on quantum photonics based on integrating semiconductor quantum dots into conventional semiconductor devices. The electroluminescence of a single quantum dot in a p-i-n junction can be used to realise a light emitting diode (LED) for single photons.[1] We describe here recent work on incorporating cavities to enhance the emission efficiency,[2] control the polarisation of the emission,[3] as well as gating schemes to reduce the jitter in the emission time and exceed GHz repetition rates.[4] Engineering the dot nanostructure allows the emission wavelength to be tuned to the fibre optic transmission band at 1300nm.[5] We show also that quantum dots integrated inside resonant tunnelling diodes make efficient, low noise detectors of single photons.[6]

[1] Yuan et al, Science 295, 102 (2002)
[2] Bennett et al, Appl. Phys. Lett. 86, 181102 (2005)

[3] Unitt et al, Phys. Rev. B 72, 033318 (2005)
[4] Bennett et al, Phys. Rev. B 72, 033316 (2005)
[5] Ward et al, Appl. Phys. Lett. 86, 201111 (2005)
[6] Blakesley et al, Phys. Rev. Lett. 94, 067401 (2005)

Keynote Talk HL 12.2 Tue 11:45 HSZ 01

Size-tunable exchange interaction in InAs/GaAs quantum dots — •U. W. Pohl, A. Schliwa, R. Seguin, S. Rodt, K. Pötschke, and D. Bimberg — Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

A systematic variation of the exciton fine-structure splitting ranging from above 500 μeV to -80 μeV was found in self-organized InAs/GaAs quantum dots of decreasing, well-defined sizes [1]. This finding is of basic interest for novel applications in e.g. quantum cryptography and logics. The assignment of the dependency was enabled by the recently reported multi-modal size distribution of equally shaped dots in our ensembles [2], providing a major step towards controlling the exchange interaction of confined excitons and resulting properties. We will discuss the origin of such intriguing dot ensembles and show how the comprehensive knowledge of structural dot properties advances understanding and control of excitonic properties. Comparison with model calculations allow statements on the main effects governing the electronic states, yielding the degree of correlation and piezoelectricity as key parameters being responsible for exciton binding energy and fine-structure splitting, respectively.

[1] R. Seguin et al., Size-dependent fine-structure splitting in self-organized InAs/GaAs quantum dots, Phys. Rev. Lett., in print.
[2] U. W. Pohl et al., Evolution of a multimodal distribution of self-organized InAs/GaAs quantum dots, Phys. Rev. B, in print.

Keynote Talk HL 12.3 Tue 12:15 HSZ 01

Quantum Optics of Excitons in Semiconductors — •Heinrich Stolz — Institut für Physik, Universität Rostock,

The quantum optical properties of excitons,the bound states of the electron hole system at low and moderate densities in semiconductors are determined by the interplay between the fermionic nature of their constituents and the interaction with the bosonic photon field. In semiconductors with reduced dimensionality we have in addition to take the breakdown of the k-selection rule due to the modified symmetry and due to the always present disorder into account. This leads to a large variety of effects, which go beyond those in normal atomic quantum optics.

In this talk, the properties connected with the spontaneous radiative decay of excitons will be considered in more detail. In a coherently driven state this leads to the phenomena of resonance fluorescence (RF), which in a 2d quantum well shows up as the driven specularly reflected light and the spontaneous radiation in arbitrary directions. In a real quantum well, the latter is superimposed by the disorder induced Rayleigh scattering. By doing optical homodyning of the resoannce fluorescence under quasi-monochromtic resonant excitation, the reflected light shows strong phase-dependend noise, in contrast to what is expected from the usual semiclassical picture. In the same range of excitation powers, the spectral shape of the RF changes dramatically by developing side wings similiar to the well known Mollow triplet in atomic RF. Both effects can be explained by the simple picture of an ensemble of two-level system. Applying in addition high spatial resolution, we are able to resolve RF from single exciton states and clarifiy their dependence on the disorder.

Keynote Talk HL 12.4 Tue 12:45 HSZ 01

Microscopic Theory of Semiconductor Quantum Optics — •Mackillo Kira and Stephan W. Koch — Philipps-University Marburg

Quantum optical properties of semiconductors are investigated on the basis of a microscopic theory that includes the quantized light field, Coulomb interacting fermionic electrons and holes, as well as phonons at the same consistent level. The theory is evaluated for a wide range of phenomena including excitonic photoluminescence, entanglement in incoherent emission, and squeezing in resonance fluorescence. The results provide the microscopic foundation of quantum-optical spectroscopy where one generates and detects quasi-particle states in semiconductors whose quantum-statistical properties are governed by that of the exciting light.

References:
[1] S. Chatterjee et al., Phys. Rev. Lett. 92, 067402 (2004).
[2] W. Hoyer et al., Phys. Rev. Lett. 93, 067401(2004).
[3] M. Kira and S.W. Koch, Phys. Rev. Lett. 93, 076402 (2004).
[4] M. Kira and S.W. Koch, E. Phys. J. D 36, 143 (2005).

HL 13 Spin controlled transport I

Time: Tuesday 11:00–13:15 Room: BEY 118

HL 13.1 Tue 11:00 BEY 118

Dynamics of Spin-Flip Scattering due to the Bir-Aronov-Pikus Mechanism — •Hans Christian Schneider — FB Physik, TU Kaiserslautern

After a brief review of existing theoretical results on electron-hole exchange scattering in semiconductors (Bir-Aronov-Pikus mechanism), numerical results on the dynamics of this scattering mechanism and its interplay with spin-conserving Coulomb scattering are presented. It is shown that for low electron densities a single spin relaxation-time can approximate the results of the full calculation rather well, even though the individual scattering rates are strongly energy-dependent. This spin-relaxation time is evaluated for a wide range of temperatures and densities and is shown to agree well with recent experiments. The results are also compared with widely-used simplified expressions for spin relaxation-times that are only valid for extremely high and low p-doping concentrations. The interesting range of doping concentrations and temperatures around hole degeneracy, which cannot be described by simplified expressions, is discussed in detail.

HL 13.2 Tue 11:15 BEY 118

Spin Relaxation Anisotropy in Semiconductor Quantum Wells — •Leonid Golub, Nikita Averkiev, Alexey Gurevich, Vadim Evtikhiev, Vladimir Kochereshko, Alexey Platonov, Alexey Shkolnik, and Yuri Dolgikh — A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Spin relaxation of conduction electrons is an important field of research due to rapidly developing semiconductor spintronics. The Dyakonov-Perel spin relaxation process is the dominant spin decoherence mechanism in undoped GaAs-based heterostructures. This mechanism is caused by spin splitting of electron energy spectrum which originate either from the structure inversion asymmetry (Rashba term) or the bulk inversion symmetry (Dresselhaus term). The presence of both Rashba and Dresselhaus spin-splittings results in the electron spin relaxation times anisotropy. A set of triangular and rectangular GaAs (001) quantum wells has been MBE grown on semi-insulating GaAs substrates. Circularly polarized photoluminescence (PL) spectra under circularly polarized excitation have been studied at 77K in magnetic fields up to 0.5T. The magnitude of the optical orientation signal amounts to 10% and is virtually constant within the PL contour. We observe that when the magnetic field is directed along the [110] axis the Hanle curve is about 1.6 times wider than the depolarization curve for [1-10] direction. The observed anisotropy of the Hanle effect is caused by anisotropy of the electron spin relaxation. The analysis shows that the Rashba term is about 4 times stronger than the Dresselhaus term in the studied system.

HL 13.3 Tue 11:30 BEY 118

Polarized Electric Current in Semiclassical Transport with Spin-Orbit Interaction — •P.G. Silvestrov[1] and E.G. Mishchenko[2] — [1]Theoretische Physik III, Ruhr-Universitt Bochum, 44780 Bochum, Germany — [2]Department of Physics, University of Utah, Salt Lake City, UT 84112, USA

Semiclassical solutions of two-dimensional Schrödinger equation with spin-orbit interaction and smooth potential are considered. In the leading order, spin polarization is in-plane and follows the evolution of the electron momentum for a given subband. Out-of-plane spin polarization appears as a quantum correction, for which an explicit expression is obtained. We demonstrate how spin-polarized currents can be achieved with the help of a barrier or quantum point contact open for transmission only in the lower subband.

HL 13.4 Tue 11:45 BEY 118

Optical investigation of spin polarization in semiconductor heterostructures — •Ulrich Niedermeier, Klaus Wagenhuber, Christian Gerl, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

Creating spin polarization in low-dimensional semiconductor systems is essential for the realization of new concepts in the field of spintronics. It has been shown that in systems with lifted spin degeneracy due to spin-orbit interaction a new class of spin-related effects can be observed [1]. While the spin-galvanic effect is referred to as a current induced by spin orientation we are investigating the reversed spin-galvanic effect, i.e. a spin orientation induced by a current. Recently, it has been demonstrated by means of optical interband spectroscopy that passing an electric current in lateral geometry through a two-dimensional hole system leads to an orientation of spins [2]. In order to reproduce this effect photoluminescence measurements of modulation doped p-type AlGaAs/GaAs heterojunctions under current flow are performed. The analysis of the circular polarization of the photoluminescence signal should give a low-limit estimate of the spin polarization achieved.

[1] S. D. Ganichev, W. Prettl, J. Phys.: Condens. Matter (Topical Review) **15**, R935 (2003).
[2] A. Yu. Silov et al., Appl. Phys. Lett. **85**, 5929-5931 (2004).

HL 13.5 Tue 12:00 BEY 118

Suppression of Spin Relaxation in n-InGaAs-Wires — •Alexander Holleitner — Center for NanoScience (CeNS), Munich, Germany

The spin dynamics of electrons have been investigated in narrow two-dimensional n-InGaAs channels as a function of the wire width [1]. We find that electron-spin relaxation times increase with decreasing channel width, in accordance with recent theoretical predictions [2]. Surprisingly, the suppression of the spin relaxation rate can be detected for widths that are an order of magnitude larger than the electron mean free path. We find the spin diffusion length and the wire width to be the relevant length scales for explaining these effects. We discuss to which extent confinement, spin-orbit coupling, and structural parameters such as strain explain the observed effects. For the presented work, we acknowledge financial support by AFOSR and ONR. [1] A.W. Holleitner, V. Sih, R.C. Myers, A.C. Gossard, and D.D. Awschalom in preparation (2005). [2] A.G. Malshukov, K.A. Chao, Phys. Rev. B 61, 2413 (2000).

HL 13.6 Tue 12:15 BEY 118

Rashba Spin Splitting in GaN Heterostruckturen — •Wolfgang Weber[1], S.D. Ganichev[1], Z.D. Kvon[2], V.V. Belkov[3], L.E. Golub[3], S.N. Danilov[1], D. Weiss[1], W. Prettl[1], Hyun-Ick Cho[4], and Jung-Hee Lee[4] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]Institut für Halbleiterphysik, Novosibirsk, 630090, Russland — [3]A. F. Ioffe Physikalisch-Technisches Institut, 194021 St. Petersburg, Russland — [4]Kyungpook Staatliche Universität, 1370, Sankyuk-Dong, Daegu 702-701, Korea

The spin splitting in k-space of the conduction band of low-dimensional GaN-structures was experimentally proved. It is shown, that the excitation of (0001)-oriented GaN quantum wells with infrared or terahertz radiation causes the circular photogalvanic effect. From a microscopical point of view this effect is a consequence of spin-orbit-coupling, which removes the spin-degeneration of the carriers in k-space, and the optical selection rules. The observation leads to a tunable Rashba-like spin splitting, which comes from the built-in asymmetry of the AlGaN/GaN interface. This fact, together with the anticipated high curie temperature under Mn doping and the long spin relaxation times, makes GaN an interesting material for spintronics.

HL 13.7 Tue 12:30 BEY 118

Detection of few phosphorus donors in silicon — •H. Huebl[1], D. R. McCamey[2,3], M. Lunz[1], W. Hutchison[2,4], J. C. McCallum[2,5], A. R. Hamilton[3], R. G. Clark[2,3], and M. S. Brandt[1] — [1]Walter Schottky Institut, Germany — [2]Australian Research Council Centre of Excellence for Quantum Computer Technology — [3]School of Physics, The University of New South Wales, Sydney, Australia — [4]School of Physical, Environmental and Mathematical, University College, The University of New South Wales ADFA,Canberra, Australia — [5]School of Physics, University of Melbourne, Australia

One of the concepts for scalable solid-state based quantum computing is Kane's proposal based on phosphorus donors in silicon. To estimate the sensitivity which is reached with magnetic resonance techniques in the detection of donor spins, we have measured electrically detected magnetic resonance (EDMR) on devices containing a few phosphorus donors only.

In the devices studied phosphorus with a concentration of 2×10^{17} cm^{-3} is implanted at 15 keV into intrinsic silicon in an area of 100×100 nm^2 defined by electron beam lithography. The leads contacting this island are also obtained by implantation with P, however to a concentration above the Mott transition which does not lead to an EDMR signal.

At 5 K and under illumination, a resonant change of the conductivity $\Delta\sigma/\sigma \approx 10^{-5}$ is observed for an island containing 85 ± 10 atoms. From the signal-to-noise ratio, a sensitivity of about 600 P/$\sqrt{\text{number of field scans}}$ can be deduced for the samples investigated so far. This experiments demonstrate the possibilities for investigating the properties of a few of donors and indicates that single spin resolution should be achievable.

HL 13.8 Tue 12:45 BEY 118

Pure Spin Currents by Spin Dependent Electron Phonon Interaction — •Stephan Giglberger[1], S.D. Ganichev[1], S.N. Danilov[1], V.V. Belkov[2], E.L. Ivchenko[2], S.A. Tarasenko[2], D. Weiss[1], W. Prettl[1], W. Janzsch[3], F. Schaffler[3], and D. Gruber[3] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]A.F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russland — [3]Institut für Halbleiter- und Festkörperphysik, Johannes-Kepler-Universität, Linz, Österreich

It is shown that in gyrotropic quantum wells Drude absorption of terahertz radiation leads to a pure spin current. This current is caused by spin dependent electron phonon interaction wich can be described by k-linear terms in their matrix element. Due to these k-linear terms Drude absorption leads to an asymmetric allocation of charge carriers within each subband and hence to a spinpolarised electric current. Due to the fact that direction of this current is antipodal for both spin subbbands the resulting electric net current will be zero, but there will be two spin currents. Here both the theory and the experimental verification of such spin currents will be presented. In experiment the pure spin current was converted to an electric current by applying a small magnetic field parallel to the plane which leads to Zeeman spin splitting and destroys the equilibrium of the opposing spin currents. Experiments were carried out on (001)-oriented asymmetric SiGe quantum wells under excitation with linearly polarised radiation of 140 μm wavelength.

HL 13.9 Tue 13:00 BEY 118

Magnetic anisotropy and antiferromagnetic exchange of Co impurities in ZnO — •Roland Hayn[1], Pascal Sati[1], Anatole Stepanov[1], Roman Kuzian[2], Thomas Chanier[1], Steffen Schäfer[1], Sonia Régnier[1], and Christian Morhain[3] — [1]Laboratoire Materiaux et Microelectronique de Provence, 13397, Marseille Cedex 20, France — [2]Institute for Material Science, Krzhizhanovskogo 3, 03180 Kiev, Ukraine — [3]Centre de Recherche sur l'Hetero-Epitaxie et ses Applications-CNRS, 06560, Valbonne Sophia-Antipolis, France

We report on the magnetic properties of (Zn,Co)O epitaxial thin films with low Co concentration. Magnetic and EPR measurements, combined with crystal field theory, reveal that isolated Co impurities possess a strong single ion anisotropy, which would lead to an easy plane ferromagnetic state when a hypothetical Co-Co interaction would be considered. However, the magnetization measurements show the presence of short-range antiferromagnetic exchange interactions between nearest-neighbor magnetic ions which is supported by LSDA+U calculations.

HL 14 II-VI semiconductors I

Time: Tuesday 11:00–13:15 Room: POT 151

HL 14.1 Tue 11:00 POT 151

Magnetic field studies of bound exciton complexes in Lithium doped ZnO — •Rob McKenna[1,2], Markus R. Wagner[1], Axel Hoffmann[1], Joachim Sann[3], Stefan Lautenschläger[3], and Bruno K. Meyer[3] — [1]Intitute for Solid State Physics, Technical University Berlin — [2]University of Technology Sydney — [3]I. Physics Institute, Justus Liebig University Giessen

Lithium located at the Zn site in the ZnO matrix could be a valid acceptor for p-conduction. Our magneto-PL and -PT investigation of a Lithium doped ZnO film on a ZnO substrate found I_6 to I_8, as well as I_0 and I_1 bound exciton complexes, with the smallest FWHM of 80 μm. Zeeman-splitting of peaks up to 580 μeV at 5 T, produced electron g-values in good agreement with previous publications. An additional splitting of peaks in magnetic fields stronger than 3 T, was also clearly apparent. A non-zero an-isotropic hole effective g-value for $B \perp c$ is discussed as the possible origin of the observed splitting. The neutral or ionised nature of the I_0 and I_1 bound exciton complexes in the magnetic field was also further clarified and the appearance of a new peak on the lower energy side of the I_1 peak, indicating zero-field-splitting, was also investigated. In addition to this, the forbidden exciton could be observed. Temperature dependent measurements were employed to investigate the donor or acceptor character of the bound exciton complexes and angular and polarisation dependent measurements clarify whether the involved holes originate from a valence band with Γ_7 or Γ_9 symmetry.

HL 14.2 Tue 11:15 POT 151

Photoluminescence properties of $Mg_xZn_{1-x}O$ thin films grown by pulsed laser deposition — •Susanne Heitsch, Gregor Zimmermann, Holger Hochmuth, Daniel Spemann, Gabriele Benndorf, Heidemarie Schmidt, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

$Mg_xZn_{1-x}O$ thin films ($0 \leq x \leq 0.18$) have been grown on a-plane sapphire substrates with or without ZnO buffer layers by pulsed laser deposition. The Mg content in the films was controlled by using different MgZnO targets and by applying different oxygen partial pressures $p(O_2)$ during the deposition, respectively. Higher oxygen partial pressures caused a lower Mg content in the thin films. The surface roughness measured by AFM shows no dependence on x, but on $p(O_2)$. A minimum could be found for samples grown at $p(O_2) \sim 1 \times 10^{-3}$ mbar. Samples with equal x grown at lower oxygen partial pressures show a broader photoluminescence (PL) emission than samples grown at higher pressures. With increasing x the PL maximum shifts approximately linearly to higher energies and the emission exhibits a broadening not only due to alloy broadening. The blueshift of the PL peak position on x is found to be larger at room temperature than at 2 K. Deposition of the $Mg_xZn_{1-x}O$ thin films on ZnO buffer layers improves the surface quality as well as the half width of the emission.

HL 14.3 Tue 11:30 POT 151

Excitonic-recombination dynamics of individual ZnO nanowires — •Lars Wischmeier, Tobias Voss, Ilja Rückmann, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Zincoxide (ZnO) nanowires show near band-edge photoluminescence (PL) in the UV spectral region ($E_{gap} = 3.37\ eV$ at room temperature) and have therefore recently attracted many research activities because they are considered to be promising building blocks for nanometer-scale optoelectronic devices. Here the optical properties of individual nanowires with diameters $< 200\ nm$ prepared from an as-grown ensemble are analyzed.
The PL of ZnO is composed of various near band-edge emissions which are accompanied by phonon-assisted recombinations. These different emissions of an individual nanowire are measured time-resolved by a combination of a micro-photoluminescence setup and the time-correlated single-photon counting technique. The temporal development of the PL is studied as a function of intensity, temperature, and size of the wires. From the experimental results the decay times are determined. The results are analyzed by use of rate equations to model the excitonic recombination processes.
Additionally the results performed on an individual nanowire are compared to the results performed on the as-grown nanowire ensemble.

HL 14.4 Tue 11:45 POT 151

Optical and microelectrical characterization of ZnO single crystals implanted with group V elements — •Matthias Brandt[1], Holger von Wenckstern[1], Gabriele Benndorf[1], Jörg Lenzner[1], Heidemarie Schmidt[1], Michael Lorenz[1], Marius Grundmann[1], Gabriel Braunstein[2], and Gerhard Brauer[3] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany — [2]University of Central Florida, Department of Physics, Orlando, Florida, USA — [3]Institut für Ionenstrahlphysik und Materialforschung, FZ Rossendorf, Dresden, Germany

We have implanted ZnO single crystals produced by pressurized melt growth with nitrogen, phosphorous and arsenic ions, as well as with argon. The samples have been annealed at temperatures ranging from 300 to 1000°C in an oxygen atmosphere for 45 minutes or in air for 60 minutes. They were characterized optically by cathodoluminescence and photoluminescence measurements and electrically by scanning capacitance microscopy and scanning surface potential microscopy. Results have been compared to the properties of as-grown samples. We find a strong dependence on a) the implanted species and b) the annealing temperature. An intense donor-acceptor pair transition was observed in luminescence of N-implanted crystals annealed at 700°C only. Strong indication for a p-type conductivity surface layer was found for P-implanted ZnO annealed at 700°C.

HL 14.5 Tue 12:00 POT 151

Deep defects generated in *n*-conducting ZnO:TM thin films — •Heidemarie Schmidt, Mariana Diaconu, Holger Hochmuth, Michael Lorenz, Holgerr von Wenckstern, Gisela Biehne, Daniel Spemann, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

The ferromagnetism in highly transparent and intrinsically n-type conducting zinc oxide doped with 3d transition metals (TM), is predicted to be defect mediated. We investigate the generation of deep defects in n-conducting 1 μm thick ZnO:TM films (TM=Co, Mn, Ti) with a nominal TM content of 0.02, 0.20 and 2.00 at% grown by pulsed laser deposition on a-plane sapphire substrates using deep level transient spectroscopy. We find that a defect level is generated, independent of the TM content, located 0.31 eV and 0.27 eV below the conduction band minimum of ZnO:Mn and ZnO:Ti, respectively. Different defect levels are generated in dependence on the Co content in ZnO:Co. The undoped ZnO reference sample reveals the well-known E1, E3 and Eα1 [1] defect level. This work shows that an optimization of defect-related ferromagnetism in n-conducting ZnO:TM thin films will only be possible if the preparation sensitive formation of deep defects is controlled in the same time.
[1] F. D. Auret et al., Appl. Phys. Lett. 80 (2002) 1340 and F. D. Auret et al., phys. stat. sol. (c) 1 (2004) 674.

HL 14.6 Tue 12:15 POT 151

Resonantly and Non-Resonantly Excited Bound Excitons in ZnO Epilayers — •Frank Bertram, Sören Giemsch, Jürgen Christen, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

The photoluminescence (PL) spectrum of ZnO exhibits a rich excitonic structure in the near bandgap region at 4K. A 8 μm thick ZnO epi-layer MOVPE grown on a GaN / sapphire template was investigated. The non-resonant PL spectrum is dominated by the impurity bound exciton I_8 and exhibits further individual BE lines (I_1, I_2, I_6, I_9), the TES-lines of I_8 and I_9 as well as the LO phonon replica exclusively from I_8. Under resonant excitation, i.e. $E_{excitation}= E(I_8)$ the TES-$I8$ line and the I_8-LO line are much more intense and reveal a smaller line width. Under excitation at the spectral position of I_9 the optical features associated with I_8 completely disappear, while TES-I_9 increases and I_9-LO shows up. Resonantly excited time-resolved PL yields a mono-exponential decay with lifetimes $\tau(I_8)$=270 ps and $\tau(I_9)$=280ps, respectively, - distinctively different from the lifetimes obtained for non-resonant excitation. Measuring the decay lifetime as a function of tuned laser photon energy, both, I_8 and I_9 reveals a clear resonance, i.e. drop in time constant (< 200 ps), for E_{laser}-E_{BE}=5 meV. This corresponds to the A-B-valence band splitting and indicates strong scattering into the B-valence band.

HL 14.7 Tue 12:30 POT 151

Mid-infrared photocurrent spectroscopy of thin ZnO films — •H. Frenzel, A. Weber, H. v. Wenckstern, G. Biehne, H. Hochmuth, M. Lorenz, and M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We investigate mid-infrared photocurrent properties of thin ZnO films in a temperature range from 4 K to 300 K. The films were grown by pulsed laser deposition on *a*-plane sapphire substrates with substrate temperatures varying from 550°C to 800°C and oxygen partial pressures between 10^{-3} to 0.1 mbar [1]. High-quality Pd/ZnO Schottky diodes were realized by thermal evaporation of Pd on the Zn-face of the *c*-oriented thin films. The ideality factors of the diodes were characterized with Current–Voltage (I–U) measurements.

The optical absorption by shallow impurity traps in the ZnO space charge region of the diodes is studied with Fourier transform infrared photocurrent spectroscopy. The results are compared to non-optical techniques like deep level transient spectroscopy [2].

[1] E. M. Kaidashev, et al., Appl. Phys. Lett. **82**, 3901 (2003).
[2] M. Grundmann, et al.: in *Zinc Oxide – A Material for Micro- and Optoelectronic Applications* (eds.: N. H. Nickel and E. Terukov), 47–57, Springer (2005).

HL 14.8 Tue 12:45 POT 151

ZnO nanorods as laser emitters — •Robert Hauschild[1], Holger Lange[1], Alexander Urban[1], Hongjin Fan[2], Margit Zacharias[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Universität Karlsruhe, Karlsruhe, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

By means of time resolved spectroscopy and numerical calculations we evaluate different ZnO nanorods samples with respect to their suitability as stimulated emitters. The influence of diameter and length on the field enhancement inside the nanorods is studied numerically by solving the scalar Helmholtz equation in 3D. According to our simulations the interface nanorod/substrate is mainly responsible for the low Q value of the nanorod resonators. In one sample a variation in VLS growth results in gold nanoparticles being present at the bottom of nanorods. This layer enhances the resonator properties of the nanorods due to the larger reflectivity. The better mode confinement in these nanorods is also confirmed by the finite element analysis. Consequently, laser emission from single rods of this sample is evidenced up to 150 K.

HL 14.9 Tue 13:00 POT 151

Thickness dependent magnetoresistance of ZnCoO:Al thin films — •Qingyu Xu, Lars Hartmann, Heidemarie Schmidt, Holger Hochmuth, Michael Lorenz, Rüdiger Schmidt-Grund, Daniel Spemann, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

$Zn_{0.90}Co_{0.10}O$ films doped with 0.5 at% Al of different thickness (689 nm, 408 nm, 355 nm) were prepared by pulsed laser deposition (PLD) on a-plane sapphire substrates. The room temperature electron concentration and mobility increase from 2×10^{18}cm^{-3} and 12 cm^{2}V^{-1}s^{-1} to 2×10^{19}cm^{-3} and 36 cm^{2}V^{-1}s^{-1} with increasing film thickness, respectively. Magnetoresistance (MR) effects were measured in the temperature range from 5 K to 290 K. At low temperature, the positive MR increases with decreasing film thickness. With increasing temperature, the MR of the thicker film will change to negative, while positive MR was still observed for the 355 nm thick film at room temperature. Anomalous Hall effect (AHE) provides information about the Co-generated internal field experienced by itinerant carriers. AHE was observed in the 355 nm thick film at 20 K, indicating possible intrinsic ferromagnetism in $Zn_{0.90}Co_{0.10}O$. The observed thickness dependence of the MR suggests that structural defects may play an important role in the ferromagnetism of ZnCoO:Al thin films.

HL 15 III-V semiconductors II

Time: Tuesday 11:00–13:15 Room: POT 51

HL 15.1 Tue 11:00 POT 51

Incorporation of N at GaAs and InAs Surfaces — •Hazem Abu-Farsakh[1,2], Alexey Dick [1], 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

Recently, GaAsN and GaInNAs alloys with low N content have attracted a remarkable interest for making laser diodes operating in the 1.3-1.6 μm region which is interesting for optical fiber communications. A specific problem for practical applications is the extremely low bulk equilibrium solubility of N in GaAs at typical growth temperatures. An interesting option to increase the concentration of N is the use of surface kinetics by (i) identifying GaAs and InAs surfaces with a large N solubility, and (ii) identifying conditions which prevent/reduce surface aggregation of N. We have therefore calculated the surface phase diagrams of N at GaAs and InAs surfaces using density functional theory in the GGA approximation. Based on these results, we have estimated the maximum N equilibrium concentration at various surface orientations ((110), (001)) for given temperature and chemical potentials, and compared them with recent experimental results. In addition, STM simulation of selected structures have been made and compared with available experimental images.

HL 15.2 Tue 11:15 POT 51

Combining quasiparticle energy calculations with exact-exchange density-functional theory: the bandgap of InN — •Patrick Rinke[1], Abdallah Qteish[2], Jörg Neugebauer[1,3], and Matthias Scheffler[1] — [1]Fritz-Haber-Institut der MPG, Berlin — [2]Department of Physics, Yarmouk University, Irbid - Jordan — [3]MPI für Eisenforschung, Düsseldorf

Amongst the group-III-nitrides InN assumes a special place because the magnitude of its bandgap is still controversial. If one believes density-functional theory (DFT) calculations in the local-density approximation (LDA) or LDA based quasiparticle energy calculations in the G_0W_0 approximation InN should be metallic. Recent experiments [1,2], however, place the band gap between 0.7 and 1.0 eV, significantly lower than previously thought. For GaN and II-VI compounds we have shown that DFT in the exact-exchange (EXX) approach gives an improved description of the *d*-electron hybridization compared to the LDA. In combination with G_0W_0 calculations we achieve very good agreement with experiment for the band gaps of these compounds [3]. For InN the EXX calculations yield a semiconductor with a band gap of 0.8 eV in the zincblend phase [4] and 1.0 eV for wurtzite. In contrast to GaN the G_0W_0 corrections are negative and lower the band gap to 0.5 eV and 0.7 eV, respectively - in very good agreement with the new experimental data.

[1] J. Wu *et al.*, Appl. Phys. Lett. **80**, 3967 (2002)
[2] T. Takachi *et al.*, Appl. Phys. Lett. **81**, 1246 (2002)
[3] P. Rinke *et al.*, New J. Phys. **7**, 126 (2005)
[4] A. Qteish *et al.*, Phys. Rev. B **72**, 155317 (2005)

HL 15.3 Tue 11:30 POT 51

RARE-EARTH DOPANT IMPLANTATION INTO GAN AND ZNO — •R. Nédélec[1], R. Vianden[1], and ISOLDE Collaboration[2] — [1]HISKP, Nußallee 14-16, D-53115 Bonn, Germany — [2]CERN, CH-1211 Genève, Switzerland

In the past, wide band-gap semiconductors for optical, high-power and high-temperature application have been intensively investigated. The observation of room temperature luminescence for various Rare Earth dopants in GaN has stimulated further interest in the incorporation these impurities in appropriate host lattices. A convenient way of introducing impurities into semiconductors is ion implantation. In order to study the implantation induced damage and its recovery by annealing we used the perturbed angular correlation technique (PAC). Our samples were implanted at the ISOLDE facility at CERN and then treated in a rapid thermal annealing furnace.

We have studied the annealing behaviour and the temperature dependence of the electric field gradient (EFG) using the Rare Earth PAC probe 172-Lu. The temperature dependence was investigated for temperatures below and above room temperature. The results will be discussed and compared to results obtained with the PAC probe 181-Hf.

HL 15.4 Tue 11:45 POT 51

Evolution of N Defect States and Optical Transitions in Ordered and Disordered $GaP_{1-x}N_x$ Alloys — •Eoin OReilly, Clive Harris, and Andrew Lindsay — Tyndall National Institute, Lee Maltings, Cork, Ireland

We show using an sp^3s^* tight-binding model that the band anti-crossing (BAC) model describes well the evolution of the lowest N-related conduction states in ordered $GaP_{1-x}N_x$ alloys, including the evolution of the Γ character with increasing x. We obtain a good description of the lowest conduction states in disordered GaPN structures by explicitly treating the interaction between the GaP host Γ conduction band minimum and defect states associated with a random distribution of N atoms. We find a very similar value for the total Γ character mixed into the N levels in the ordered and disordered cases but a wider distribution of states with Γ character in the disordered case. We show that in the very dilute limit ($< 0.1\%$) inhomogeneous broadening of the N state energies prevents the band-gap reduction predicted by the BAC model, while the band-gap reduction at higher composition is determined by the increasing formation of N cluster states. Overall key features of the band structure can be well described using a modified BAC model which explicitly includes the broad distribution of N levels in disordered GaPN alloys.

HL 15.5 Tue 12:00 POT 51

Magneto-excitons in GaInNAs / GaAs quantum well structures — •M. Hetterich, A. Grau, W. Löffler, and H. Kalt — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

In recent years, GaInNAs-based quantum wells have attracted considerable interest due to their possible utilization in near-infrared optoelectronic devices. From a band structure point of view, Ga(In)NAs is quite unusual, because the interaction of N-related states with the conduction band leads to a strong non-parabolicity of the latter, which can be described within the so-called band anti-crossing (BAC) model.

In this contribution we investigate the influence of a magnetic field (up to $B = 14$ T) on the excitonic states in GaInNAs / GaAs quantum wells with various compositions and well widths. Magneto-photoluminescence has been used to measure the diamagnetic shift of the exciton ground state. In addition, absorption measurements have been carried out to investigate the field dependence of excited magneto-exciton states. The theoretical approach we use to fit our data is based on the BAC model for the conduction band and a 4-band Luttinger Hamiltonian for the valence bands. The coupling between the valence and conduction bands is taken into account perturbatively using a semi-empirical approach. The in-plane part of the exciton wavefunction is expanded in a Gaussian basis set and the resulting generalized eigenvalue problem is solved numerically on a parallel computer. From a comparison between theory and experiment we can extract data for the exciton binding energy as well as the conduction band dispersion in GaInNAs / GaAs quantum wells.

HL 15.6 Tue 12:15 POT 51

The influence of defects on the recomination dynamics in InGaN quantum wells grown on sapphire and GaN substrates — •T. Stempel Pereira[1], M. Dworzak[1], A Hoffmann[1], G. Franssen[2], T. Suski[2], S. Grzanka[2], R. Czernecki[2], M. Leszczynski[2], and I. Grzegory[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut of High Pressure Physics 'Unipress', Polish Academy of Sciences, Sokołowska 29/37, 01-142 Warsaw, Poland

We studied the influence of localization and defects on the recombination in single InGaN quantum wells on sapphire- and GaN-substrates, respectively. Time-integrated and time-resolved PL measurements were performed. Temperature dependent radiative and non-radiative lifetimes and the depth of the localization potentials could be determined. It appears on both substrates, that due to the high density of defects, localization is a crucial condition for radiative recombination. When carriers leave their localization potential due to thermal activation, they recombine non-radiatively at defects.

Intensity dependent time-resolved PL measurements cast new light on the significance of defects. At 10 K we observe an increasing influence of non-radiative recombination via defects with growing excitation intensity due to the filling of the localized states. However, at room temperature the decay decelerates with increasing excitation intensity. This decreasing significance of the defects can be explained with a saturation of defect states.

HL 15.7 Tue 12:30 POT 51

Electronic Transport Studies of Single InAs Nanowhiskers — •Quoc Thai Do — University Duisburg-Essen, Solid-State Electronics Dept., Lotharstr. 55 / ZHO, D-47057 Duisburg

InAs nanowhiskers were grown in the vapour-liquid-solid growth mode using low-pressure metal-organic vapor phase epitaxy. Electrical characterization of single nanowhiskers was done by conductive scanning force microscopy directly of the wafer. Contacting the whiskers scratched from the wafer and deposited on an insulator-covered conductive substrate using e-beam lithography allowed to realize the field-effect transistor consisting of single nanowhisker only. We observed the n-type conductivity of the nominally undoped whisker material. The nanowhisker-based transistors showed with well-defined linear regimes and pronounced switching behaviour at room temperature. Using the data of I-Vg measurements on the nanowhiskers with different n-doping concentration, the electron density and the electron mobility within investigated nanowhiskers could be estimated. Mechanism of electron transport through the nanowhisker in dependence on the nanowhisker dimensions are discussed. Our work demonstrate the feasibility of nanoelectronic and nanosensor applications for III-V nanowhiskers.

Quoc Thai Do, Ingo Regolin, Victor Khorenko, Werner Prost, Franz Josef Tegude University Duisburg-Essen, Duisburg, Germany Solid-State Electronics Department, Lotharstr. 55 / ZHO, D-47057 Duisburg

HL 15.8 Tue 12:45 POT 51

Segregation of Antimony in InP in MOVPE — •Martin Leyer[1], S. Weeke[1], M. Pristovsek[1], and Prof. Dr. W. Richter[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Università di Roma "Tor Vergata", Dipartimento di Fisica, Via della Ricerca Scientifica 1, I-00133 Roma, Italy

The optimization of $GaAs_{0.5}Sb_{0.5}$/InP interfaces in semiconductor devices is a critical point since antimony segregation is a well known phenomenon. We investigated this segregation in MOVPE in-situ with Reflectance Anisotropy Spectroscopy. InP layers were exposed to different amounts of TMSb and afterwards overgrown with InP. An unexpected second antimony containing layer developed in a distance between 50 – 200nm. This double layer structure was confirmed by SIMS and X-Ray diffraction measurements. We systematically studied the position of the second Sb layer as a function of temperature, precursor partial pressure and amount of antimony on the semiconductor surface. The existence of a second Sb layer could be explained by a quasi liquid surface phase above InSb melting point of 527^oC.

HL 15.9 Tue 13:00 POT 51

Spectroscopic investigations of GaAsSb/GaAs based structures for 1.3 μm VCSELs — •G. Blume[1], T.J.C. Hosea[1], S.J. Sweeney[1], P.J. Klar[2], G. Weiser[2], A. Thränhardt[2], S.W. Koch[2], S.R. Johnson[3], and Y.-H. Zhang[3] — [1]ATI, University of Surrey, Guildford, UK — [2]Dept. Physics and WZMW, Philipps-University Marburg, Germany — [3]MBE research group, Arizona State University, Tempe, USA

Metro-area communication (fibre to the home) requires lasers emitting at 1.3 μm due to the zero dispersion and low loss of silica fibres at this wavelength. Vertical-cavity surface-emitting lasers (VCSELs) grown on GaAs offer the best performance and temperature stability at low cost. Amongst the different approaches to realise a GaAs based VCSEL, the GaAsSb/GaAs material system shows great potential and VCSEL operation at 1.3 μm has recently been demonstrated. The band alignment (type I or II) of the GaAsSb/GaAs interface is still a matter of discussion and of significant importance for the further development of devices. We employ electro-absorption spectroscopy on GaAsSb/GaAs structures. The spectra obtained are compared with those calculated for different offset situations using a sophisticated microscopic model accounting for Coulomb effects. The comparison indicates that our GaAsSb/GaAs quantum wells have an almost flat alignment of the conduction band.

HL 16 Semiconductor laser I

Time: Tuesday 11:00–13:15 Room: BEY 154

HL 16.1 Tue 11:00 BEY 154

Spatio-Temporal Emission Dynamics of VCSELs with a Surface Grating — •Christian Fuchs[1], Tobias Gensty[1], Joachim Kaiser[1], Johannes Michael Ostermann[2,3], Pierluigi Debernardi[3], and Wolfgang Elsässer[1] — [1]Institut für Angewandte Physik, Schloßgartenstr. 7, 64289 Darmstadt, Germany — [2]Optoelectronics Department, University of Ulm, Albert-Einstein-Allee 45, 89069 Ulm, Germany — [3]IEIIT-CNR c/o Politecnico di Torino, 10129 Torino, Italy

VCSELs are a low-cost lightsource for optical datacom applications. Because of the modal dispersion in fibers, not only spectrally single-mode, but in addition polarisation stable emission with high Orthogonal Polarisation Suppression Ratio (OPSR) at high output power is desired. We present 2D-spatially, spectrally and polarisation resolved picosecond measurements of the nearfield emission dynamics of small diameter oxide-confined VCSELs with an integrated surface grating based on a relief technique to enhance the selection of one polarisation mode [1]. The characterisation of the repetitive part of the dynamics within the turn-on process is realized with Temporally Resolved Imaging by Differential Analysis (TRIDA) providing a time resolution down to 10 ps. In addition single-shot measurements are performed to analyse the non-repetitive part of the emission dynamics. The influence of the grating parameters on the polarisation behaviour is discussed in comparison to numerical simulations.

[1] J.M. Ostermann, P. Debernardi, C. Jalics, A. Kroner, M.C. Riedl, R. Michalzik, Opt. Commun. 246, 511 (2005)

HL 16.2 Tue 11:15 BEY 154

Gain and threshold current in quantum-wire intersubband laser structures — •Thomas Herrle, Stephan Haneder, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik Universität Regensburg, 93040 Regensburg

In recent years quantum cascade structures with quantum-wire and quantum-dot active regions are more and more investigated. The reason for this is the theoretical prediction of a decrease of non-radiative losses in lower dimensional systems. This is experimentally confirmed by the superior performance of quantum cascade lasers in an applied magnetic field, where the lower dimensionality of the electron system is achieved by the Landau quantization [1]. In the presented work we calculate the gain and the threshold current for a quantum-wire intersubband laser structure proposed in [2], which is fabricated by the cleaved edge overgrowth technique. We report on the influence of the formation of excited states in these structures on the gain and threshold current. It turns out that these excited states have to be avoided in the sample design of such structures to end up with higher gain values in the quantum-wire structures compared to conventional quantum-well systems.

[1] C. Becker, C. Sirtori, O. Drachenko, V. Rylkov, D. Smirnov, J. Leotin, Appl. Phys. Lett. **81**, 2941 (2002).
[2] Ingo Keck, Stefan Schmult, Werner Wegscheider, Martin Rother, Andreas P. Mayer, Phys. Rev. B **67**, 125312 (2003).

HL 16.3 Tue 11:30 BEY 154

Solutions towards high temperature AlGaInP-VCSEL — •Marcus Eichfelder[1,2], Robert Rossbach[1,2], Heinz Schweizer[1], Michael Jetter[1,2], and Peter Michler[2] — [1]4th Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]5th Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

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). This material system seems to fail the requirements of e.g. automotive applications (+125°C) due to the poor electron confinement and therefore they show high temperature sensitivity. We investigated the internal heating of our VCSELs by using a cylindrical heat dissipation model [1]. Out of these data we found a strong dependence of the aperture and mesa diameter and their ratio on the temperature behaviour. With this knowledge we designed new devices with an additional heat spreading layer for further heat removal. First results will be presented.

[1] W. Nakwaski, M. Osinski. Thermal resistance of top-surface-emitting vertical-cavity semiconductor lasers and monolithic two-dimensional arrays, Electron. Lett., 28, p. 572, 1992.

HL 16.4 Tue 11:45 BEY 154

Temperature and Band gap Dependence of Carrier Recombination Processes in GaAsSb/GaAs Quantum Well Lasers — •Konstanze Hild[1], Igor Marko[1], Shirong Jin[1], Stephen Sweeney[1], Jiang-Bo Wang[2], Shane Johnson[2], and Yong-Hang Zhang[2] — [1]Advanced Technology Institute, University of Surrey, Guildford, GU2 7XH, Surrey, United Kingdom — [2]MBE Optoelectronics group, Arizona State University, Tempe, USA

GaAs-based vertical cavity surface emitting lasers (VCSELs) emitting at 1.31 μm are of considerable importance for the development of fibre-to-the home communication systems. GaAs is the preferred substrate for VCSELs due to the strong index contrast achievable with AlGaAs Distributed Bragg Reflector (DBR) mirrors. One possible and compatible active region is GaAsSb/GaAs QWs. Lasers based upon this material have been successfully produced but remarkably little research has been undertaken to assess the carrier recombination processes occurring in this material and their temperature variation. In this study we used low temperature and high pressure techniques (to vary the band gap) to investigate edge-emitting lasers processed from wafers grown by Solid Source MBE. We find that at room temperature the device behaviour is dominated by non-radiative recombination accounting for approximately 90% of the total threshold current density. Furthermore, our pressure dependence measurements suggest that this may be attributed to thermalisation of electrons into the GaAs barriers.

HL 16.5 Tue 12:00 BEY 154

Polarization and emission direction dependend measurements on CEO Quantum Wire Cascade Emitter Devices — •Stephan Haneder, Thomas Herrle, Christian Gerl, Dieter Schuh, and Werner Wegscheider — Institut für Experimentielle und Angewandte Physik Universität Regensburg, 93040 Regensburg

We developed a quantum wire cascade device emitting in the Mid-Infrared spectral range by using the Cleaved Edge Overgrowth (CEO) technique [1]. Basic theoretical considerations predict a decrease of non-radiative losses in lower dimensional systems [2]. To investigate the origin of the emitted light and to analyse the electronic intersubband transitions between quantum wire states, polarization and emission direction depend measurements have been carried out. It turns out that the emitted light is TM polarized, but not TE polarized. This can be attributed to the weak confinement in the [110] direction. Temperature dependend measurements show a redshift of the intersubband transition with increasing temperature and a limitation of the performance to about 130 K. We have also performed measurements on quantum wire cascade structures equipped with a T-shaped waveguide [3].

[1] S.Schmult, I.Keck, T.Herrle, W.Wegscheider, M.Bichler, D.Schuh and G.Abstreiter, Appl. Phys. Lett. 83, 1909 (2003). [2] I.Keck, S.Schmult, W.Wegscheider, M.Rother and A.P.Mayer, Phys. Rev. B67, 125212 (2003). [3] T.Herrle, S.Schmult, M.Piendl, U.T.Schwarz and W.Wegscheider, Phys. Rev. B72, 035316 (2005).

HL 16.6 Tue 12:15 BEY 154

Low divergence single-mode edge emitting 650 nm lasers based on longitudinal photonic bandgap crystal — •Kristijan Posilovic[1], Thorsten Kettler[1], Leonid Ya. Karachinsky[2], Vitaly A. Shchukin[1,3], Vladimir P. Kalosha[4], Udo W. Pohl[1], Nikolai N. Ledentsov[1,3], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Ioffe Physico-Technical Institute, St.Petersburg — [3]NL Nanosemiconductor GmbH, Dortmund — [4]Department of Physics, University of Ottawa

Conventional edge-emitting lasers suffer from large vertical beam divergence due to a narrow modal spot size of the optical mode, and therefore are seriously limiting practical applications. We present a novel approach to achieve large optical spot size and low divergence. The waveguide is broadened and a one-dimensional photonic bandgap crystal is used to filter higher order modes. The structure was realised in the GaInP-AlGaInP material system grown on GaAs-substrates and processed into narrow ridge waveguide lasers using standard techniques. The devices show fundamental mode emission over a wide range of injection currents proved by near field as well as far field measurements. The lasing

wavelength remained stable at 650 nm over all injection currents. The measured vertical beam divergence is below 10° for all stripe widths investigated. A 4 micron stripe shows lateral beam divergence of 8°, resulting in a circular shaped far field emission.

HL 16.7 Tue 12:30 BEY 154

Diode lasers for Terahertz applications — •Carsten Brenner, Stefan Hoffmann, and Martin Hofmann — AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, IC2/152, D-44780 Bochum

In recent years the research in Terahertz (THz) radiation has caused a great demand in new industrial applications. Despite this development there is no system for the generation and detection of THz radiation which is able to satisfy the necessary requirements for industrial use, as low cost and sufficient THz emission power. Our approach to close this gap is based on nonlinear processes in semiconductor lasers. We operate a semiconductor laser on two colours in an external cavity and the difference frequency in the THz regime is generated in the cavity itself [1,2]. The necessary steps to increase the THz output power to facilitate imaging applications are presented. Furthermore we discuss a new concept to detect THz radiation at room temperature involving semiconductor lasers.

[1]S. Hoffmann, M. Hofmann, E. Bründermann, M. Havenith, M. Matus, J.V. Moloney, A.S. Moskalenko, M. Kira, S.W. Koch, S. Saito and K. Sakai, Four-wave mixing and direct terahertz emission with two-color semiconductor lasers, Appl. Phys. Lett. 84, 3585 (2004)

[2]S. Hoffmann, M. Hofmann, M. Kira, ans S.W. Koch, Two-color diode lasers for generation of THz radiation, Semiconductor Science and Technology 20, 205 (2005)

HL 16.8 Tue 12:45 BEY 154

Theory of Nonlinear Optics in Quantum Cascade Lasers — •Carsten Weber, Fouad Banit, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate nonlinear optical effects, such as Rabi flopping and pump-probe signals, in quantum cascade lasers as model systems to study multisubband semiconductor heterostructures. Nonequilibrium states are formed as an interplay of the optical excitation and different scattering processes. Here, we consider the electron-phonon interaction as well as scattering at ionized doping centers, where the influence of the resonant excitation between two subbands on further subbands can be studied.

HL 16.9 Tue 13:00 BEY 154

Fabrication and characterization of mid-infrared GaAs/$Al_{0.45}Ga_{0.55}$As quantum cascade lasers — •Jan Heinrich[1], Sven Höfling[1], Jochen Seufert[2], Johannes Koeth[2], Johann Peter Reithmaier[1], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]nanoplus Nanosystems and Technologies GmbH, Oberer Kirschberg 4, 97218 Gerbrunn, Germany

Quantum cascade lasers (QCLs) emitting in the mid-infrared (MIR) have made an enormous improvement during the last 10 years. For the fabrication of the devices, we use the GaAs/Al_xGa_{1-x}As material system which has the advantage of nearly perfect lattice-matched layers irrespective of the aluminium content. Moreover, the processing of GaAs/Al_xGa_{1-x}As is easier to handle than for InP based samples. For MIR QCLs, an aluminium content of 45 percent has turned out to be the optimal value for samples operating at high temperatures. Special attention has to be turned on the waveguide and the doping which are essential for efficient devices. In this work we fabricated and investigated QCL designs with 45 percent aluminum content. Particularly the influence of different growth parameters was analyzed. We achieved optimized characteristics with regard to threshold current and output power of the devices by variation of growth parameters and report room temperature operation up to 360 K in pulsed mode. Furthermore, we investigated in particular the dependence of threshold current on injector doping and temperature.

HL 17 Invited Talk Geim

Time: Tuesday 14:30–15:15 Room: HSZ 01

Invited Talk

HL 17.1 Tue 14:30 HSZ 01

QED in a Pencil Trace — •Andre Geim and Kostya Novoselov — University of Manchester, UK

Dimensionality is one of the most defining materials parameters such that the same chemical compound can exhibit dramatically different properties, depending on whether it is arranged in a 0, 1, 2 or 3 dimensional structure. While quasi-0D, quasi-1D and, of course, 3D atomic crystals have been well recorded and investigated, dimensionality 2 was conspicuously absent among experimentally known crystals. I will describe free-standing atomic crystals that are strictly 2D and can be viewed as individual planes pulled out of bulk crystals or, alternatively, as unrolled single-wall nanotubes. After discussing the preparation and characterization of such crystals, this talk will concentrate on electronic properties of graphene that is the most 'clean' of the 2D crystals obtained so far. Our experiments show that electron transport in graphene is essentially governed by the relativistic Dirac equation rather than the (non-relativistic) Schrödinger equation and its charge carriers mimic particles with zero rest mass and an effective speed of light. We have found a variety of unusual phenomena characteristic of two-dimensional Dirac fermions. In particular, we have observed that a) the quantum Hall effect in graphene is anomalous in that it occurs at half-integer filling factors; b) graphene's conductivity never falls below a minimum value corresponding to the conductance quantum, even when carrier concentrations tend to zero; c) the cyclotron mass of massless carriers in graphene is described by Einstein's equation E =mc2; and d) Shubnikov-de Haas oscillations in graphene exhibit a phase shift of pi due to Berry's phase.

HL 18 Symposium Quantum optics in semiconductors II

Time: Tuesday 15:15–17:15 Room: HSZ 01

Keynote Talk

HL 18.1 Tue 15:15 HSZ 01

Light Matter Interaction Effects in Quantum Dot Microcavities — •S. Reitzenstein[1], C. Hofmann[1], A. Löffler[1], J. P. Reithmaier[1], M. Kamp[1], A. Forchel[1], G. Sek[2], V. D. Kulakovskii[3], A. Bazhenov[3], A. Gorbunov[3], L. V. Keldysh[4], and T. L. Reinecke[5] — [1]Technische Physik, Universität Würzburg, Am Hubland, D 97074 Würzburg,Germany — [2]University of Technology, Wroclaw, Poland — [3]Institute for Solid State Physics, Rus. Acad. of Science, Chernogolovka, Russia — [4]Lebedev Institute, Rus. Acad. Of Science, Moscow, Russia — [5]Naval Research Laboratory, Washington DC , USA

Using high quality factor microcavities with quantum dots and long photon lifetimes the weak and strong interaction regimes between single quantum dot excitons and electric fields given by single photons are investigated by photoluminescence spectroscopy. The cavities are based on undoped GaAs/AlAs VCSEL structures with embedded InGaAs quantum dots from which micropillars with diameters between 1.0 μm and 4 μm are realized by reactive etching. The cavity photon lifetimes range from about 2 to close to 20 ps. In the weak coupling regime we observe e.g. an enhancement of the exciton and biexciton emission probability due to the Purcell effect. By using dots with large dipole moment we observe clear anticrossing effects due to strong interaction characterized by a vacuum Rabi splitting of up to 140 μeV.

Keynote Talk

HL 18.2 Tue 15:45 HSZ 01

CQED with II-VI nanocrystals — •Ulrike Woggon[1], Nicolas LeThomas[1], Oliver Schoeps[1], and Mikhail Artemyev[2] — [1]FB Physik, University Dortmund, Otto-Hahn-Str. 4, 44227 Dortmund — [2]Minsk State University, Minsk, Belarussia

Cavity QED concepts stimulated a tremendous technological development towards solid-state based, compact, and scalable cavity QED systems. In this contribution we report on a strongly coupled cavity QED system consisting of a CdSe nanocrystal coupled to a single photon mode of a polymer microsphere. The strong exciton-photon coupling is manifested by the observation of a cavity mode splitting of $\hbar\omega \approx 37\mu$eV and photon lifetime measurements of the coupled exciton-photon state. The single photon mode is isolated by lifting the mode degeneracy in a slightly deformed microsphere and addressing it by high-resolution imaging spectroscopy. This cavity mode is coupled to a localized exciton of an anisotropically shaped CdSe nanocrystal on the microsphere surface that emits highly polarized light in resonance to the mode. With colloidal CdSe NRs we add a new material class for which solid-state based cavity QED was implemented.

Keynote Talk

HL 18.3 Tue 16:00 HSZ 01

Deutsch-Jozsa Algorithm using Triggered Single Photons from a Single Quantum Dot — •Oliver Benson[1], Matthias Scholz[1], Thomas Aichele[2], and Sven Ramelow[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Hausvogteiplatz 5-7, 10117 Berlin, Germany — [2]CEA/Université J. Fourier, Laboratoire Spectrométrie, Grenoble, France

Recently, wide attention has been drawn to the implementation of quantum algorithms by solely using linear optics. Previous experimental demonstrations along this line focused on coherent photon states from attenuated laser pulses [1] or spontaneous parametric down-conversion [2] in order to simulate simple quantum algorithms or to demonstrate concepts of noise resistant quantum computation [3]. We realize the on-demand operation of the two-qubit Deutsch-Jozsa algorithm using a triggered single-photon source. Our experimental setup resembles a classical Mach-Zehnder interferometer that is combined with a single-photon source realized by an exciton transition in a single quantum dot [4]. A variation of our experimental setup enables us to implement ideas of the concept of decoherence-free subspaces [5] in a triggered quantum algorithm on the single-photon level.

[1] S. Takeuchi, Phys. Rev. A 62, 032301 (2000)
[2] M. Bourennane et al., Phys. Rev. Lett. 92, 107901 (2004)
[3] M. Mohseni et al., Phys. Rev. Lett. 91, 187903 (2003)
[4] V. Zwiller et al., Appl. Phys. Lett. 82, 1509 (2003)
[5] P. Zanardi and M. Rasetti, Phys. Rev. Lett. 79, 3306 (1997)

Keynote Talk

HL 18.4 Tue 16:30 HSZ 01

Imaging the Local Density of Photonic States in Photonic Crystal Nanocavities — •Michael Kaniber, Felix Hofbauer, Simon Grimminger, Max Bichler, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching

We present investigations of the coupling of InGaAs quantum dots (QDs) to both extended and strongly localised optical modes in 2D photonic crystal (PC) nanostructures. The samples consist of a 180nm thick GaAs membrane into which a PC is formed by etching a triangular lattice of air holes. By measuring the local QD spontaneous emission rate (R_{spon}) we "image"the photonic DOS at frequencies throughout the photonic bandgap (PBG) and close to localised modes at single missing hole defects (Q$\sim$10000, $V_{mode} < 0.5(\lambda/n)^3$). For QDs emitting into the PBG but detuned from the cavity mode, we observe a strong suppression of R_{spon} compared to its value in a homogenous photonic environment (R_0/R_{spon}=30±6) due to the reduced photon DOS. In contrast, for QDs coupled to the cavity modes we measure $1/R_{spon} \sim$ 50ps, corresponding to a large Purcell enhancement (R_{cavity}/R_0=18x).
Single dot measurements reveal clear photon anti-bunching when the emission frequency is detuned from the cavity mode and enhanced photon extraction efficiency ($\sim$30%) due to the PBG which suppresses inplane emission. Most surprisingly, anti-bunching is not observed for QDs coupled to the cavity modes possibly due to the onset of low threshold lasing.

Supported financially via Sonderforschungsbereich-631

Keynote Talk

HL 18.5 Tue 16:45 HSZ 01

Theory of optical properties for quantum dots in microcavities — •Frank Jahnke, Jan Wiersig, Norman Baer, and Christopher Gies — Institute for Theoretical Physics, University of Bremen

Semiconductor quantum dots are of strong current interest due to their application potential in light-emitting devices and single photon sources. The emission properties can be controlled to a high degree by embedding the quantum dots in a semiconductor microcavity. We present a microscopic theory for this system. In addition to carrier-photon interaction, also carrier-carrier and carrier-phonon interaction are included, which are the sources of scattering and dephasing processes. We investigate the photoluminescence dynamics for weak excitation and the laser regime for elevated pumping. The influence of the Purcell effect and of large spontaneous emission coupling on the optical properties is demonstrated. Signatures of carrier and photon correlations due to various interaction processes are analyzed.

HL 19 Quantum dots and wires: Optical properties II

Time: Tuesday 17:15–19:30 Room: HSZ 01

HL 19.1 Tue 17:15 HSZ 01

Influence of doping on the electronic and optical properties of Si nanocrystallites — •Luis Ramos[1], Elena Degoli[2], Stefano Ossicini[2], Jürgen Furthmüller[1], and Friedhelm Bechstedt[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena, Germany — [2]Università di Modena e Reggio Emilia, via Fogliani, I-42100 Reggio Emilia, Italy

Silicon nanocrystallites (NCs) have been intensively studied in the last years, since they can confine holes and electrons and circumvent the indirect-gap character of the lowest-energy optical transitions of Si bulk. Besides quantum confinement, oxidation, oxygen-related defects,[1] and doping have been investigated. Recently, an increase of the photo luminescence (PL) intensity was observed for Si NCs doped with both group-III and group-V species. Since measurements for single NCs are difficult, *ab initio* theoretical investigations become important to suggest dopants and to clarify the mechanisms of PL in Si NCs. Our calculations are based on the density-functional theory, the generalized-gradient approximation, the projector-augmented wave method, and the pseudopotential approximation. The electronic structure and optical absorption spectra of free-standing doped Si NCs of different sizes and shapes are investigated in simple-cubic supercells. Besides the influence of shape and size on the impurity formation energies, bond lengths, and radiative lifetimes, significant changes in the optical absorption spectra are predicted for Si NCs doped with group-V impurities.

[1] L.E. Ramos, J. Furthmüller, and F. Bechstedt, Appl. Phys. Lett. **87**, 143113 (2005); Phys. Rev. B **71**, 035328 (2005)

HL 19.2 Tue 17:30 HSZ 01

Temperature dependent fluorescence quantum efficiency of cascaded energy transfer nanocrystal structures — •S. Rohrmoser, T. Franzl, T.A. Klar, A.L. Rogach, and J. Feldmann — Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität München

We present temperature dependent fluorescence studies of cascaded energy transfer (CET) structures made of CdTe nanocrystals. Funnel like band gap profiles are realized by applying layer-by-layer assembly to CdTe nanocrystals of distinct sizes. For high-energetic excitation, the CET structure comprising only one layer of red-emitting nanocrystals emits 4 times more red light than a reference sample of equal absorbance consisting of only red emitting nanocrystals, hence increasing the final excitation density by a factor of 28. To investigate the underlying process in more detail, temperature dependent and time resolved measurements have been performed. The results reveal an activation barrier involved in the energy transfer process and help to understand the long-lived feeding of the central layer.

1. T. Franzl, T.A.Klar, S. Schietinger, A.L. Rogach, J. Feldmann, "Exciton recycling in graded gap nanocrystal structures" Nano Letters, 4, 1599 (2004)

HL 19.3 Tue 17:45 HSZ 01

Structural investigations of MBE-grown InN Nano-Whiskers — •Ratan Debnath[1], Toma Stoica[1,2], Ralph Meijers[1], Thomas Richter[1], Raffaella Calarco[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich,52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest, Romania

Nanowires are intensively studied for future device applications of low-dimensional systems. GaN nanowhiskers were investigated in great detail showing for instance high crystalline quality and efficient luminescence. Investigations of InN nanowhiskers have been staying behind since it is more difficult to produce InN of good quality. However InN has interesting properties like high electron mobility, low bandgap and non-toxicity. InN was grown by plasma-assisted molecular beam epitaxy (PAMBE) on Si(111) substrates under N-rich conditions resulting in columnar morphology of the grown layers. Substrate temperature was considerably lower compared to GaN growth. The samples were investigated using scanning electron microscopy (SEM) as well as Photo- and Cathodoluminescence (PL and CL) spectroscopy. The growth was optimized to obtain uniform columns of good crystalline quality. An optical bandgap was found in the range 0.73-0.82eV and electron concentrations between 8×10^{17} and $6 \times 10^{18} cm^{-3}$ were determined.

HL 19.4 Tue 18:00 HSZ 01

Storage of excitons in elongated semiconductor nanocrystals — •Robert M. Kraus[1], Pavlos G. Lagoudakis[1], Andrey L. Rogach[1], John M. Lupton[1], Jochen Feldmann[1], Dmitry Talapin[2], and Horst Weller[2] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität München, Germany — [2]Institute of Physical Chemistry, University of Hamburg, Germany

Spherical CdSe nanocrystals capped by a CdS rod-like shell, referred to as nanorods, exhibit interesting spectral dynamics on the single particle level.[1,2] However, for the purpose of applications, the ensemble properties of nanorods are most interesting. We are especially interested in the behaviour of an ensemble of nanorods under the influence of an electric field, as this bears great relevance for future devices. We show here that by applying an electric field to an ensemble of nanorods in a vertical sample geometry a linear quantum-confined Stark shift of the order of 60 meV can be observed in the emission energy. During the application of the electric field the excitons are effectively hindered from radiative recombination and can be stored coulombically for up to 100 μs. Furthermore, modulation of the electric field leads to a modulation in both the wavelength and the spectral width of the nanoparticle emission.

[1] J. Müller *et al.*, Phys. Rev. Lett. 93, 167402 (2004)
[2] J. Müller *et al.*, Nanoletters 5, 2044 (2005)

HL 19.5 Tue 18:15 HSZ 01

Electric field induced photoluminescence quenching in CdSe nanocrystal doped SiO_2 on Si — •Helmut Karl, Alexander Achtstein, and Bernd Stritzker — Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany

Buried CdSe nanocrystals were synthesized by sequential ion implantation of Cd and Se in 500 nm thick thermally grown SiO_2 on p-doped silicon. The formation of the CdSe nanoclusters was initiated by a post-implantation thermal annealing step. Then an optically semitransparent thin Au gate electrode was evaporated on top of the SiO_2 forming a MOS capacitor structure. The embedded surface near CdSe nanocrystals show efficient steady state CdSe bandedge photoluminescence when excited by a cw-HeCd laser at a wavelength of 442 nm at room temperature. The silicon substrate was electrically contacted by indiffusion of an evaporated Al thin film. With this structure we observe strong electric field induced photoluminescence quenching when a voltage is applied between the Au gate electrode and the silicon substrate for temperatures between 10 K and room temperature. PL quenching of more than 80 % was found for an electric field variation between 0 and +/- $4x10^7$ V/m. CV-characteristics in conjunction with the electric field dependence of the PL quenching will be discussed.

HL 19.6 Tue 18:30 HSZ 01

Size dependence of the dynamics of the Mn 3d^5 luminescence in wire-like arrangements of (Zn,Mn)S nanoparticles — •L. Chen[1], P.J. Klar[1], W. Heimbrodt[1], F.J. Brieler[2], and M. Fröba[2] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]Institute of Inorganic and Analytical Chemistry, Justus-Liebig-University of Gießen, Germany

(Zn,Mn)S nanoparticles with Mn concentrations ranging from 1% to 30% and in a wire-like arrangement were formed inside mesoporous SiO_2 matrices of various pore diameters. The nanoparticles were characterised using photoluminescence and excitation spectroscopy. It is found, that the Mn^{2+} ions are incorporated on cation lattice sites replacing Zn. The decay times of the internal Mn^{2+} ($3d^5$) luminescence are studied in detail by time resolved spectroscopy over more than 5 orders of magnitude in intensity. A concentration and a remarkable size dependence of the time behaviour has been observed indicating a geometry dependence of the energy-transfer processes within the Mn system.

HL 19.7 Tue 18:45 HSZ 01

Optical properties of implanted single ZnO nanowires — •Daniel Stichtenoth[1], Sven Müller[1], Carsten Ronning[1], Lars Wischmeier[2], Chegnui Bekeny[2], and Tobias Voss[2] — [1]II. Institute of Physics, University of Göttingen, Germany — [2]Institute for Solid State Physics, University of Bremen, Germany

Doping of semiconductor nanostructures via ion implantation processes offers the advantage of precise control of the doping concentration in both lateral and depth direction beyond any solubility limit. In this study, single crystalline ZnO nanobelts and -wires were synthesized according to the VLS mechanism and subsequently dispersed on top of Si substrates. The nanowires were implanted either with ^{14}N, ^{31}P, ^{14}N & ^{31}P, or ^{20}Ne ions. Nitrogen and Phosphorous are potential acceptors in ZnO; whereas, the objective of the Ne-implantation was to monitor the implantation induced damage. The range of the ions, set by the ion energy, matched the diameter of the nanowires, and post-implantation annealing procedures were done under vacuum conditions in order to remove the introduced damage. The treated nanowires were individually investigated by temperature-dependent μ-PL measurements; correlations between the optical spectra and the implanted species as well as the implantation parameters are discussed.

HL 19.8 Tue 19:00 HSZ 01

Nitrogen implanted ZnO nanowires — •Sven Müller, Daniel Stichtenoth, Daniel Schwen, and Carsten Ronning — 2nd Institute of Physics, University Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Single crystalline ZnO nanowires were grown via a chemical vapor deposition process: ZnO powder was placed into a horizontal tube furnace and heated up to 1350°C. The vapour was transported by an Ar gas flow to the substrates in a temperature zone between 1000 - 1180°C. Prior growth the Si substrates were covered with a thin gold layer, which acts as a catalyst for the vapour-liquid-solid (VLS) mechanism. The wurtzite ZnO nanowires grew along the c-axis and had a belt-like shape in the nanometer range. These ZnO nanowires were implanted with 50 keV nitrogen ions (as a potential acceptor) in order to change the electrical and optical properties. Directly after the implantation process, the properties were dominated by the radiation damage, which was subsequently healed by annealing in vacuum or in an oxygen atmosphere. The nitrogen implantation generated three new luminescence transitions at energies of 3.35 eV, 3.32, and 3.235 eV. The origin of these features will be discussed in respect to their temperature- and power-dependencies.

HL 19.9 Tue 19:15 HSZ 01

Optical Spectroscopy on Silicon Nanoparticles — •Stephan Lüttjohann[1], Cedrik Meier[1], Andreas Gondorf[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Laboratorium für Festkörperphysik, Universität Duisburg–Essen, 47048 Duisburg — [2]Institut für Verbrennung und Gasdynamik, Universität Duisburg–Essen, 47048 Duisburg

The optical properties of silicon nanoparticles have been studied by photoluminescence and Raman spectroscopy. The particles are fabricated in a low pressure microwave reactor by decomposition of silane.

We have investigated particles in a size range of between d=4.2nm and 60nm. For particles with diameters smaller than 30nm, quantum effects become relevant and are observed in Raman spectra as well as in photoluminescence spectra. The Raman spectra show the phonon confinement

effect which redshifts the energy of the observed phonons.

The PL emission wavelength (between 600nm and 1000nm) shifts towards lower wavelengths with decreasing particle sizes. Investigations of the PL intensity as a function of the temperature reveal an interesting behaviour. The PL intensity has a maximum at about T=80K and decreases for higher as well as lower temperatures.

To get a better understanding about the origin of these effects, micro-photoluminescence is employed. First results showing sharp emission lines (FWHM $\approx$ 1meV) originating from excitonic and biexcitonic recombination are presented. As a result of the strong Coulomb interaction in the particles the spectra show a remarkable high exciton to biexciton energy splitting of 32meV.

HL 20 Spin controlled transport II

Time: Tuesday 15:15–16:30 Room: BEY 118

HL 20.1 Tue 15:15 BEY 118

Vertical cavity surface emitting lasers for amplification of spin information at room temperature — •Stephan Hövel[1], Nils C. Gerhardt[1], Martin Hofmann[1], Junling Yang[2], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, IC2/152, 44780 Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, NB 03, 44780 Bochum

Spin injection into semiconductor light emitting diodes at room temperature usually results in effects much too small for applications. This is due to low injection efficiencies and, in particular, to strong spin relaxation in the semiconductor. We show experimentally and theoretically that spin information can be amplified using the nonlinearity of vertical cavity surface emitting lasers at threshold. By polarized optical excitation of a GaInAs VCSEL we can achieve an output polarization which is higher than that of the excitation [1]. For further improvement, we analyse the spin relaxation in different semiconductor materials to determine the optimal active material for a spin-VCSEL. Finally, we discuss electrical injection schemes for room temperature and low external magnetic fields [2].We thank the DFG for providing support in the SFB 491.

[1] S. Hövel, N. Gerhardt, M. Hofmann, J. Yang, D. Reuter and A. Wieck, Electronics Letters 41, 251 (2005)

[2] N. C. Gerhardt, S. Hövel, C. Brenner, M. R. Hofmann, F.-Y. Lo, D. Reuter, A. D. Wieck, E. Schuster W. Keune and K. Westerholt, Appl. Phys. Lett. 87, 032502 (2005)

HL 20.2 Tue 15:30 BEY 118

Spin Dynamics During Transport Via Dynamic Quantum Dots — •James AH Stotz, Rudolph Hey, Paulo V Santos, and Klaus H Ploog — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

Quantum information processing using electron spins in semiconductor structures requires the coherent transport and manipulation of spin polarized carriers. Previous studies have typically focussed on either the transport of spins with little control of their microscopic movement or the use of quantum dots to manipulate spins locally without microscopic transport. Recent work [1] using the unique system of dynamic quantum dots (DQDs) shows that electron spins can be transported over long distances and manipulated while retaining their microscopic confinement. The DQDs are produced by the superposition of piezoelectric potentials from surface acoustic waves propagating along orthogonal directions on a GaAs/(Al,Ga)As quantum well sample. While it is clear that the confinement potential of the DQDs reduces D'yakonov-Perel' spin dephasing during transport, the effects of the strain and magnetic fields on spin dephasing are much more complicated. We will discuss the underlying mechanisms behind the ability to transport spins over long distances including the impact of confinement on spin coherence. In addition, the strong dephasing of the spin coherence in an external magnetic field will be addressed, and the influence of the acoustic strain field on the transport will be introduced.

[1] J.A.H. Stotz *et al.*, Nature Materials **4**, 585-588 (2005)

[2] Financial support from the BMBF Nanoquit project is appreciated.

HL 20.3 Tue 15:45 BEY 118

Entanglement distillation by adiabatic passage in coupled quantum dots — •jaroslav fabian[1] and ulrich hohenester[2] — [1]Institute for Theoretical Physics, University Regensburg — [2]Institute of Physics, University of Graz

Adiabatic passage of two correlated electrons in three coupled quantum dots is shown to provide a robust and controlled way of distilling, transporting and detecting spin entanglement, as well as of measuring the rate of spin disentanglement. Employing tunable interdot coupling the scheme creates, from an unentangled two-electron state, a superposition of spatially separated singlet and triplet states. A single measurement of a dot population (charge) collapses the wave function to either of these states, realizing entanglement to charge conversion. The scheme is robust, with the efficiency close to 100\%, for a large range of realistic spectral parameters.

HL 20.4 Tue 16:00 BEY 118

Conductance Quantization in Quantum Point Contacts with Spin-Orbit Interaction — •Sebastian von Oehsen, Guido Meier, Toru Matsuyama, and Ulrich Merkt — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany

InAs has a strong and tunable spin-orbit interaction [1] and is thus an interesting material for spintronic devices. We present measurements on quantum point-contacts on InAs/InGaAs heterostructures.

Hallbars are predefined on the samples by wet etching. To achieve lateral electrostatic confinement we use either split gates on a SiO_2 layer or side gates. With the latter technique peripheral charging effects can be avoided because of the absence of an isolator. The measurements are performed at 250 mK and in magnetic fields up to 5 Tesla. Quantization steps in the conductance are measured. The transition from electrostatic to magnetic confinement is examined and compared with recent theoretical results [2].

[1] Ch. Schierholz, T. Matsuyama, U. Merkt, and G. Meier. Phys. Rev. B **70**, 233311 (2004)

[2] S. Debald and B. Kramer, Phys. Rev. B **71**, 115322 (2005)

HL 20.5 Tue 16:15 BEY 118

Current Assisted Magnetization Switching in (Ga,Mn)As Nanodevices — •K. Pappert, C. Gould, C. Rüster, R. Giraud, T. Borzenko, G. M. Schott, K. Brunner, G. Schmidt, and L. W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Current induced magnetization switching of metallic nanometer-sized magnets has attracted much attention over the past years. It is viewed as an attractive alternative technique for magnetic information storage. However, the current densities presently needed highly exceed the limits tolerated by today's integrated circuits.

Ferromagnetic semiconductors on the other hand are anticipated to react to much smaller current densities. Yamanouchi et al.[1] observed current assisted magnetization switching in a (Ga,Mn)As Hall bar close to its Curie temperature using the magnetooptical Kerr and Hall effect. Here we present current assisted switching of the island of a (Ga,Mn)As double constriction device at 4.2 K. We adapt a read-out scheme demonstrated by Rüster et al.[2]. They used the resistance of domain walls pinned by nanoconstrictions to determine the magnetic configuration in a similar structure. Combining current assisted switching and the pinned domain wall resistance read-out in a single device constitutes a significant step forward towards a spintronic storage device, which may use domain walls to realize information storage, transport, manipulation and read-out.

[1] M. Yamanouchi et al., Nature **428**, 539 (2004).

[2] C. Rüster et al., Phys. Rev. Lett. **91**, 216602 (2003).

HL 21 Transport properties I

Time: Tuesday 16:30–19:30 Room: BEY 118

HL 21.1 Tue 16:30 BEY 118

DENSITY-OF-STATES IN MICROCRYSTALLINE SILICON FROM THERMALLY-STIMULATED CONDUCTIVITY — •Nacera Souffi, Rudolf Brüggemann, and Gottfried H. Bauer — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

The technique of thermally stimulated currents has been applied to extract the density-of-states profile in microcrystalline silicon. Exploiting the experimental parameter space a consistent density-of-states profile emerges with an exponential conduction band tail and a broader deeper distribution. Calibrating the absolute density of states profile from other techniques like modulated photoconductivity, steady-state photocarrier grating technique and intensity-dependent photoconductivity allows a determination of the capture coefficient of the probed localised states.

HL 21.2 Tue 16:45 BEY 118

Characterization of Ti / TiO_2 / Pt - Schottky diodes — •Philipp Zabel[1], Sven Bönisch[1], Germà García-Belmonte[2], Juan Bisquert[2], and Thomas Dittrich[1] — [1]Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany — [2]Departament de Ciències Experimentals, Universitat Jaume I, E-12080 Castelló, Spain

UV photodiodes (sglux tw30sx, TiO_2 made by sol-gel processing) were used as a model system to study Ti / TiO_2 / Pt - Schottky diodes by temperature dependent current-voltage, impedance spectroscopy and transient photocurrent measurements. The equivalent circuit has been taken into account for the analysis. The Schottky barrier is about 1.3 eV which is equal to the work function difference between Ti and Pt. At lower potentials, the current is limited by the barrier while at higher potentials, control by space charge limited currents sets on. The temperature dependent dielectric constant of the TiO_2 layer was obtained. Photocurrent transients were excited with short UV laser pulses. The current at 1 μs and the integral of the photocurrent transients depend linearly on the laser intensity until an electron density of about 10^{12} cm^{-2} is reached in the TiO_2 layer (thickness 160 nm). At higher intensities, the photocurrent goes to saturation due to recombination. The electron drift mobility depends only weakly on the illumination intensity and temperature.

HL 21.3 Tue 17:00 BEY 118

Surface photovoltage for characterization of porous semiconductors — •Thomas Dittrich[1], Iván Mora-Seró[2], Germà García-Belmonte[2], and Juan Bisquert[2] — [1]Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany — [2]Departament de Ciències Experimentals, Universitat Jaume I, E-12080 Castelló, Spain

The surface photovoltage method is a locally sensitive technique with respect to even extremely short charge separation lengths. In conventional semiconductors, the charge separation length is given mainly by the thickness of the space charge region. The situation may change for porous semiconductors. In such systems, a time dependent development of the charge separation length from an initial value, given also by the duration time of the laser pulse, up to a screening length (Debye screening length in homogeneous media) has been observed and described by a diffusion model. The processes of diffusion and screening will be discussed on the example of porous TiO_2 layers sensitized with dye molecules.

HL 21.4 Tue 17:15 BEY 118

Quantitative modelling of the temperature and magnetic-field dependence of the resistivity of paramagnetic $Ga_{1-x}Mn_xAs$ with x up 7% — •C. Michel[1], S. Ye[1], V. Rajevac[1], P.J. Klar[1], S.D. Baranovskii[1], P. Thomas[1], W. Heimbrodt[1], and B. Goldlücke[2] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]MPI for Computer Science, Saarbrücken, Germany

We measured and modelled quantitatively the magneto-resistance behaviour above the Curie-temperature of several different p-type $Ga_{1-x}Mn_xAs$ samples with x up to 7%. A network model [1] accounting for alloy disorder and tuning of the band structure due to the strong s,p-d exchange interaction between the spins of the extended band states and the localized Mn $3d$ spins was employed. The band structure description is based on parabolic hole bands and an acceptor level with a Gaussian broadening. The calculated temperature dependence of the resistance in zero-field as well as the magnitude of the magneto-resistance effects are very sensitive to the choice of model parameters, e.g. the valence band exchange-integral $N_0\beta$, the width of the Gaussian broadening of the acceptor level, the degree of zero-field disorder etc., allowing one to determine these parameters by fitting the experimental data. The magnitude of the extracted parameters and the trends with x will be discussed and compared with literature values.

[1] Phys. Rev. B **69**, 165211 (2004).

HL 21.5 Tue 17:30 BEY 118

Transistor characteristics of three leaky contacts defined in a two dimensional electron gas — •Daniela Spanheimer, Lukas Worschech, Christian R. Müller, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

The capacitance of leaky nanojunctions has recently attracted considerable attention. It has been stated that in mesoscopic system the capacitance not only depends on the geometry, but also on electrochemical entities and the transmission probability between the reservoirs [1]. We have studied the capacitive couplings between three leaky contacts by studying the gain properties of a transistor like junction. For that purpose we have realized two rows of etched holes in a modulation doped GaAs/AlGaAs heterostructure. The two rows define three electron reservoirs, which are leaky coupled to each other. We have determined the current voltage characteristics for several possible variations of the three terminals for different separations between the rows and different hole diameters. For row separations in the order of 1 μm transistor characteristics have been observed even at room temperature, which we discuss in terms of a leaky capacitor model.

[1] T. Christen and M. Büttiker, Phys. Rev. Lett. 77, 143 (1996).

HL 21.6 Tue 17:45 BEY 118

Full non-equilibrium quantum transport theory of high-scattering semiconductor devices — •Tillmann Kubis, Alexandros Trellakis, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present fully self-consistent non-equilibrium Green's function (NEGF) calculations for semiconductor heterostructures in a regime where multiple scattering and quantum effects such as interference, carrier confinement and carrier capture must be treated on an equal footing. We have implemented non-local energy- and momentum-dependent scattering self-energies in the self-consistent Born approximation for charged impurities, as well as acoustic and polar optical phonons. Electron-electron interaction is included via the self-consistent Hartree potential. This ab-initio implementation of quantum transport theory allows us to predict carrier dynamics in any kind of semiconductor nanodevice, ranging from simple n-i-n resistors to complex multi-quantum well structures. We present the I-V characteristics, the charge density and potential profile of a 12nm InGaAs quantum well that illustrates carrier capture into multiple bound states/resonances and compare the results with ballistic and quantum drift diffusion models.

HL 21.7 Tue 18:00 BEY 118

Source switching in an electron Y-branch switch — •Stefan Lang, David Hartmann, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We have observed gate controlled source switching in an electron Y-branch switch. The Y-branched nanojunctions were realized on the basis of a modulation doped $GaAs/AlGaAs$ heterostructure and are controlled by four side-gates. Gate voltage up-sweeps at one side-gate firstly open the first source channel. Then the second source-branch becomes conductive and above a critical gate voltage the first source is pinched-off. This leads to a peak in the current-voltage characteristic of the first source-branch. We have modeled the source switching taking into account gating as well as selfgating of the Y-branch nanojunction.

HL 21.8 Tue 18:15 BEY 118

Mobility Enhancement of Shallow Modulation Doped GaAs/AlGaAs Heterostructures by Presence of Metal at the Surface — •Holger Welsch, Christian Heyn, and Wolfgang Hansen — Universität Hamburg, Institut für Angewandte Physik, Jungiusstrasse 9-11, 20355 Hamburg

We perform magneto-transport measurements on shallow modulation doped GaAs/AlGaAs heterostructures. Compared to standard structures, where the two-dimensional electron gas (2-DES) is unaffected of surface states, shallow structures need higher doping in order to prevent depletion of the 2-DES. High doping concentrations as well as small spacer layers, both applied at shallow structures, are normally accompanied by reduced mobility due to scattering of the 2-DES electrons at ionised donators in the doping layer. On account of this, the minimum distance between 2-DES and surface is limited by vanishing carrier density and reduced mobility. Here we compare shallow heterostructures with open and metal coated surfaces. We find that surface metal coating on samples with a 2-DES 23 nm beneath the surface feature an up to three times higher mobility compared to the uncoated ones.

HL 21.9 Tue 18:30 BEY 118

Photoexcited electron and hole transport in thin film tunnel systems — •Peter Thissen[1], Domokos Kovacs[2], Jörg Winter[2], Eckart Hasselbrink[1], and Detlef Diesing[1] — [1]Institut für Physikalische Chemie, Universität Duisburg Essen — [2]Institut für Experimentalphysik 2, Ruhr Universität Bochum

The photoeffect in semiconductor based devices is often discussed as transport of the majority carriers across the metal–semiconductor interface. The photoexcited charge carriers propagate over the Schottky barrier ($E_{barrier} \approx 0.7\ eV$ for silicon–metal interfaces). In tunnel barrier systems ($metal_1$–$metal_1oxide$–$metal_2$) with thin oxide layers ($\approx$ 3 nm) and metal films (10 - 70 nm) other transport channels may also contribute to the measured photocurrent: 1. tunneling of electrons through the conduction band barrier. 2. tunneling of holes through the valence band barrier. 3. excitation of charge carriers both in the top and in the ground metal film of the tunnel device. By applying a bias voltage between the metals, the band structure of the tunnel device can be changed allowing a discrimination between the different transport channels. Photoinduced tunnel currents ($h \cdot \nu = 1.53, 1.37, 1.27\ eV < E_{barrier} = 1.8\ eV$) were investigated as well as photoinduced UV-electronic excitations ($h \cdot \nu = 11eV >> E_{barrier}$) with different bandstructures in the the tunnel devices. The investigations show a clear contribution of hot hole induced tunnel currents to the measured photo current even in the low energy range. Transport effects of excited charge carriers in the metal films are discussed refering to experiments with variable metal film thicknesses.

HL 21.10 Tue 18:45 BEY 118

Thermoelectric cooling: a new approach — •G.N. Logvinov[1], J. E. Velazquez[2], and Yu. G. Gurevich[2,3] — [1]SEPI-ESIME Culhuacan, I.P.N., Santa Ana 1000, Culhuacan, C.P. 04430, D.F., Mexico — [2]Depto. de Física Aplicada, Universidad de Salamanca, Pza. de la Merceds/n, E-37008 Salamanca, Spain — [3]On leave at the University of Salamanca. Permanent address: Depto. de Física, CINVESTAV-IPN, D.F., Mexico

A new approach is suggested to explain the Peltier effect. It assumes that the Peltier effect is not an isothermal effect. The approach is based on the occurrences of induced thermal fluxes in a structure which consists of two conducting media, through which a dc electric current flows [1]. These induced thermal diffusion fluxes arise to compensate for the change in the thermal flux caused by the electric current (the drift thermal flux) flowing through the junction, in accordance with the general Le Châtelier*Braun principle. The occurrence of these thermal diffusion fluxes leads to temperature heterogeneity in the structure and, as a result, to a cooling or heating of the junction. Within the framework of this concept, the thermoelectric cooling is analysed. It is shown that in the general case the Peltier effect always occurs together with another thermoelectric effect [1]. This thermoelectric effect is predicted for the first time. Both these effects essentially depend on the junction surface thermal resistance [2].

[1] Yu. G. Gurevich and G.N. Logvinov 2005 Semicon. Sci. Technol. vol. 20 R57 [2] Gurevich Yu G and Logvinov G N 1992 Sov. Phys. Semicond. vol. 26 1091

HL 21.11 Tue 19:00 BEY 118

Admittance of open quantum systems — •Paul Racec[1,2], Roxana Racec[3,4], and Ulrich Wulf[3,1] — [1]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany — [2]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [3]Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany — [4]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania

We present a formalism for the treatment of mesoscopic systems under a small time dependent bias superimposed to a static external bias which defines the working point. The scheme is based on linear response theory, where the unperturbed system is considered the system under the static external bias. For the unperturbed system, Hartree calculations are performed in the Landauer-Buettiker formalism. In order to describe the time dependent quantities, the corresponding response functions (charge-charge or current-charge correlations functions) are computed in the random phase approximation. Applications for blocking structures (like metal-insulator-semiconductor) and current carrying structures (like double barrier resonant tunneling diode) are presented. Based on quantum mechanical expressions for their admittance, equivalent small signal circuits are proposed.

HL 21.12 Tue 19:15 BEY 118

Non-linear I-V characteristics of nano-transistors in the Landauer-Büttiker formalism — •Ulrich Wulf[1,2], Paul Racec[2,3], and Alexandru Nemnes[4,5] — [1]Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany — [2]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany — [3]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [4]Institut für Physik, Technische Universität Chemnitz, — [5]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania

We present the non-linear I-V characteristics of a nanoscale metal-oxide-semiconductor field-effect-transistor in the Landauer-Büttiker formalism. In our three-dimensional ballistic model the gate, source and drain contact are treated on an equal footing. As in the drift-diffusion regime for ballistic transport a saturation of the drain current results. We demonstrate the quantum mechanism for the ballistic drain current saturation. As a specific signature of ballistic transport we find a specific threshold characteristic with a close-to-linear dependence of the drain current on the drain voltage. This threshold characteristic separates the ON-state regime from a quasi OFF-state regime in which the device works as a tunneling transistor. Long- and short-channel effects are analyzed in both regimes and compared qualitatively with existing experimental data by INTEL [B. Doyle et al., Intel Technol. J. 6, 42, (2002)].

HL 22 Semiconductor laser II

Time: Tuesday 15:15–17:15 Room: BEY 154

HL 22.1 Tue 15:15 BEY 154

Low powerconsumption of blue-violet laser diodes — •C. Rumbolz, C. Eichler, M. Schillgalies, A. Avramescu, M. Furitsch, G. Brüderl, A. Lell, U. Strauss, and V. Härle — OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055Regensburg

Commercial applications like post DVD data storage systems or high resolution printing require blue-violet laser diodes with low power consumption. Mobile devices with limited battery capacities and small sizes need diodes with low heat dissipation to avoid extensive cooling systems. Low heat dissipation also guarantees longer lifetimes of the diodes. We achieve electrical power dissipation values as low as 400mW at 30mW optical cw-output by improving threshold current, slope efficiency and voltage. One step of optimization is the adjustment the n-cladding layer. Layers with strong wave guidance are good for low threshold current but increase the voltage. We found a n-cladding layer optimum for low power dissipation. Next step of improvement is the reduction of the operation current by lowering the internal losses. One main loss mechanism is the absorption at Mg-dopants in the p-GaN- and p-AlGaN layers. A com-

promise between hole injection and minimization of absorption has been found. With these optimizations we show cw-threshold currents smaller 35mA for 1,5μm wide ridgewaveguide lasers and slope efficiencies up to 1,2W/A.

HL 22.2 Tue 15:30 BEY 154

2.5 Gbit/s data transmission and 800 mW single mode filamentation free operation of InAs/InGaAs quantum dot lasers emitting at 1.5 μm — •T. Kettler[1], L.Ya. Karachinsky[2], G. Fiol[1], M. Kuntz[1], K. Posilovic[1], A. Lochmann[1], O. Schulz[1], L. Reissmann[1], N.Yu. Gordeev[2], I.I. Novikov[2], M.V. Maximov[2], Yu.M. Shernyakov[2], N.V. Kryzhanovskaya[2], A.E. Zhukov[2], A.P. Vasilev[2], E.S. Semenova[2], V.M. Ustinov[2], N.N. Ledentsov[3], A.R. Kovsh[3], V.A. Shchukin[3], S.S. Mikhrin[3], and D. Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Ioffe Physico-Technical Institute, St. Petersburg — [3]NL Nanosemiconductor GmbH, Dortmund

In recent years semiconductor lasers with self organised quantum dots as an active media grown on GaAs demonstrated theoretically predicted superior characteristics. Until now special emphasis was placed on GaAs-based QD lasers emitting at the datacom and telecom wavelength of 1.3 μm. Here we report on QDs emitting at 1.5 μm using the novel concept of metamorphic growth. The active region consists of InAs/InGaAs QDs, grown on top of a metamorphic InGaAs layer deposited on GaAs. Such devices demonstrate 220 mW single transverse mode cw operation as well as 800 mW single transverse mode pulsed operation, limited only by power supply and showing no sign of filamentation. Small signal modulation and eye pattern back-to-back measurements have been performed at room temperature and show the feasibility to use these devices for 2.5 Gbit/s data transmission. Aging tests showed more than 800 h of operation at 50 mW with less than 10% decrease in output power.

HL 22.3 Tue 15:45 BEY 154

Recombination dynamics in InAs-quantum dots coupled to the tilted cavity waveguide mode — •P. Zimmer[1], N.V. Kryzhanovskaya[2], N.N. Ledentsov[3], A. Hoffmann[1], D. Bimberg[1], A.R. Kovsh[3], S.S. Mikhrin[3], V.A. Shchukin[1], L.Ya. Karachinsky[2], and M.V. Maximov[2] — [1]Institut für Festkörperphysik, Technische Universität, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Abraham Ioffe Physical Technical Institute, Politekhnicheskaya 26, 194021 St.Petersburg, Russia — [3]NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

In this report we present recombination dynamics of nonequilibrium carriers in InAs-quantum dots embedded in a "tilted-mode" cavity. All epitaxial structure is based on a resonantly coupled planar waveguide and a multilayer interference reflector. In accordance with the theoretical prediction, the radiative recombination rate increases when the emission wavelenght corresponds to the tilted cavity waveguide mode whereas the off-resonance emission is suppressed. This effect has similar nature as the Purcell effect. Time-resolved photoluminescence studies indeed pointed out that the recombination dynamics is affected by the coupling of photons to the tilted-mode cavity. We found out that the radiative lifetime of carriers whose transition energy is in resonance to a tilted cavity waveguide mode is reduced by a factor of 1,5. The resonant wavelenght can be tuned by the design of the multilayer waveguide structure and it shows only a weak temperature dependence compared to the band gap temperature shift. This approach is promising for the realisation of highly-efficient wavelenght-stabilised LED's and lasers.

HL 22.4 Tue 16:00 BEY 154

Influence of electrostatic confinement on optical gain in GaInNAs quantum well lasers — •Sorcha Healy and Eoin OReilly — Tyndall National Institute, Lee Maltings, Cork, Ireland

There remains controversy surrounding the cause of the magnitude and temperature sensitivity of the threshold current density of 1.3 μm GaInNAs quantum well (QW) lasers, with several authors attributing the strong temperature sensitivity to hole leakage, due to the relatively low valence band offset in GaInNAs/GaAs QW structures. We use a Poisson solver along with a 10-band **k.p** Hamiltonian to calculate self-consistently the influence of electrostatic confinement on the optical gain in such lasers. We find that the proper inclusion of such effects significantly reduces the hole leakage effect, with the electrostatic attraction of the electrons significantly increasing the binding of heavy holes in the QW region. We conclude by comparison with previous theoretical and experimental studies that the room temperature threshold current is generally dominated by monomolecular recombination, while the temperature sensitivity is due predominantly to Auger recombination.

HL 22.5 Tue 16:15 BEY 154

GaInAsN Quantum Dot Lasers grown by RF MBE — •Bernd Marquardt[1], Dirk Bisping[1], Marc Fischer[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]nanoplus Nanosystems and Technologies GmbH, Oberer Kirschberg 4, 97218 Gerbrunn, Germany

Two different approaches are currently used to achieve long wavelength emission on GaAs substrate: InGaAs quantum dot (QD) and GaInAsN quantum well (QW) material. Laser emission with promising device properties has been demonstrated in both material systems. Here we report on the successful combination of both approaches: the realization of a GaInAsN QD laser. First, high quality N-free lasers emitting at 1280 nm with an active region consisting of InAs QDs embedded in an InGaAs Quantum Well (QW) were realized by solid source MBE. Based on this active region the incorporation of nitrogen in either the QDs or the embedding QW material or both was studied to extend the emission wavelength. Active nitrogen was supplied by an RF plasma source. A QD density of about 3.5 1010 cm-2 combined with excellent photoluminescence (PL) properties was obtained from PL test structures. Subsequently SCH laser structures with N-containing QD active region were realized. Based on a multi stack active region, a GaInAsN QD laser emitting at 1360 nm has been realized for the first time.

HL 22.6 Tue 16:30 BEY 154

Study of the dark line defects caused by the catastrophic optical mirror damage in broad area red-emitting high-power AlGaInP lasers — •Marwan Bou Sanayeh, Arndt Jaeger, Wolfgang Schmid, Sönke Tautz, and Klaus Streubel — OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg

Red-emitting AlGaInP lasers are being used in many applications such as optical discs, barcode readers, and color printers. Moreover, AlGaInP high-power broad area lasers have found usage in display technology and especially in the medical field, where they are required to show an outstanding performance and long-term reliability of many thousand hours. However, compared to infrared-emitting high-power AlGaInAs lasers, AlGaInP lasers are still lacking behind in showing high output powers, one reason is due to their low catastrophic optical mirror damage (COMD) levels. Therefore, studying the COMD in these lasers is of utmost importance to improve their performance and reliability.

In this work, we present deep analysis of the COMD on broad area red-emitting high power 650 nm AlGaInP lasers by studying the dark line defects (DLDs) caused by the COMD at the mirror facets and their propagation in the active region using micro-photoluminescence mapping and scanning electron microscopy.

HL 22.7 Tue 16:45 BEY 154

Carrier Losses in Semiconductor Laser Structures — •Angela Thränhardt[1], Christoph Schlichenmaier[1], Irina Kuznetsova[1], Stephan W. Koch[1], Jörg Hader[2], and Jerome V. Moloney[2] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, 35032 Marburg — [2]Arizona Center for Mathematical Sciences, The University of Arizona, Tucson, AZ 85721, USA

Microscopic modelling of semiconductor heterostructures offers the advantages of a better understanding of laser operation as well as enhanced predictability and possibility of optimisation. A theory on the level of the semiconductor Bloch equations including scattering in second Born and Markov approximation has been shown to quantitatively reproduce and predict optical spectra for, among others, gain, refractive index and linewidth enhancement factor [1,2]. To accurately determine the threshold, losses in laser operation are also important [3]. Simple dependencies as e.g. a quadratic rise of radiative losses with density are often assumed; however, these are valid for a Boltzmann distribution of carriers, i.e. far below lasing threshold, and may not be used for laser operation.

In this talk, we present a microscopic theory to accurately predict optical gain/absorption, refractive index, photoluminescence and laser losses on the same level. Good agreement with experiment is obtained. We investigate the validity of simple rules of thumb commonly used for laser simulations and find strong deviations in the lasing regime.

[1] J. Hader, S. W. Koch, J. V. Moloney, Sol. Stat. El. **47**, 513 (2003).
[2] A. Thränhardt et al., Appl. Phys. Lett. **86**, 201117 (2005).
[3] J. Hader et al., IEEE J. Quant. El. **41**, 1217 (2005).

HL 22.8 Tue 17:00 BEY 154

Multi-spectral infrared imaging of high-power diode lasers —
•Mathias Ziegler, Fritz Weik, and Jens W. Tomm — Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, 12489 Berlin, Germany

Below band gap radiation of 808 nm GaAs-based high-power diode laser arrays in several spectral channels, namely the mid (MIR: 2.4-6 μm) and the near infrared (NIR: 1.5-2 μm), is used to reveal potential signs of the driving forces of an enhanced device degradation. By applying a fast infrared camera setup the infrared images of the devices can be analyzed spatially resolved down to the diffraction limit. Thus a localization of these degradation signs is possible on the scale of an emitter of the multi-emitter bar and even of parts of it.

With the multi-spectral approach it is possible to distinguish between the different mechanisms involved. The MIR signal mainly is assigned to the thermal radiation according to Planck's law and the NIR signal to deep-level-related luminescence These assumptions are supported by complementary measurements of the arrays infrared emission and absorption spectra, which indeed show the described spectral features.

HL 23 Interfaces/surfaces

Time: Tuesday 17:15–19:30 Room: BEY 154

HL 23.1 Tue 17:15 BEY 154

X-ray grazing incidence investigations of focused ion beam interactions with a Si and GaAs surfaces —
•Jörg Grenzer[1], Ullrich Pietsch[2], Lothar Bischoff[1], and Matthias Posselt[1] — [1]Forschungszentrum Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, POB 51 01 19, D-01314 Dresden, Germany — [2]FB7 - Physik , Universität Siegen, 57068 Siegen, Germany

We report on the study of a two-dimensional dot lattice structures which was produced on GaAs and Si (001) substrates using a Ga^+ focused ion beam in normal incidence with a spot size of about $50nm$, an energy of $25keV$ and a dose of $10^{14}cm^{-2}$. The fabricated 2D-lattice structures consist of dots of almost circular shape ($2000nm^2$) and a period of $250x250nm^2$. We have investigated the interaction of the implanted ions with the host lattice as a function of the implantation conditions using grazing incidence diffraction at the ID10 and ID1 beam lines at the ESRF. The low-dose implantation creates interstitials and vacancies below the surface generating a weak displacement field resulting in a 2D periodical strain field in case of Si substrate. For the GaAs substrate we found a much more complex scattering pattern which depends on the in-plane orientation of the 2D dot lattice with respect to the substrate crystallographic orientation. A much stronger scattering contrast can be found if the 2D dot lattice misaligned by 14° degree. A simulation taking the interaction between the implanted ions and the host lattice into account shows an enhanced channelling of the ions into low-index crystallographic directions. Thus the dependence of the implantation damage profile on the crystalline structure influences the scattering patterns.

HL 23.2 Tue 17:30 BEY 154

Distribution of Co atoms on Si (100) investigated by high resolution Rutherford backscattering spectrometry. —
•Saroj Prasad Dash, Dagmar Goll , and Heinz Dieter Carstanjen — Max- Planck- Institut für Metallforschung, Stuttgart, Germany

We have investigated the initial stages of the growth of Co on a Si (100) surface at room temperature. The structural evolutions and the material distribution on and below the surface for 0.08 ML to 3 ML Co coverage have been probed in situ by high resolution Rutherford back scattering spectrometry. We can clearly classify the coverage from 0.08 ML to 3 ML into two different regimes. For coverage of 0.08 ML to 1.09 ML we were able to observe Co atoms chemisorbed in the form of 2D islands on the surface and atoms on the sub-surfaces, showing higher bulk diffusivity than surface diffusivity of Co in Si. For coverage of 2 ML and 3 ML we could observe silicide-like phases on the surface. This gives a strong indication that for 2 ML and 3 ML coverage Si mass transport occurs from the substrate for silicide formation and lowers the surface free energy.

HL 23.3 Tue 17:45 BEY 154

Ripple morphology versus Ar+ implantation dose in silicon —
•Souren Grigorian[1], Joerg Grenzer[2], and Ullrich Pietsch[1] — [1]University of Siegen, Institute of Physics, 57072 Siegen, Germany — [2]Forschungszentrum Rossendorf, Institut fuer Ionenstrahlphysik und Materialforschung, P.O. Box 510119, 01314 Dresden, Germany

Investigations of ripples morphology of Ar+ implanted silicon are presented. Particularly we have measured the degree of amorphization as a function of implantation dose by means of x-ray grazing amorphous scattering (GIAS). For perfect silicon crystals GIAS shows monotone decreasing background intensity versus the 2θ scattering angle. For implanted samples we find two broad peaks indicating short-range ordering of amorphous material changing with the penetration depth of probing x-ray. The appearance of embedded crystalline domains is indicated by additional sharp peaks on top of the amorphous scattering. 2θ- scans taken at different azimuthal angles of sample display strong anisotropy of amorphous scattering which only slightly changes with dose. Based on these results we suggest a model of dose-dependent amorphization. The strong damage of crystalline structure takes place along particular crystallographic directions and strongly reveal for low doses, before it becomes complete amorphous and mostly uniform at high doses of implantation. This mechanism can be used as a hint for the appearance of a ripples amorphous-crystalline interface found at these structures.

We would like to thank S. Hazra and T.K. Chini for research collaborations. This work was supported by the DST-DAAD India-Germany Collaborative Program.

HL 23.4 Tue 18:00 BEY 154

Quantitative characterization of a crystalline-amorphous interface by Q-HRTEM —
•Karsten Thiel[1], Nikolai Borgardt[2], Boris Plikat[3], Tore Niermann[1], and Michael Seibt[1] — [1]IV. Physikalisches Institut der Universität Göttingen and SFB 602, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]permanent address: Moscow Institute of Electronic Technology, 103498 Moscow — [3]now at: Infineon Technologies AG, 93049 Regensburg

The atomic structure of the transition region between c-Si(111) and a-Ge as well as a-Si has been studied by means of Q-HRTEM. Our approach involves averaging of the images along the interface, and simulating them within the "averaged-projected-potential"approximation by multi-slice simulation. This includes the use of a 2D-distribution function $\rho(x, y)$ for the density of the atoms on the amorphous side and the well known atomic positions on the crystalline side.

$\rho(x, y)$ reveals lateral ordering close to the crystalline substrate in addition to a pronounced layering. The width of both transition regions could be estimated to ≈1.4nm and the bond-angle distribution in the 1st layer is determined as 11.5° for a-Ge and ≈2.1° for a-Si.

For the a-Ge sample, we also investigated the lateral variations of $\rho(x, y)$ and how far these changes are significant. It results, that there are no significant variations in the 1st atomic layer. This indicates homogenous properties for this layer on the scale of ≈23nm. In contrast, for the 2nd and 3rd layer we observe significant variations on a lateral scale of ≈10nm. We attribute these lateral variations to the response of the atomic network in the transition region on the volume misfit.

HL 23.5 Tue 18:15 BEY 154

The Role of Hydrogen in the Pre-epitaxial Cleaning of Silicon(100)-Surfaces —
•Markus Schindler[1], Matthias Schmidt[1], Dorota Kułaga-Egger[1], Tanja Stimpel-Lindner[1], Jörg Schulze[1], Ignaz Eisele[1], and William Taylor[2] — [1]Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg — [2]Freescale Inc., Austin TX, USA

Due to the continous trend to smaller device dimensions in silicon microelectronics dopant diffusion and hence process temperature must be limited. In this work we investigate the minimum thermal budget to achieve contamination-free silicon surfaces prior to expitaxy in a commercial low pressure chemical vapour deposition (LPCVD)-system. Process parameters varied are temperature and oxygen partial pressure (steady-state-boundary). The samples are characterized with secondary-ion-mass-spectroscopy (SIMS) for oxygen- and carbon impurities. The presence of hydrogen in the growth enviroment leads to less stringent requirements for oxygen partial pressure and a complete removal of carbon impurities. For oxygen removal cleaning in inert gas ambient behaves similar to ultra-high-vacuum (UHV). The same reaction path seems to

be valid for silicon substrate cleaning under hydrogen, argon and UHV conditions. We conclude that for low-temperature preepitaxial cleaning the oxygen partial pressure has to be lowered considerably in future LPCVD-systems.

HL 23.6 Tue 18:30 BEY 154

Structural and electronic properties of Si/SiOxNy interfaces — •Alberto Martinez-Limia, Rebecca Janisch, Philipp Plänitz, and Christian Radehaus — Institute for Electrical and Information Egineering, TU Chemnitz, 09112 Chemnitz, Germany

The incorporation of N into the gate oxide of metal-oxide-semiconductor devices is an extended practice in the present microelectronic technology. Improvements in the dielectric properties and suppression of dopant diffusion and material defects have been reported for this kind of materials.

To study structural an electronic properties of Si/SiOxNy interfaces we performed DFT calculations with CPMD and ABINIT codes. We generated several Si/SiOxNy model interfaces for low N concentrations. After structural optimization, the site projected density of states (DOS) was calculated for representative atoms of the system. With this information and using GW band gap results for the bulk phase of SiOxNy and Si we can evaluate valence and conduction band offsets of these systems. Changes of the DOS at the interface depending on concentration and position of the N atoms on the SiOxNy phase are discussed.

HL 23.7 Tue 18:45 BEY 154

Removal of carbon and oxygen contaminants from silicon surfaces by atomic hydrogen — •Tanja Stimpel-Lindner[1], Markus Schindler[1], Günther Dollinger[2], Hermann Baumgärtner[1], and Ignaz Eisele[1] — [1]Institut für Physik, Fakultät für Elektrotechnik, Universität der Bundeswehr München, 85577 München-Neubiberg, Deutschland — [2]Institut für Angewandte Physik und Messtechnik, Fakultät für Luft- und Raumfahrttechnik, Universität der Bundeswehr München, 85577 München-Neubiberg, Deutschland

For the growth of nanostructures on silicon (Si), the previous cleaning of the substrate surface is an important step. Common processes for surface preparation in UHV involve temperatures up to 1200°C. For atomically sharp doping profiles and other innovative structures, this is far too high. Cleaning procedures at lower temperature regularly either leave carbon (C) and oxygen on the surface or produce a significant roughening of the surface which is also unwanted. In our work, a cleaning process using atomic hydrogen was developed. Starting from oxide-covered Si(100) after RCA-Cleaning or native silicon dioxide, both covered with carbon contaminations, the surfaces were exposed to atomic hydrogen which was generated by dissociative adsorption of hydrogen on a hot tantalum surface. With this new process, C can already be removed at substrate temperatures of about 500°C. Oxygen removal starts at slightly higher temperatures. The cleaning process was investigated in detail by XPS, AES and STM. These results will be compared with cleaning processes used by the semiconductor industry which also employ hydrogen.

HL 23.8 Tue 19:00 BEY 154

Electronic structure at Si-Insulator interfaces — •Rebecca Janisch, Alberto Martinez-Limia, and Christian V. Radehaus — Institute for Electrical and Information Engineering, Technical University Chemnitz, 09107 Chemnitz, Germany

Several materials systems are currently under consideration as potential alternatives to SiO$_2$ as the gate dielectric material for complementary metal-oxide-semiconductor (CMOS) technology. One of the main challenges for the alternative high-k dielectric are the advantageous structural features of the Si-SiO$_2$ interface. Pseudobinary alloys of SiO$_2$ and the oxides of the group-IV transition metals Ti, Zr, and Hf are currently considered to be the most promising candidates that combine the outstanding structural features of the former with excellent dielectric properties of the latter.

To study the electronic properties of Si-high-k interfaces, we performed ab initio calculations employing the ABINIT and the CPMD electronic structure code. In a first step we constructed a model Si-SiO$_2$ interface. After structural optimization we calculated site-projected density of states (DOS) for representative atoms in the supercell. From these we were able to derive information about band-offsets and the density of interface states. Starting with the relaxed structure of the Si-SiO$_2$ interface we then substituted selected Si atoms in the SiO$_2$ slab with Ti or Zr respectively. We currently investigate the preferred position of the substituting atom, its influence on the bulk and interface structure, as well as the resulting changes in the electronic structure at the interface. We will discuss the results of this ongoing work in this presentation.

HL 23.9 Tue 19:15 BEY 154

Ab initio Calculation of Structural and Electronic Properties of Interfaces between Ionic Compounds: PbTe(rs)/CdTe(zb) — •Roman Leitsmann, L.E. Ramos, and F. Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

The structural and electronic properties of {100} and {110} PbTe(rs)/CdTe(zb) interfaces are investigated by means of an ab initio pseudopotential method. Both materials have a strong polar character. The repeated slab approximation to model the interfaces gives rise to resulting dipole moments in the {100} case. Therefore an artificial potential is induced due to the periodic boundary conditions of the super cell approach[1]. We have developed a new scheme to calculate the interface energies and the projected band structures of such systems. First results will be presented and compared with recent experimental observations.

[1] Jörg Neugebauer and Matthias Scheffler, Phys. Rev. B 46, 16067 (1992)

HL 24 Ultra fast phenomena

Time: Tuesday 15:15–18:00 Room: POT 151

HL 24.1 Tue 15:15 POT 151

Microscopic analysis of extreme nonlinear optics in semiconductors — •Daniel Golde, Torsten Meier, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg

Extreme nonlinear optics denotes the regime where the Rabi frequency is comparable to or even larger than the band gap frequency. This regime can be reached experimentally by using intense ultrashort laser pulses which have a duration of just a few femtoseconds, see, e.g., [1]. As shown in [2] for the case of a two-level system, a theoretical analysis of extreme nonlinear optics requires one to describe the dynamics on ultrashort time scales beyond the rotating-wave approximation. Such calculations describe, e.g., the generation of higher harmonics and Mollow tripletts [1,2]. Here, we use a microscopic model of a two-band semiconductor with Coulomb interaction to analyze the regime of extreme nonlinear optics. It is, in particular, shown that the importance of excitonic effects which are known to dominate the nonlinear optical response at moderate excitation intensities become less important at largely elevated intensities [3].

[1] Q.T. Vu, H. Haug, O.D. Mücke, T. Tritschler, M. Wegener, G. Khitrova, and H.M. Gibbs, Phys. Rev. Lett. **92**, 217403 (2004).
[2] T. Tritschler, O.D. Mücke, and M. Wegener, Phys. Rev. A **68**, 033404 (2003).
[3] D. Golde, T. Meier, and S.W. Koch, unpublished.

HL 24.2 Tue 15:30 POT 151

Decay of non-equilibrium states created by half-cycle pulses in mesoscopic semiconductor rings — •Andrey Moskalenko, Alex Matos-Abiague, and Jamal Berakdar — Max-Planck Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Picosecond half-cycle electromagnetic pulses can be utilized for the ultrafast generation of non-equilibrium states in mesoscopic semiconductor rings [1,2,3]. We investigate the relaxation processes of these states towards equilibrium using the density matrix formalism. We show that for low temperatures and clean rings the characteristic relaxation times can be much longer than the pulse duration and long enough to observe the characteristic properties of the non-equilibrium states.

[1] A. Matos-Abiague, J. Berakdar, Phys. Rev. B 70, 195338 (2004).
[2] A. Matos-Abiague, J. Berakdar, Europhys. Lett. 69, 277 (2005).
[3] A. Matos-Abiague, J. Berakdar, Phys. Rev. Lett. 94, 166801 (2005).

HL 24.3 Tue 15:45 POT 151

Transient gain spectroscopy in III-V semiconductor structures — •Kapil Kohli[1], Sebastian Borck[1], Christoph Lange[1], Sangam Chatterjee[1], Kerstin Volz[1], Wolfgang Stolz[1], Lutz Geelhaar[2], Henning Riechert[2], Klaus Köhler[3], and Wolfgang Rühle[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Infineon Technologies AG, Corporate Research Photonics, D-81730 Munich, Germany — [3]Fraunhofer Institute for Applied Solid-State Physics, Tullastraße 72 D-79108 Freiburg, Germany

The temporal dynamics of absorption and gain spectra after optical excitation with femtosecond pump pulses are measured on a femto- to picosecond time-scale by white-light probe pulses. The material systems under investigation are GaAs and (GaIn)(NAs). Both, multi quantum well structures and bulk material, are studied.

HL 24.4 Tue 16:00 POT 151

Femtosecond formation of collective modes due to meanfield fluctuations — •K. Morawetz[1,2], B. Schmidt[1], M. Schreiber[1], and P. Lipavsky[3] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 12116 Prague 2

Starting from a quantum kinetic equation including the mean field and a conserving relaxation-time approximation we derive an analytic formula which describes the time dependence of the dielectric function in a plasma created by a short intense laser pulse. This formula reproduces universal features of the formation of collective modes seen in recent experimental data of femtosecond spectroscopy. The presented formula offers a tremendous simplification for the description of the formation of quasiparticle features in interacting systems. Numerical demanding treatments can now be focused on effects beyond these gross features found here to be describable analytically.

[1] K. Morawetz, P. Lipavský, M. Schreiber, Femtosecond formation of collective modes due to meanfield fluctuations, Phys. Rev. B in press, cond-mat/0506443

HL 24.5 Tue 16:15 POT 151

Observation of coherent acoustic phonons in semiconductors via asynchronous optical sampling — •Florian Hudert[1], Albrecht Bartels[1], Christof Janke[1], Thomas Dekorsy[1], and Klaus Köhler[2] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, D-79108 Freiburg

We report on the observation of coherent acoustic phonons in bulk semiconductors (GaAs, GaSb) as well as in semiconductor superlattices (GaAs/AlGaAs) via a recently developed femtosecond time resolved pump-probe technique without a mechanical delay line. The experimental setup constitutes of two modelocked femtosecond lasers with a repetition rate of 1 GHz that are coupled at a fixed difference of 11 kHz with one laser providing the pump and the other one providing the probe pulse. This setup allows scanning a measuring window of one nanosecond with 11 kHz and a resolution of about 200 femtoseconds. The measurement of the transient reflectivity reveals coherent longitudinal acoustic phonons over more than a few hundred picoseconds. The frequencies observed agree very well with Brillouin scattering theory. The decay of the coherent amplitude is dominated by propagation of the acoustic modes.

HL 24.6 Tue 16:30 POT 151

Efficient terahertz radiation of a large-area photoconductive device. — •André Dreyhaupt[1], Stephan Winnerl[1], Thomas Dekorsy[2], and Manfred Helm[1] — [1]Institute of Ion-Beam Physics and Materials Research, Forschungszentrum Rossendorf, 01314 Dresden, Germany — [2]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

We present an approach of photoconductive terahertz (THz) generation providing a broad bandwidth and exceptional electric field amplitude. A large-area interdigitated two-electrode structure is applied to a GaAs substrate to offer high electric fields. Photocarriers excited by a Ti:Sapphire oscillator laser with MHz repetition rate are accelerated there, yielding an intense THz output. An appropriate binary mask covers every second electrode interval and carriers are excited in uniform electric field areas only. Hence contrary carrier acceleration and destructive interference is avoided. The maximum THz field amplitude, detected by electro-optic sampling, is 1.5 kV/cm, which is almost one order of magnitude more of what is achieved with other photoconductive oscillator-excited emitters. For an excitation spot diameter of 300 μm, which corresponds to the central wavelength of the THz pulses, the THz generation is most efficient. An average THz power of 145 μW is generated with a NIR-to-THz power-conversion efficiency of 2×10^{-4}. The THz power can be improved by a sufficient cooling system. The use of LT GaAs instead of semi insulating GaAs can result in larger THz bandwidth.

HL 24.7 Tue 16:45 POT 151

Ultrafast Dynamics at the Quantum Hall Ferromagnet — •Bertram Su[1], Detlef Heitmann[1], Werner Wegscheider[2], and Christian Schüller[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We report ultrafast spectroscopy experiments at the v = 1 quantum Hall state of a high-mobility two-dimensional electron system (2DES) in a GaAs single quantum well. Via a semitransparent metallic gate, the density of the 2DES can be tuned in a broad range. By spectrally-resolved four-wave-mixing (SR-FWM) experiments we have investigated the coherent dynamics of photo-excited electron-hole pairs. We observe a strong maximum of the SR-FWM signal around v = 1 in the right-circularly polarized spectra, i.e., if we selectively excite into the empty upper spin level. In this situation, the dephasing time T2 is as long as 14 ps. At v < 1 and v > 1, the dephasing time decreases dramatically, where the decreasing is faster for v < 1. We assume that around v = 1 the formation dynamics of spin textures is dominating the ultrafast dynamics.

HL 24.8 Tue 17:00 POT 151

Generation of high-frequency transverse polarized monochromatic acoustic phonons by ultrafast optical excitation in gallium arsenide — •D. Lehmann[1], A.J. Kent[2], R.N. Kini[2], N.M. Stanton[2], Cz. Jasiukiewicz[3], and M. Henini[2] — [1]Institute of Theoretical Physics, TU Dresden, D-01062 Dresden, Germany — [2]School of Physics and Astronomy, University of Nottingham, NG7 2RD, Nottingham, UK — [3]Department of Physics, University of Technology, ul. W. Pola 2, PL-35-359 Rzeszow, Poland

There is interest in developing useable sources of THz monochromatic acoustic phonon beams for applications in phonon spectroscopy, acoustic microscopy, probing of nanostructures etc. In recent years, the generation of high intensity pulses of acoustic phonons by ultrafast optical techniques has been demonstrated, but the work has concentrated mainly on longitudinally polarized phonons [1].

We have generated coherent transverse polarized acoustic phonons by ultrafast optical excitation of GaAs/AlGaAs superlattices grown on low-index planes of GaAs [2]. The frequency of the generated phonons is determined by the superlattice period. The phonons can leak out of the superlattice and propagate over macroscopic distances as a monochromatic pulse. We show that theoretical estimations and pump probe measurements suggest a Raman scattering process is responsible for the coherent phonon generation.

[1] N.M. Stanton, R.N. Kini, A.J. Kent, M.Henini and D. Lehmann, Phys. Rev. B 68, 113302 (2003)

[2] R.N. Kini et al., submitted to Appl. Phys. Lett.

HL 24.9 Tue 17:15 POT 151

Ultrafast dynamics of the mid-infrared response of carbon nanotubes and graphite — •Christian Frischkorn, Tobias Kampfrath, Luca Perfetti, and Martin Wolf — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

We report on time-resolved measurements of low-energy excitations in 1- and 2-dimensional solids like carbon nanotubes and thin graphite films. The mid-infrared response of these systems has been obtained from time-resolved THz spectroscopy data in the 10 - 30 THz spectral range. For carbon nanotubes, we find essentially two processes governing an electronic current dynamics [1]. First, strongly bound excitons are the main photoproduct in large-band gap tubes and thus prevent a typical free-carrier response, while in small-gap and metallic tubes carrier localization due to defects is observed as manifested in a substantial dichroism. In these measurements, the reduced polarizability perpendicular to the tube axis is exploited. In the case of graphite, a 2-dimensional semimetal, our results show that strongly coupled optical phonons in the

graphite layer dominate the ultrafast energy and transport relaxation dynamics after optical excitation [2]. These phonon modes heat up on a femtosecond time scale and cool down with a time constant of several picoseconds. Moreover, the observed pronounced increase in the Drude relaxation rate significantly originates from these few active lattice vibrations. Our findings for both carbon nanotubes and graphite are of fundamental importance for technological applications in nanoelectronics. - [1] PRL (submitted); [2] PRL **95**, 187403 (2005).

HL 24.10 Tue 17:30 POT 151

Intersubband relaxation dynamics in narrow InGaAs/AlAsSb and InGaAs/AlAs quantum well structures using pump-probe spectroscopy — •C V-B Tribuzy[1], S Ohser[1], J Neuhaus[2], T Dekorsy[2], S Winnerl[1], H Schneider[1], M Helm[1], K Biermann[3], H Künzel [3], M.P Semtsiv[4], and W.T Masselink[4] — [1]Inst of Ion Beam Phys and Mat Res, Fz-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany — [2]Dep Phys, Univ Konstanz, 78457 Konstanz, Germany — [3]FI für Nachrichtentechnik-HHI, 10587 Berlin, Germany — [4]Dep Phys, Humboldt-Univ. of Berlin, 12489 Berlin, Germany

Intersubband (ISB) transitions in semiconductor quantum wells (QWs) can be employed for various mid-infrared optoelectronic devices. Presently there is strong interest to extend the available wavelength range into the near infrared, by using materials with a large conduction band offset. To achieve such short wavelengths thin QWs are required, where the first excited state inside the QW may lie higher than some state related to indirect valleys. Examples for such material systems are strained InGaAs/AlAs or lattice matched InGaAs/AlAsSb, both grown on InP. We have studied the ISB relaxation dynamics in multi QWs of both material systems by femtosecond pump-probe measurements. The transient transmission as a function of the pump-probe delay does not show a single-exponential decay, indicating a more complicated relaxation dynamics. This can be caused by transfer of electrons to X- or L- states in the QWs or the barriers. We will show results on samples with different QW thicknesses and compare them to simulations based on rate equations.

HL 24.11 Tue 17:45 POT 151

Ultrafast near resonant nonlinear propagation in GaAs - a theoretical model study — •Martin Schaarschmidt, Jan Kloppenburg, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Pulse propagation close but well below the semiconductor excitonic resonance is investigated. In this spectral region the excitonic resonance often dominates over most off-resonant material resonances. We discuss the suitability of different model systems for the description of occuring material nonlinearities ranging from Kerr nonlinearity, excitonic Pauli-Blocking up to semiconductor Bloch equations (SBE) including many particle effects. The differences between the nonlinear Schrödinger equation with Kerr-type nonlinearity usually applied for propagation far from the resonance, the optical Bloch equations known from propagation in atomic gases and the Maxwell semiconductor Bloch equations are studied and compared with recent experiments.

HL 25 C/diamond

Time: Tuesday 18:00–19:00 Room: POT 151

HL 25.1 Tue 18:00 POT 151

Electronic and optical properties of boron-doped nanocrystalline diamond — •Wojciech Gajewski[1], Jose Garrido[1], Ken Haenen[2], Oliver Williams[2], and Martin Stutzmann[1] — [1]Walter Schottky Institute, - TU München, Am Coulombwall 3, 85748 Garching — [2]Institute for Materials Research, University of Hasselt, Wetenschapspark 1, 3590, Belgium

We report the optical and electronic properties of boron-doped nanocrystalline diamond (B-NCD) thin films, grown on quartz substrates by CH4/H2 plasma CVD. Diamond thin films with a thickness below 200 nm and with boron concentractions rangeing from 0 to 5000 ppm have been investigated. Hall effect measurements confirmed the expected p-type conductivity. The conductivity of B-doped NCD samples with low boron concentrationin the gas phase strongly depends on temperature. The carrier concentration in the temperature range from 400K to 700K is thermally activated. At higher boron doping, the conductivity and the carrier concentration are no longer temperature dependent, and the samples exhibit quasimetallic properties. The Hall mobility shows no clear temperature dependence. As expected, the higher the carrier concentration, the lower the mobility. Spectrally resolved photocurrent measurements have revealed a strong dependence of the photosignal on the surface termination. Major differences occur in the energy range 3.5 - 5.4 eV. The influence of grain boundaries and surface states on the electronic transport and optical properties will be discussed.

HL 25.2 Tue 18:15 POT 151

Thin films of metallic carbon nanotubes and their optical spectra — •Sabine Blatt[1], Frank Hennrich[1], Hilbert v. Löhneysen[2,3], and Ralph Krupke[1] — [1]Forschungszentrum Karlsruhe, Institut für Nanotechnologie, 76021 Karlsruhe — [2]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe — [3]Forschungszentrum Karlsruhe, Institut für Festkörperphysik, 76021 Karlsruhe

The exceptional electrical and structural properties of single-walled carbon nanotubes (SWNTs) open up a wide range of future applications provided that metallic and semiconducting nanotubes can be separated on a large scale. The separation through dielectrophoresis makes use of the different electric field-induced polarizabilities of the two types leading to a separation in ac electric fields [1, 2]. This method allows for the first time to produce thin films of only metallic SWNTs and to measure their optical absorption spectra [3]. Recent experiments address the dependence of the separation yield on the type and the concentration of the surfactant used to disperse the nanotubes and on the conductivity of the dispersion. For a better understanding of the dielectrophoretic forces finite elements simulations are performed additionally.

[1] Krupke,R.; Hennrich, F.; v. Löhneysen, H.; Kappes, M. M. Science 2003, 301, 344-347 [2] Krupke R.; Hennrich F.; Kappes M. M.; v. Löhneysen H. Nano Lett. 2004, 4, 1395-1399 [3] Krupke, R.; Linden, S.; Rapp, M.; Hennrich, F. cond-mat/0508418

HL 25.3 Tue 18:30 POT 151

Chemical functionalization of ultrananocrystalline diamond thin films with aromatic molecules — •S.Q. Lud[1], M. Dankerl[1], J. Hernando[1], M. Steenackers[2], R. Jordan[2], P. Bruno[3], D.M. Gruen[3], P. Feulner[4], J.A. Garrido[1], and M. Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Lehrstuhl für Makromolekulare Stoffe, Technische Universität München, Lichtenbergstrasse 4, 85747 Garching, Germany — [3]Materials Science Department, Argonne National Laboratory, Argonne, Illinois 60439, USA — [4]Physics Department E20, Technische Universität München, James-Franck-Strasse, 85748, Garching, Germany

We present a novel approach for the surface functionalization of ultrananocrystalline diamond films via grafting of high-reactive 4-nitrobiphenyl-4-diazonium cations. The grafting process is associated with the cleavage of dinitrogen followed by the binding of the remaining radicals to the surface, forming a stable and covalent C-C bond. X-ray photoelectron spectroscopy, ac impedance spectroscopy, atomic force microscopy and cyclic voltammetry have been used to investigate the stucture and surface coverage of the organic overlayer. We have further explored the electrochemically controlled conversion of the surface nitro group to an amino group. The resulting surface offers a reliable surface chemistry for subsequent modification in contrast to the non-reactive nitro group. With this approach, an adressable coupling of biological molecules to an inert and inorganic solid substrate, with considerable importance for biosensing tasks, can be explored.

HL 25.4 Tue 18:45 POT 151

Simulations of Novel Nanoporous Carbon Materials — •Johan M. Carlsson and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin

Carbon is one of the most versatile elements in nature and Nanoporous carbon (NPC) constitutes yet another class of carbon materials that exhibit unusual properties. NPC has the ability to catalyze dehydrogenation reactions, but the actuating chemical reaction steps are still unclear.

This uncertainty is also due to the fact that the atomic structure of NPC depends on the preparation conditions. TEM experiments suggest that NPC derived from hydrocarbons has the form of crumpled graphene sheets with a significant amount of non-hexagonal rings in the structure. We have therefore carried out an extensive study to characterize NPC. Our density-functional theory (DFT) calculations reveal that the atomic relaxation transforms defects into combinations of non-hexagonal rings, which we identify as the "motifs of NPC". These motifs lead to strain and local buckling of the structure. They also induce defect states close to the Fermi level, leading to that some of them being charged, which may facilitate molecule dissociation. These motifs can then be combined to build models of new carbon materials. A random distribution of the motifs leads to the formation of a NPC material while an ordered configuration of the motifs can instead form new, graphene like, carbon structures based on non-hexagonal rings, similar to the Haeckelites. Our calculations indicate that both NPC and the generalized Haeckelites can have a heat of formation comparable to other metastable carbon materials such as nanotubes.

HL 26 II-VI semiconductors II

Time: Tuesday 15:15–18:45 Room: POT 51

HL 26.1 Tue 15:15 POT 51

Homoepitaxial Growth of ZnO — •Stefan Lautenschläger, Arndt Zeuner, Joachim Sann, Niklas Volbers, Swen Graubner, and Bruno K. Meyer — I. Physikalisches Institut, Justus Liebig Universität Giessen, Heinrich Buff Ring 16, 35392 Giessen

ZnO, 1960's promising semiconductor, is regaining increased interest after the first reports of p-type doping. Its direct bandgap and total transparency for visible light suppose this material is suitable for many applications. Nowadays ZnO single crystals are available in sizes up to two inches.

Here we report on homoepitaxial growth of ZnO on ZnO single crystals with a home-bulit CVD epitaxy system. We were able to grow nominally undoped thin films of high quality. In doped samples we found the incorporation of nitrogen acceptors and lithium into the ZnO lattice.

All films were characterised by PL, XRD, SEM, SIMS and Hall measurements.

HL 26.2 Tue 15:30 POT 51

Defect mediated ferromagnetism in $Zn_{0.95}Co_{0.5}O$:(Cu,Al) thin films — •Lars Hartmann, Qingyu Xu, Heidemarie Schmidt, Holger Hochmuth, Michael Lorenz, Rüdiger Schmidt-Grund, Daniel Spemann, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

Only recently it has been experimentally shown that defects mediate the ferromagnetism in $Zn_{0.95}Co_{0.05}O$ codoped Cu [1]. Cu is an acceptor lying only 0.17 eV below the ZnO conduction band [2]. Our work focusses on the optimization of defect mediated ferromagnetism in n-conducting $Zn_{0.95}Co_{0.05}O$:(Cu,Al) thin films grown by pulsed laser deposition on sapphire substrates. Numerical simulations [3] revealed that for codoping with $10^{20}cm^{-3}$ Cu and $10^{20}cm^{-3}$Al even at room temperature the Cu acceptors are occupied by unpaired electrons. The influence of the Co transition metal on the position of the Fermi level has been accounted for by growing ZnO:(Cu,Al) reference samples. By relating the temperature dependent position of the Fermi level with the experimentally determined free charge carrier concentrations, it will be shown how unpaired electrons being localized on the Cu acceptors influence the magnetoresistance of $Zn_{0.95}Co_{0.05}O$:(Cu,Al) thin films.

[1] M.H.F. Sluiter, Phys. Rev. Lett. 94 (2005) 187204
[2] Y. Kani, Jpn. J. Appl. Phys. 30 (1991) 703
[3] using NextNano3 (http://www.nextnano.de/)

HL 26.3 Tue 15:45 POT 51

Alloy Fluctuations and Phase separation in ZnCdO Layers: Thermalization and Carrier Freeze Out — •Alexander Franke[1], Thomas Hempel[1], Silke Petzold[1], Frank Bertram[1], Jürgen Christen[1], R. Kling[2], Christoph Kirchner[2], and Andreas Waag[3] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Department of Semiconductor Physics, Ulm University, Germany — [3]Department of Semiconductor Technology, Braunschweig Technical University, Germany

An inherent problem for the epitaxial growth ZnCdO is a different crystallization of ZnO and CdO into wurtzite and rock-salt structure, respectively resulting in local stoichiometry fluctuation and decomposition up to phase separation. A series of MOCVD grown $Zn_{1-x}Cd_xO$ layers with systematically increasing Cd-content (0.3%–2.0%) were analyzed using photoluminescence spectroscopy (PL). A systematic red-shift (3.239eV–3.150eV) and broadening of the PL peak is observed with increasing [Cd] merging into a splitting into two well distinguished peaks. While the high energetic main PL peak (dominant Cd-concentration) shows a linear excitation density dependence over more than 4 orders of magnitude, a super-linear dependence is found for the evolving satellite peak (minor Cd-rich local phase). The temperature dependence exhibits a pronounced s-shape behavior of the peak energy characteristic for thermalization and freeze out of the carriers in local potential fluctuations. The PL results are compared with highly spatially resolved cathodoluminescence directly visualizing the Cd-fluctuations and the phase separation.

HL 26.4 Tue 16:00 POT 51

Whispering gallery modes in hexagonal nanocavities – theory vs. experiment. — •Thomas Nobis, Andreas Rahm, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstraße 5, D-04103 Leipzig

Concerning nano-photonics, zinc oxide (ZnO) nanostructures are frequently envisioned as resonator cavities in future optical devices, such as nanolasers. Thus, a precise understanding of their optical modes is strongly necessary. In this work we analyzed the lateral optical modes, so-called whispering gallery modes (WGMs), of ZnO nanopillars grown by pulsed laser deposition with diameters around 800 nm. The regular hexagonal cross-section of the pillars naturally defines a two-dimensional (2D) dielectric cavity with the light circulating inside being totally internally reflected. Our analysis includes detailed numerical simulations of hexagonal WGMs solving the 2D Helmholtz-equation with respect to resonant wave numbers, line widths, mode patterns, polarization, mode degeneracy and spectral dispersion. Utilizing our numerical results we are able to simulate characteristic resonance lines of individual ZnO nanopillars in perfect agreement with the experiment [1]. As a result we can extract the birefringence of single pillars out of their WGM spectrum. Hence, the whispering gallery effect has been utilized to detect optical constants of nano-sized samples.

[1] Th. Nobis and M. Grundmann, Phys. Rev. A, in press

HL 26.5 Tue 16:15 POT 51

MOCVD-Growth of Arsenic and Nitrogen (dual)-doped epilayers: structural, electrical and optical properties — •Sören Giemsch, Armin Dadgar, Andre Krtschil, Frank Bertram, Jürgen Christen, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

The direct semiconductor ZnO with a large band-gap of 3.3 eV at room temperature and a binding energy of 60 meV for the free exciton offers great potential for inexpensive optoelectronic devices in the blue and near UV spectral region. Despite numerous research activities over the last years, reproducible and long-time-stable p-type ZnO is still difficult to achieve. Nitrogen at an oxygen-site and arsenic are potential candidates for the realisation of acceptor levels in ZnO and thereby p-type-conductivity. In scanning-capacitance-microscope measurements the long-time-stable p-type behaviour of MOCVD-grown nitrogen and arsenic dual doped ZnO-epilayers was shown [1]. Here we show further investigations of As-mono-doped and N / As-dual-doped MOCVD-grown ZnO-layers. The structural, electrical and optical properties of the epilayers grown under different AsH_3- and UDMHy-flows will be compared. [1]: A. Krtschil, A. Dadgar, N. Oleynik, J. Bläsing, A. Diez, and A. Krost, *Local $p-type$ conductivity in zinc oxide $co-$ doped with nitrogen and arsenic*, APL, to be published

HL 26.6 Tue 16:30 POT 51

Photoluminescence investigations on a native donor in ZnO — •Joachim Sann, Niklas Volbers, Stefan Lautenschläger, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

The shallow donor impurities in ZnO with binding energies between 46 and 56 meV have been studied in great detail in the recent years. They give rise to neutral donor bound exciton recombinations with the A- and B-valence bands, show rotator states and two-electron-satellite transitions. These properties allowed to establish the excited state splittings of the donors as well as confirming Hayne's rule in ZnO. So far they all seem to be of extrinsic origin, hydrogen, aluminum, gallium and indium in order of increasing binding energy. For many years it was common sense that intrinsic defects would dominate the n-type conductivity of ZnO. Interstitial zinc as well as oxygen vacancies should be double donors, and in order to contribute to the n-type-conduction they should have shallow levels, and low formation energies to be abundant. Undoped Zn-rich epitaxial films grown by CVD on GaN/Sapphire-templates as well as on ZnO templates show a dominant I_{3a} recombination at 3.367 eV in low temperature PL which according to Haynes rule is consistent with a shallow donor level at 37 meV. Moreover, they have free n-type carrier densities of 8x10^{18} cm^{-3} and as revealed by SIMS the common donor impurities (Al, Ga, In) cannot account for the high carrier densities. By changing the Zn/O ratio towards oxygen rich conditions the I_{3a} recombination is suppressed, a similar effect is found when annealing in oxygen atmosphere.

HL 26.7 Tue 16:45 POT 51

Fe^{2+} in ZnO studied by Fourier-transform transmission spectroscopy — •Enno Malguth[1], Axel Hoffmann[2], Matthew Phillips[1], and B. Hausmann[2] — [1]Microstructural Analysis Unit, University of Technology, Sydney, Australia — [2]Institut für Festkörperphysik, Technische Universität Berlin, Germany

ZnO crystals, coated with a 1 μm thick Fe layer and subsequently annealed under different atmospheres were studied by means of Fourier-transform infrared (FTIR) transmission spectroscopy. At 50 K, a pronounced absorption structure was detected around 395 meV exhibiting at least five distinct lines. Even at room temperature, a broad peak centered around 400 meV was observed. We attribute this absorption feature to the internal $^5E \longrightarrow {}^5T_2$ transition of the isolated Fe^{2+} center. This transition has been thoroughly studied in several cubic III-V and II-VI semiconductor materials, where it was found at similar energetic positions. However so far, it has not been established satisfactorily in ZnO where a crystal field of c_{3V} symmetry causes an additional splitting of the involved electronic states. By means of polarized measurements the observed lines are tentatively assigned to single transitions between ^5E and $^5T_2$ sublevels according to transition rules.

HL 26.8 Tue 17:00 POT 51

Hyperfine splitting in hydrogenated ZnO measured by electron spin resonance — •Marc A. Gluba, Felice Friedrich, and Norbert H. Nickel — Hahn-Meitner-Institut Berlin, Abteilung Silizium-Photovoltaik, Kekuléstraße 5, D-12489 Berlin

The source of the natural n-type doping of zinc oxide single crystals is still not completely clarified. However, hydrogen as an indispensable permanent impurity plays a crucial role. To elucidate the importance of hydrogen X-band electron spin resonance (ESR) measurements were performed on zinc oxide single crystals before and after hydrogenation. Hydrogen was introduced by annealing the samples for two hours at 830°C in sealed ampoules under hydrogen atmosphere. The ESR-measurements were performed at 5K.

As-grown zinc oxide exhibits a single ESR line arising from two shallow donors with similar g-values ($g_{||} = 1,957$, $g_{\perp} = 1,956$). One of which was identified as hydrogen [1]. On the other hand, hydrogenated zinc oxide shows distinctly different ESR spectra. Besides the intensification of the donor related line a variety of new features in a broad range of about 1000G around the center line is observed. These are likely to arise from hyperfine interaction between electrons of neutralized hydrogen donors and adjacent ^{67}Zn nuclei of spin 5/2. Based on the performed experiments conclusions on the position of the hydrogen centers in the ZnO lattice can be drawn.

[1] Detlev M. Hofmann et al., Phys. Rev. Lett., **88** no. 4, 045504 (2002)

HL 26.9 Tue 17:15 POT 51

First-principles study of migration mechanisms and diffusion of oxygen in zinc oxide — •Paul Erhart and Karsten Albe — Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt

We have performed density-functional theory (DFT) calculations in conjunction with the climbing image-nudged elastic band method (CI-NEB) in order to study the self-diffusion of oxgyen in zinc oxide. To this end, we have generalized the migration paths accessible for vacancies as well as interstitials in wurtzite crystals and derived expressions which provide the link to experimentally accessible tracer diffusion coefficients. The calculated migration barriers are consistent with annealing experiments on irradiated samples. We find that vacancy and interstitialcy mechanisms dominate under zinc and oxygen-rich conditions, respectively. Either mechanism can in principle lead to the experimentally observed diffusivities. However, diffusion experiments are normally carried out in oxygen atomosphere and will, therefore, sample oxygen interstitial diffusion. Our results provide the basis for the (re-)interpretation of previous and future diffusion experiments, and pave the way towards the development of reliable continuum models for device simulation.

HL 26.10 Tue 17:30 POT 51

A comparative study of the substrate influence on the structure of pulsed laser-deposited ZnO thin films — •Felice Friedrich, Ina Sieber, and Norbert H. Nickel — HMI Berlin, Abt. SE1, Kekuléstr. 5, D-12489 Berlin

Nominally undoped ZnO thin films were deposited by pulsed laser deposition (PLD) on different substrates, namely silicon, quartz, sapphire, and magnesium oxide. For better comparability ZnO was grown on all substrates simultaneously. The thickness of the resulting ZnO layers was about 1 μm. The chamber pressure was varied between 10^{-3} mbar and 3 mbar depending on the oxygen flow whereas the deposition temperature was held constant at 700°C. The films were characterized using SEM and Raman backscattering spectroscopy.

With increasing pressure a transition from ZnO thin films to the formation of nanostructures was observed. Furthermore a strong influence of the substrate on the layer orientation and the degree of disorder in the ZnO films has been found. This is likely due to the respective lattice mismatch. Raman spectra of the films on quartz substrates show the recently controversially discussed additional local vibrational modes that were observed in doped ZnO thin films and amongst others related to the presence of nitrogen [1]. However, in connection with the SEM results we tend to assign these modes to disorder activated Raman scattering of the silent B_1 modes in ZnO [2]. This will be discussed in detail.

[1] Haboeck et al., PSS (b) 242 (2005) R21
[2] Manjón et al., JAP 97 (2005) 053516

HL 26.11 Tue 17:45 POT 51

Optical and electrical properties of phosphorous doped ZnO thin films — •M. Grundmann[1], H. von Wenckstern[1], J. Sann[2], M. Brandt[1], G. Benndorf[1], S. Heitsch[1], A. Krtschil[3], M. Lorenz[1], B. K. Meyer[2], and A. Krost[3] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig — [2]I.Physikalisches Institut JLU-Gießen, Heinrich-Buff-Ring 16, D-35392 Gießen — [3]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, PO Box 4120, 39016 Magdeburg

ZnO is a wide band-gap semiconductor with remarkable material properties. First and foremost the large excitonic binding energy of about 60 meV makes ZnO interesting for UV optoelectronic applications. The major obstacle nowadays is the difficulty of reproducibly growing high quality p-type ZnO. We have investigated the properties of ZnO thin films doped with phosphorous. The samples are grown by pulsed-laser deposition on sapphire or ZnO single crystalline substrates. The optical properties are investigated by means of recombination spectra. Integral electrical properties are obtained from Hall effect measurements. The Fermi level close to the surface is determined by scanning surface potential microscopy. Possible lateral dependencies of the net doping density are investigated by scanning capacitance microscopy, showing p-type domains for homo-epitaxially grown ZnO:P, for instance. Independent on the growth conditions the samples show a pronounced correlation between the resistivity and with that the Fermi level and the intensity ratio between the near band edge and deep level emission.

HL 26.12 Tue 18:00 POT 51

Electrical characterization of deep acceptor states in N implanted ZnO single crystals — •H. von Wenckstern[1], H. Schmidt[1], R. Pickenhain[1], G. Biehne[1], M. Brandt[1], G. Brauer[2], M. Lorenz[1], and M. Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig — [2]Institut für Ionenstrahlphysik und Materialforschung, FZ Rossendorf, Postfach 510119, D-01314 Dresden

ZnO is investigated again in the past few years with enormous effort due to, e.g., the availability of ZnO substrate material or the promising material properties of ZnO such as the high exciton binding energy or the radiation hardness. Up to now, several deep electron traps in ZnO have been characterized electrically. To our knowledge there do not exist any reports concerning elctrical characterization of deep acceptor-like states in ZnO. We report in this contribution on acceptor-like states in ZnO investigated by deep level transient spectroscopy (DLTS). For that, a ZnO single crystal was implanted by N^+ ions using an acceleration voltage of 150 keV. The crystal was annealed prior to the electrical characterization for 30 min at 500°C in an oxygen ambient to reduce damage caused by implantation. Scanning capacitance microscopy measurements on the implanted side of the sample revealed *p*-type conduction. With that, the observation of both electron and acceptor-like defects is possible. The DLTS measurements confirmed the existence of the electron traps E3 and E4. Additionally, we were for the first time able to characterize a deep acceptor state labelled W2. The thermal activation energy of W2 is estimated to be 260 - 280 meV.

HL 26.13 Tue 18:15 POT 51

ZnO films doped with rare earth metals — •M. Diaconu[1], H. Schmidt[1], H. Hochmuth[1], H. von Wenckstern[1], D. Spemann[1], M. Lorenz[1], M. Grundmann[1], M. Fecioru-Morariu[2], K. Schmalbuch[2], and G. Güntherodt[2] — [1]Inst. für Exp. Physik II, Fakultät für Physik, Uni. Leipzig, Linnestrasse 3-5, 04103 Leipzig — [2]II. Physikalisches Institut, RWTH Aachen, Physikzentrum Melaten, Huyskensweg Turm 28B, 52074 Aachen

The electrical and magnetic properties of ZnO:Gd and ZnO:Nd were studied for films grown by pulsed laser deposition on *a*-plane sapphire. Different growth conditions were used to prepare ZnREO films with RE = Gd or Nd contents around 0.01, 0.1 or 1 at% and thicknesses from 50 nm to 1000 nm. The rare earth concentration and position in the wurtzite lattice were determined by Rutherford backscattering and particle induced X-ray emission. Hall investigations revealed a dependence of the electrical properties on film thickness and composition. Magnetic properties were investigated in a wide temperature range using a superconducting quantum interference device and magneto-optical Kerr effect.

HL 26.14 Tue 18:30 POT 51

Optical characterisation of ZnO nanostructures grown by various methods — •Chegnui Bekeny[1], Houcem Gafsi[1], Tobias Voss[1], Bianca Postels[2], Marc Kreye[2], Sandra Börner[3], and Wolfgang Schade[3] — [1]Institute of Solid State Physics, University of Bremen, P.O Box 330440, D-28334 Bremen — [2]IHT, TU Braunschweig, P.O Box 3329, D-38023 Braunschweig — [3]IPPT, TU Clausthal, Leibnizstraße 4, D-38678, Clausthal-Zellerfeld

ZnO, a semiconductor with a band gap of 3.37 eV, is currently in the focus of research due to its relatively large exciton binding energy of 60 meV and its ability to emit light in the uv spectral region. In order to integrate ZnO nanostructures into optoelectronic devices, it is imperative to thoroughly understand their optical properties. We present systematic photoluminescence studies of ZnO nanorods fabricated by aqueous chemical growth (ACG). These nanorods show significant near band-edge excitonic luminescence accompanied by very little green and orange defect luminescence. In combination with distinct phonon replica of the excitonic lines observed this indicates a good optical quality of the ACG nanorods. The optical properties of nanorods grown on different substrates (Si and plastic foil) will be compared with ZnO nanostructures grown by other epitaxial methods. Additional investigations concerning possible laser action in ZnO nanowires were performed using vapour-liquid-solid grown nanowires. At high excitation densities (>0.5 MW/cm*) single nanowires (dispersed on a sapphire substrate) showed a narrow emission line at ~3.2 eV (line width 0.5 meV) even at room temperature.

HL 27 Symposium New phenomena in edge transport of QHE systems

Time: Wednesday 14:30–16:30 Room: HSZ 01

Keynote Talk

HL 27.1 Wed 14:30 HSZ 01

Bending the quantum Hall effect: Novel metallic and insulating states in one dimension — •Matthew Grayson — Walter Schottky Institut, TU-Muenchen

One-dimensional conductors are the wires that will connect the circuits of tomorrow's nanoworld, so it is important to characterize their possible conducting phases. We study a novel one-dimensional wire state which arises at the corner of two quantum Hall systems joined at a 90 degree angle, and observe one-dimensional metallic and insulating states. Such non-planar confinement structures are unconventional for the quantum Hall effect and reveal the striking observation of a macroscopic one-dimensional state whose conductance increases with decreasing temperature. This single system can map out generic properties of disordered one-dimensional conductors since the metallic, critical, or insulating character is tunable with an external parameter, the magnetic field.

Keynote Talk

HL 27.2 Wed 15:00 HSZ 01

Particle-hole symmetric Luttinger liquids in a quantum Hall circuit — •Vittorio Pellegrini[1], Stefano Roddaro[1], Fabio Beltram[1], Lucia Sorba[2], Giorgio Biasiol [2], Loren N. Pfeiffer[3], and K.W. West[3] — [1]NEST CNR-INFM, Scuola Normale Superiore, Pisa — [2]TASC CNR-INFM Trieste — [3]Lucent Technologies, NJ USA

We report evidence of a novel class of one-dimensional Tomonaga-Luttinger liquids (TLLs) with tunable properties. These electron liquids are induced by a nanocostriction defined with metallic gates on a two-dimensional electron gas in the quantum Hall (QH) regime. TLLs occur in the QH edges and they are usually observed when the occupation of the lowest Landau level of the two-dimensional electron gas subjected to a magnetic field is equal to particular fractional values [1,2]. Our work shows that the observation of TLLs in edge states is not restricted to the extreme quantum limit of the fractional QH effects [3,4]. The evidences are based on the experimental and theoretical analysis of the out-of-equilibrium (finite-bias) current transmission and reflection characteristics through the split-gate constriction. Split-gate biasing drives inter-edge backscattering and is shown to lead to suppressed or enhanced transmission even in the integer QH regime, in marked contrast with the expected linear Fermi-liquid behavior. This evolution is described in terms of particle-hole symmetry and allows us to conclude that an unexpected class of gate-controlled particle-hole-symmetric TLLs can exist at the edges of our integer QH circuit [4]. These results highlight the role of particle-hole symmetry on the properties of TLL edge states.

[1] A.M Chang, Rev. Mod. Phys. 75, 1449 (2003), [2] S. Roddaro, V. Pellegrini, G. Biasiol, L. Sorba, R. Raimondi, G. Vignale, Phys.Rev.Lett. 90, 046805 (2003), [3] S. Roddaro, V. Pellegrini, F. Beltram, G. Biasiol, L. Sorba Phys. Rev. Lett. 93, 046801 (2004), [4] S. Roddaro, V. Pellegrini, F. Beltram, L.N. Pfeiffer, K.W. West Phys. Rev. Lett. 95, 156804 (2005)

Keynote Talk

HL 27.3 Wed 15:30 HSZ 01

The Detection and Spectroscopy of Millimeter Wave Radiation based on the Interference of Edge-Magnetoplasmons — •Jurgen Smet[1], Igor Kukushkin[1,2], Chunping Jiang[1], Sergey Mikhailov[1,3], and Klaus von Klitzing[1,2] — [1]Max-Planck-Institute for Solid State Physics, 70569 Stuttgart, Germany — [2]Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, 142432 Russia — [3]Mid-Sweden University, ITM, Electronics Design Division, 85170 Sundsval, Sweden

A two-dimensional electron system patterned in a suitable shape and subjected to monochromatic microwave radiation exhibits a photovoltage, which oscillates periodically with an applied magnetic field. This phenomenon is distinct from the recently discovered microwave induced zero resistance effect and persists even in samples of moderate quality. The periodicity depends approximately linearly on the carrier density

and is inversely proportional to the frequency of the incident radiation. This photovoltaic effect is ascribed to the interference of coherently excited edge magnetoplasmons. Its robustness up to liquid nitrogen temperatures offers interesting perspectives for using it for millimeter and sub-millimeter wave detection and spectroscopy.

Keynote Talk HL 27.4 Wed 16:00 HSZ 01

Selective edge excitations - inter-edge magnetoplasmon mode and inter-edge spin diode — •Frank Hohls[1,2], Gennadiy Sukhodub[2], and Rolf J. Haug[2] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Abteilung Nanostrukturen, Institut für Festkörperphysik, Universität Hannover

The selective excitation and detection of quantum Hall edge states has opened access to several interesting phenomenons, two of which I will review in this talk: Firstly I will present time-resolved current measurements of edge magnetoplasmons. At filling factors close to $\nu = 3$ we observe two decoupled modes of edge excitations, one of which is related to the innermost compressible strip and is identified as an inter-edge magnetoplasmon mode [1]. From the analysis of the propagation velocities of each mode the internal spatial parameters of the edge structure are derived. Secondly we have studied the tunnelling between spin polarised edge states at high magnetic fields up to 28 T. Measurements of the inter-edge I-V characteristic in tilted magnetic fields B allow to determine the effective g-factor $g^*(B)$ [2]. We also observe a dynamical nuclear spin polarization.

[1] G. Sukhodub, F. Hohls, and R. J. Haug, PRL **93**, 196801 (2004).
[2] G. Sukhodub *et al.*, Int. J. Mod. Phys. B **18**, 3649 (2004).

HL 28 Transport in high magnetic field/Quantum Hall-effect

Time: Wednesday 16:30–17:00 Room: HSZ 01

HL 28.1 Wed 16:30 HSZ 01

Electron interference and single electron charging in electronic Mach-Zehnder interferometer — •Leonid Litvin, Thomas Geiger, Peter Tranitz, Werner Wegscheider, and Cristoph Strunk — Institute for Experimental and Applied Physics; University of Regensburg, D-93040 Regensburg, Germany

Mach-Zehnder interferometer is promising device for two beam experiments with electrons in the integer quantum Hall regime where the electron flow is confined to a few edge states [1]. The effective path length and thus the phase accumulated along the edge states can be tuned by external magnetic field and a gate electrode. We have prepared Mach-Zehnder interferometers using high mobility GaAs/AlGaAs heterostructures and found two types of oscillation in current through the device as function of gate voltage: Aharonov-Bohm oscillations and smaller oscillation with six times smaller period. The small period oscillation show a beating pattern indicating two underlying frequencies, which correspond to the presence of two edge states (v=2) in the interferometer. From the temperature dependence of the small oscillation amplitude we infer a characteristic energy scale of 17*10ˆ(-6) eV, which is in reasonable agreement with the charging energy of the interferometer. This points towards single electron charging as the origin of the additional small period oscillation. [1] Yang Ji et al., Nature 422, 415 (2003)

HL 28.2 Wed 16:45 HSZ 01

Surface-Acoustic-Wave study of the spin phase transition at ν=2/3 in narrow quantum wells — •Dimitri Dini[1], Werner Dietsche[1], Klaus von Klitzing[1], Chris Mellor[2], and Maik Hauser[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]School of Physics and Astronomy, Nottingham University, Nottingham, Great Britain

We measure the conductivity σ_{xx} at filling factor ν=2/3 using DC as well as surface acoustic wave (SAW) techniques. Surprisingly, we detect features related to the spin phase transition in DC measurement but *not* in SAW ones. Within the composite fermion picture, ν=2/3 corresponds to two fully occupied Landau levels (LLs). With increasing magnetic field a transition from unpolarized electrons (the two LLs have different spin polarization) to spin-polarized electrons (Zeeman energy so large, that only one spin-polarization dominates) is observed. At the transition point, where two LLs cross each other, the electronic system may consist of domains with different spin polarization. We present experimental results which show that the spin phase transition is visible in DC experiments caused by the disappearing of the gap at the crossing point between LLs, whereas the SAW-damping (which depends on the conductivity) with surface acoustic waves with frequencies from 100 MHz up to 1 GHz does not show any significant signal due to the phase transition. Even at large current, where we measure an increase of more than 300% in σ_{xx} with DC techniques due to the hyperfine interection with the nuclei, the σ_{xx} measured with SAWs shows no increase.

HL 29 Transport properties II

Time: Wednesday 17:00–18:15 Room: HSZ 01

HL 29.1 Wed 17:00 HSZ 01

Magnetotransport in solids with spin splitting of the energy spectrum — •Nikita Averkiev, M.M. Glazov, N.I. Sablina, and S.A. Tarasenko — A.F.Ioffe Physico-Technical Institute, 194021 St.Petersburg, Russia

Spin-dependent and transport phenomena are the topical fields of solid state physics. The electron spin can be used in the future quantum computers and other information processing devices. Study of the conductivity oscillations (Shubnikov-de Haas effect) gives an unique opportunity to investigate the fundamental properties of condensed matter and structure characterization. In this presentation we analyze the magnetotransport in low-dimensional structures where the spin dynamics becomes important and determines the pattern of the Shubnikov-de Haas oscillations. Both cases: (i) zero-field spin splitting and (ii) Zeeman effect in external field are studied in detail. We show that in the first case the pattern of magnetooscillations depends drastically on the ratio between spin-orbit terms caused by structure and bulk inversion asymmetry. Depending on this ratio, the spectrum of the Shubnikov-de Haas oscillations contains one, two, or three harmonics. Such a behavior is caused by the magnetic breakdown between the spin branches. Zeeman splitting, that becomes pronounced in tilted magnetic field, can result in suppression of the main harmonic and appearance of the oscillations at double frequency. The effects described open new possibilities to investigate the fine energy structure of low-dimensional conducting systems.

HL 29.2 Wed 17:15 HSZ 01

Direct observation of the Aharonov-Casher phase — •Markus König, Anna Tschetschetkin, Volkmar Hock, Matthias Schäfer, Charles R. Becker, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP 3), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Since its prediction in the 1980s, the concept of geometric phases has aroused much interest. One special case of a geometric phase is the Aharonov-Casher (AC) phase [1], which is acquired by a particle with a magnetic moment, which moves around an electric field. Nitta et al. [2] stated that the existence of the AC phase affects the transmission probability in ring shaped devices with spin-orbit coupling.

Apart from the Aharonov-Bohm (AB) effect, there has been no direct observation of any other phase related effects in a solid state system. So far, only some additional structures in the Fourier transform have been interpreted as indirect evidence of the geometric phase.

We present experimental results obtained on HgTe quantum well based ring structures, which have been used to study AB type conductance oscillations as a function of Rashba spin-orbit splitting energy. Nonmonotonic phase changes were observed, indicating that an additional phase factor modifies the electron wave function. We associate these observations with the Aharonov-Casher effect. This interpretation is confirmed by numerical calculations.

[1] Y. Aharonov and A. Casher, Phys. Rev. Lett. 53, 319 (1984). [2]

J. Nitta, F. E. Meijer, and H. Takayanagi, Appl. Phys. Lett. 75, 695 (1999).

HL 29.3 Wed 17:30 HSZ 01

Ballistic rectification in single and cascaded nanoscale cross junctions — •Michael Knop[1], Ulrich Wieser[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Ballistic rectification is demonstrated in a nanoscale four-terminal Ψ-shaped semiconductor cross junction consisting of a straight voltage stem and current-injecting branches [1]. The devices are fabricated from a high mobility GaAs/AlGaAs-heterostructure by use of a mix-and-match process combining low-energy electron-beam lithography on negative-tone resist calixarene with standard photo lithography [2]. According to a simple billiard-like picture the rectifying effect relies on the pure inertial ballistic motion of the electrons through the junction. Rectification is obtained up to temperatures of $T = 125$ K. A possible remedy for the low rectification efficiency $\eta = V_{out}/|V_{in}| \approx 3\%$ of a single device is a cascade of identical rectifier stages. DC transport-measurements on a cascade of two rectifier stages show the expected enhancement of the output voltage compared to a single rectifier.

[1] M. Knop *et al.*, Physica E (accepted)
[2] M. Knop *et al.*, Semicond. Sci. Technol. **20**, 814 (2005)

HL 29.4 Wed 17:45 HSZ 01

In-plane electron tunneling between two one-dimensional — •Jean-Laurent Deborde[1], Saskia F. Fischer[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Recently, we have introduced a lateral one-dimensional (1D) to two-dimensional (2D) tunneling structure whose thin leaking potential barrier [1] was prepared by means of atomic-force microscope lithography [2]. This gate-voltage controlled device enables to probe the 1D density of states by the tunneling conductance. In the present work, we apply the same lithography technique to produce an in-plane 1D-to-1D tunneling device. The samples are fabricated on a high-mobility GaAs/AlGaAs heterostructure. The device consists of two adjacent 1D waveguides (115 nm and 120 nm wide, both 430 nm long) separated by a thin 50 nm wide and 10 nm deep groove. A Schottky-gate is deposited on top of the device in order to control the transmission through the barrier as well as the electron density inside the waveguides. At 4.2 K, each quantum wire shows conductance quantization as characteristic of 1D transport. Energy subband separations of both waveguides are investigated from the conductance under dc drain voltage. The application of a dc bias across the barrier shows signatures of tunnel coupling between the 1D subbands in the two quantum wires.

[1] J.-L. Deborde *et al.*, EP2DS-16 2005, Physica E (in press)
[2] U. Kunze, Supperlatt. Microstruct. **31**, 3 (2002)

HL 29.5 Wed 18:00 HSZ 01

Fano resonances in transport through open quantum systems — •Roxana Racec[1,2] and Ulrich Wulf[1,3] — [1]Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany — [2]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania — [3]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany

We develop a theory for the measured Fano resonances in the conductance of a quantum dot strongly coupled to the leads. A nonseparable potential is considered which assures for the channel mixing. Our central result is that there is a single, well-defined resonant transmission channel even in presence of channel coupling. This resonant channel is associated with a single pole of the S-matrix. In addition, there is a background part of the S-matrix arising from poles other than the resonant one. It can be shown that this constant part of the S-matrix can be split in one part which interferes coherently with the resonant channel (coherent background) and a noncoherent part (noncoherent background). The interplay between the coherent background and the resonant channel determines the single asymmetry parameter seen in the experiment. The noncoherent background part of the S-matrix results in a noncoherent constant contribution to the conductance which is also seen in the experiment.

HL 30 Quantum dots and wires: Transport properties II

Time: Wednesday 18:15–19:15 Room: HSZ 01

HL 30.1 Wed 18:15 HSZ 01

Tunnel-coupled one-dimensional electron systems — •S.F. Fischer[1], G. Apetrii[1], U. Kunze[1], D. Schuh[2,3], and G. Abstreiter[3] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Walter Schottky Institut,Technische Universität München, D-85748 Garching — [3]Angewandte u. Exp. Physik, Universität Regensburg, D-93040 Regensburg

Wave function mixing and splitting of degenerate one-dimensional (1D) energy levels are a direct outcome of tunnel coupling between 1D ballistic electron systems. We present the conductance and transconductance measurements of vertically stacked short electron wave guides fabricated from tunnel-coupled quantum wells in GaAs/AlGaAs heterostructures with atomic force microscope lithography [1]. Subsequent 1D subbands are populated by increasing a top gate voltage. The subladders of the top and bottom electron wave guides can be shifted relative to each other by application of a back gate voltage [2], magnetic fields or cooling under top gate bias [3]. Mode coupling is reflected by level anti-crossings. Large 1D-subband spacings (>10 meV) allow an unprecedented resolution in drain bias spectroscopy which proves as a powerful tool for the direct determination of splitting energies. Device operation above liquid helium temperature is demonstrated. In an outlook we compare vertically and laterally tunnel-coupled 1D electron systems.

[1] U. Kunze, *et al.*, Superlatt. Microstructures 31 (2002) 3.
[2] G. Apetrii, *et al.*,Physica E, in press.
[3] S.F. Fischer, *et al.*,Appl.Phys.Lett. 81 (2002) 2779.

HL 30.2 Wed 18:30 HSZ 01

Ballistic electron spectroscopy with a quantum dot — •Frank Hohls, M. Pepper, J. P. Griffith, G. Jones, and D. A. Ritchie — Cavendish Laboratory, University of Cambridge, UK

Non-equilibrium transport measurements can be used to characterise and analyze confined electron systems. However, if there is a strong interaction between electrons then the assumptions underlying these techniques should be modified. In order to investigate the energy spectrum with a method which measures the energies directly, we propose to use a quantum dot for the energy-selective detection of non-equilibrium ballistic electrons injected from a device under study into its drain lead. Here we study the feasibility of this ballistic electron spectroscopy. Our device consists of two quantum dots, one used to prepare ballistic electrons with a well defined excess energy and the other used to demonstrate their detection. We use magnetic field dependence to demonstrate the ballistic nature of the detector signal and show the energy selectivity for varying excess energy of the ballistic electron beam.

HL 30.3 Wed 18:45 HSZ 01

Prediction of a concrete two qubit quantum gate based on quantum wires — •Tobias Zibold[1], Andrea Bertoni[2], and Peter Vogl[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]National Research Center S3, INFM-CNR, 41100 Modena, Italy

We predict a concrete semiconductor nanostructure for a two qubit quantum gate based on ballistic transport in quantum wires. The device allows controlled entanglement and its determination from DC I-V characteristics. In contrast to the majority of proposals that use charge or spin in closed systems such as quantum dots, our device is based on open system qubits [1]. This allows for an especially simple DC write-in and read-out process. The device consists of two vertically stacked GaAs/AlGaAs 2DEGs that are depleted by external gates to form a Mach-Zehnder interferometer for ballistic electrons in each of the two layers. Each of which represents a single qubit [2]. We show that the entanglement between the two interferometers leads to controlled dephasing and can be determined from their I-V characteristics. We further show that correlation measurements of the I-V characteristics of both interferometers can be used to distinguish this mechanism of dephasing from other sources thereof. To this end we have developed a Green's function

method that allows us to calculate the ballistic current of the coupled system for a realistic, three-dimensional device structure. [1] G.B. Akguc et al., Phys. Rev. A 69, 042303 (2004). [2] A. Bertoni et al., Phys. Rev. Lett. 84, 5912 (2000).

HL 30.4 Wed 19:00 HSZ 01

Bias voltage controlled threshold hysteresis in GaAs/AlGaAs quantum-wire transistors with embedded InGaAs quantum dots — •Christian R. Müller, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We have studied the threshold hysteresis of quantum-wires realized by electron beam lithography and wet chemical etching on the basis of a GaAs/AlGaAs heterostructure with InGaAs quantum dots in the AlGaAs spacer. Threshold shifts are due to charging and discharging of the quantum dots and can be controlled electrically by the side-gates. We have observed that the threshold hysteresis between up- and downsweeps of the side-gate voltage decreases with increasing bias voltage, and for a critical bias voltage the threshold hysteresis is suppressed. A change of the hysteresis sign was detected for bias voltages exceeding the critical bias voltage. As a result the memory function of the studied quantum-wire transistors can be inhibited electrically. We discuss the bias voltage dependent variation of the threshold hysteresis in terms of an interplay between the capacitive couplings of the quantum-wire, the quantum dots and the side-gates.

HL 31 Organic semiconductors

Time: Wednesday 14:30–19:00 Room: POT 51

HL 31.1 Wed 14:30 POT 51

Current Limiting Mechanisms in MDMO-PPV Diodes — •Carsten Deibel[1], Vladimir Dyakonov[1], Britta Bohnenbuck[2], Elizabeth von Hauff[2], and Jürgen Parisi[2] — [1]Experimental Physics VI, Physical Institute, University of Würzburg, 97074 Würzburg, Germany — [2]Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany

We examined the current-voltage characteristics of poly[2-methoxy,5-(3,7- dimethyloctyloxy)]-1,4phenylenevinylene (MDMO-PPV) diodes in the framework of space charge limited currents (SCLC). The thickness of the MDMO-PPV layer was varied between samples, and the effect of using metal cathodes with different work functions was investigated. Since the basic SCLC model could not explain the experimental data, modifications to it were individually investigated: (1) a double Gaussian density of states to account for deep traps, (2) injection of electrons from the back contact resulting in a recombination current, and (3) the influence of the built-in potential resulting from the asymmetric work functions of the electrodes. The simple SCLC model in combination with the built-in potential and a parallel resistance was able to explain both the thickness and cathode dependence of the current-voltage characteristics.

HL 31.2 Wed 14:45 POT 51

Investigation of Frenkel and charge transfer (CT) states in PTCDA and MePTCDI crystals — •L. Gisslén, M. Schreiber, and R. Scholz — Institut für Physik, Technische Universität Chemnitz

In perylene derivatives like N,N'-dimethyl-perylene-3,4,9,10-dicarboximide (DiMePTCDI) and 3,4,9,10-perylene tetracarboxylic dian-hydride (PTCDA), neutral molecular excitations and intermolecular charge transfer occur in the same energetic range. Their mixing via electron and hole transfer has a strong impact on the photophysical properties, including *e.g.* the absorption lineshape, the minima of the excited state potential landscape resulting in various kinds of photoluminescence (PL) [1], and the decay routes between absorption and PL.

The optical transition energies and the transfer matrix elements are determined with Hartree-Fock-based methods and with time-dependent DFT applied to molecular dimers in a geometry compatible with the crystalline phase [2]. In mixed Frenkel-CT models for the photophysical properties, the degree of mixing between Frenkel and CT states can be related to their different energetic ordering in PTCDA and DiMePTCDI. The present approach is compared to a pure Frenkel exciton model [3] and a one-dimensional model for Frenkel-CT mixing [4].

[1] A. Yu. Kobitski, R. Scholz, H.P. Wagner, and D. R. T. Zahn, Phys. Rev. B **68**, 155201 (2003).
[2] R. Scholz, A. Yu. Kobitski, D. R. T. Zahn, and M. Schreiber, Phys. Rev. B (2005) *accepted*.
[3] I. Vragović and R. Scholz, Phys. Rev. B **68**, 155202 (2003).
[4] M. Hoffmann and Z. G. Soos, Phys. Rev. B **66**, 024305 (2002).

HL 31.3 Wed 15:00 POT 51

Structural and electronic characterization of Diindenoperylene single crystals — •Ashutosh Kumar Tripathi and Jens Pflaum — 3. Physikalisches Institut, University of Stuttgart, Germany

For the first time, we report on the structural and electronic characterization of DIP crystals grown by sublimation technique. X-ray diffraction measurements on uncapped as well as on Ag capped DIP crystals prove the existence of two different volume phases below and above 400 K, the high-T phase corresponding to the DIP thin film structure observed on e.g. oxide surfaces [1]. By temperature dependent studies the effect of the phase transition on the electronic transport properties indicates the strong correlation between the structural order and the charge carrier mobilities. Remarkably, both electron and hole transients were recorded along c'-direction and over the studied temperature range the electron mobility was found to be higher than that for holes by an order of magnitude. As most of the organic materials are very sensitive for oxidation in combination with trap formation, observation of electron mobility indicates this material to be a potential candidate for organic electronics. Further experiments leading to FETs based on DIP single crystals are in progress.

[1] A. C. Duerr et al., Phys. Rev. B 68, 115428 (2003)

HL 31.4 Wed 15:15 POT 51

Two dimensional dispersion of electron-hole excitations in pentacene — •Roman Schuster and Martin Knupfer — Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, D-01069 Dresden, Germany

We have investigated the dispersion of the lowest electron-hole excitation in pentacene within the a-b crystal plane using inelastic electron scattering. Surprisingly, the results indicate a significant dispersion anisotropy. The results will be discussed in consideration of different inter-molecular interactions that can cause the observed dispersions.

HL 31.5 Wed 15:30 POT 51

Novel fullerene-derivatives for plastic solar cells — •Tobias Erb[1], Uladzimir Zhokhavets[1], Harald Hoppe[1], Paul Denner[1], Gerhard Gobsch[1], Steffi Sensfuss[2], Lars Blankenburg[2], and Elisabeth Klemm[3] — [1]Institute of Physics, Ilmenau Technical University, 98693 Ilmenau, Germany — [2]TITK Institut Rudolstadt, Physical Material Research and Functional Polymer Systems, 07407 Rudolstadt, Germany — [3]Institut für Organische Chemie und Makromolekulare Chemie, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

We have investigated several fullerene-derivatives in pristine films or in bulk heterojunctions with polymers. Their structural properties were studied by X-ray diffraction in grazing incidence geometry. The lattice symmetry and the size of the fullerene and polymer nanodomains were determined. Furthermore, the optical properties were studied with spectral ellipsometry. The influence of various annealing steps on the film properties were investigated, too. The X-ray findings show particularly, under which conditions fullerene-derivates crystallize. Solar cells have been optimised using the results from X-ray and were characterized under AM 1.5 standard solar irradiation simulation.

HL 31.6 Wed 15:45 POT 51

Time resolved luminescence quenching experiments with dicyanovinylene-terthiophene — •André Holzhey, Karl Leo, and Michael Hoffmann — Institut für Angewandte Photophysik, TU Dresden

Dicyanovinylene-terthiophene (DCV3T) as a new promising material for solar cell applications [1] shows intensive luminescence and exciton diffusion but also photo-degradation. CW and time-resolved photoluminescence and luminescence quenching of DCV3T shows exciton diffusion

properties of DCV3T and permits a detailed view on the exciton diffusion mechanism. Using a spectrofluorometer and a streak camera setup, the surface luminescence quenching in double layers is investigated for various layer thicknesses and temperatures. By investigation of various degradation processes, the influence of degradation on the experiment could be minimized. The results indicate that luminescence quenching affects at least two different exciton levels in DCV3T.

[1] C. Uhrich, R. Schüppel, A. Petrich, K. Leo and M. Pfeiffer, E. Brier, P. Kilickiran, P. Bäuerle, to be submitted.

HL 31.7 Wed 16:00 POT 51

The Transport Gap of Organic Semiconductors Studied Using the Combination of Direct and Inverse Photoemission — •Gianina N. Gavrila, Mihaela Gorgoi, and Dietrich R.T. Zahn — Chemnitz University of Technology, Semiconductor Physics, D-09107, Chemnitz, Germany

Direct valence band photoemission spectroscopy in combination with inverse photoemission spectroscopy is applied to study the densities of occupied and unoccupied electronic states of organic semiconductor materials e.g. perylene derivatives and phthalocyanines. The energy separation derived from the difference between Highest Occupied Molecular Orbital (HOMO) and Lowest Unoccupied Molecular Orbital (LUMO) in an organic solid is called HOMO-LUMO gap or transport gap. The charge injection processes require promotion of an electron or a hole from the electrodes into one of the charge transport (HOMO or LUMO) states of the organic film therefore their determination is vitally important. It is proposed that the transport gap of organic materials can be obtained from the edge-to-edge distance between the HOMO and LUMO features. The resulting values of the transport gaps are in good agreement with results of electrical measurements and another method of deriving the transport gap employing measurements of the interface dipole at inorganic/organic interfaces.

HL 31.8 Wed 16:15 POT 51

Anodized gate dielectrics: Preparation, characterization and organic-based transistor application — •J. Pflaum[1], S. Goettling[2], J. Brill[2], N. Fruehauf[2], and E. Margallo-Balbás[3] — [1]3rd Inst. of Physics, Stuttgart University, 70550 Stuttgart — [2]Chair of Display Technol., Stuttgart University, 70550 Stuttgart — [3]Electr. Instr. Lab., TU-Delft, 2628 CD Delft, The Netherlands

The application of organic-based thin film transistor (TFTs) requires the controlled preparation of thin high-k gate dielectrics in combination with low-cost, large-area processes. As a possible approach, we investigated the growth and morphology of the anodized gate dielectrics Al_2O_3 and Ta_2O_5. The anodization was carried out for glass and plastic substrates using various electrolytes. For the analysis of thickness, interface roughness and chemical composition, small-angle X-ray diffraction was exploited and modelled by the Parratt-formalism. The resulting data indicate the formation of oxide layers with defined stoichiometry and sharp interfaces. An influence of the respective electrolyte on the structural properties and on the breakthrough field strength could be clearly deduced. The obtained breakthrough fields up to 5MV/cm indicate the suitability of anodized gate-dielectrics in organic-electronic devices. First application of anodized dielectrics in pentacene TFTs on glass and plastic substrates will be demonstrated. As a key result, pentacene TFTs on Al_2O_3 on glass and on plastic substrates provide reliable transistor characteristics with hole mobilities of $0.1cm^2/Vs$ and on/off-ratios of 10^7-10^8. Financial support by DFG (Project Pf 385/2), EU (FlexiDis) and Landesstiftung Baden-Württemberg is acknowledged.

— 15 min. break —

HL 31.9 Wed 16:45 POT 51

Efficient photosensitization of C_{60} microcrystals with II-VI and III-V semiconductor nanocrystals — •A. Biebersdorf[1], R. Dietmüller[1], A. S. Susha[1], A. L. Rogach[1], S. K. Poznyak[2], D. V. Talapin[3], H. Weller[3], T. A. Klar[1], and J. Feldmann[1] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität, München — [2]Physico-Chemical Research Institute, Belarusian State University, 220050 Minsk, Belarus — [3]Institute of Physical Chemistry, University of Hamburg

Photoconductors are essential and common components of optoelectronic devices such as photodetectors or photocopying machines. The sensitivity and spectral range of photoconductors can be drastically improved by sensitizers, which absorb light and provide additional charge carriers to the photoconducting material.

In the present report we demonstrate that semiconductor nanocrystals (NCs) such as CdSe, CdTe and InP can efficiently photosensitize needle-like C_{60} microcrystals. A significant increase in photocurrent (by 3 orders of magnitude) is observed for C_{60} microcrystals covered with NCs, in comparison with C_{60} microcrystals without NCs. The photocurrent spectrum of C_{60} / NCs composites is close to the NC absorption spectrum and can be tuned precisely by the NC size. Maximum external quantum efficiency was estimated by calculating the number of photoelectrons per incident photon and is about 10 % for the CdSe / C_{60} composites and about 3 % for InP / C_{60} composites.

We explain the increased photoconductivity in the following way: The photoexcited electrons in the NCs are transferred to the C_{60} microcrystals causing photoconductivity, while the holes remain trapped in the NCs.

HL 31.10 Wed 17:00 POT 51

Charge modulation spectroscopy and electrical transport in single crystalline OFETs — •MATTHIAS FISCHER[1], BRUNO GOMPF[1], ASHUTOSH TRIPATHI[2], JENS PFLAUM[2], and MARTIN DRESSEL[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart. — [2]3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart.

Transport in organic thin films is limited by grain boundaries, traps and imperfections of the film morphology. To get access to the intrinsic properties of organic semiconductors, for example the maximum possible mobility, investigations on single crystals are essential. We have fabricated organic field effect transistors (OFETs) on sublimation grown high quality single crystals of rubrene, tetracene and anthracene. As gate insulator we use PPX. To avoid photoreaction at the surface all investigations were carried out under yellow light. In the case of rubrene these crystals show hole mobilities well above 1 cm^2/Vs in surface space charge limited current and in FET measurements, respectively. Charge-modulation spectroscopy in the far- and mid infrared of the accumulation layer in the conductive channel gives additional information of the high frequency conduction and the physics of the charge transport in these presumably small bandwidth materials. *Supported by the DFG through Go 642/6-1,2 and PF385/2.*

HL 31.11 Wed 17:15 POT 51

Comparison of two-dimensional device simulations with potentiometry measurements on pentacene OFETS — •R Scholz[1], F. Müller[1,2], A.-D. Müller[1,2], M. Hietschold[1], I. Thurzo[1], D. R. T. Zahn[1], C. Pannemann[3], and U. Hilleringmann[3] — [1]Institut für Physik, TU Chemnitz — [2]Anfatec Instruments AG, Oelsnitz — [3]Elektrotechnik und Informationstechnik, Universität Paderborn

Potentiometry with a Kelvin probe atomic force microscope is used to investigate the contact resistances of pentacene OFETs. The potentiometry measurements are performed *ex situ* under atmospheric conditions after storing the samples in air for several weeks. At room temperature, the device performance is limited by the resistance at the Au/pentacene injection contact, so that the mobility in the channel region as deduced from potentiometry is about one order of magnitude higher than the value obtained from the output characteristics [1].

From two-dimensional device simulations in the accumulation regime, we can deduce the hole mobility close to the interface between the active channel and the SiO_2 gate insulator. In the pinchoff regime, the charge carriers are pushed away from the gate towards the interface pentacene/air. The comparison between the device simulation and the potentiometry traces reveals a larger mobility in this region of the pentacene film. This finding indicates trap states at the pentacene/SiO_2 interface, probably related to adsorbed water molecules.

[1] R. Scholz, A.-D. Müller, F. Müller, I. Thurzo, B. A. Paez, L. Mancera, D. R. T. Zahn, C. Pannemann, and U. Hilleringmann, Proc. of SPIE **5940** (2005), 59400I.

HL 31.12 Wed 17:30 POT 51

Relation between chain length, disorder and conductivity in Polypyrrole films — •Thomas Heinzel[1], Cesar Bof Bufon[1], Pamela Espindola[2], and Jürgen Heinze[2] — [1]Heinrich-Heine-Universität Düsseldorf — [2]Albert-Ludwigs-Universität Freiburg

The effects of polymerization temperature, electrosynthesis current density and voltammetric cycling on the transport properties of polypyrrole (PPy) films are investigated. PPy films are prepared by galvanos-

tatic electropolymerization at a variety of experimental conditions. The films are investigated by UV-VIS spectroscopy, cyclic voltammetry and temperature-dependent transport measurements. It is observed that as the current density is reduced or the growth temperature is increased, the formation of short oligomers (PPy II) is favored, at the expense of the formation of long polymer chains (PPy I). Surprisingly, we observe a higher conductivity in films with a higher fraction of PPY II. In samples containing predominantly PPY II, quais-metallic behavior is found. Furthermore, PPY II can be transferred in PPY I by voltammetric cycling, which goes along with a decrease of the conductivity and a localization of the states at the Fermi level. We interpret these results in terms of a disorder-dominated conductivity.

HL 31.13 Wed 17:45 POT 51

Influence of the active layer morphology on the device performance of polymer-fullerene bulk heterojunction solar cells — •Ingo Riedel[1], Carsten Deibel[2], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research (ZAE-Bayern e.V.), Div. Funtional Materials for Energy Technology, Am Hubland, D-97074 Würzburg — [2]Experimental Physics VI, Institute of Physics, University of Würzburg, Am Hubland, D-97074 Würzburg, Germany

Recent achievements in organic photovoltaics demonstrate the high potential of using polymer-fullerene blends, such as P3HT:PCBM, as photoactive films for PV applications. Blending of the two materials introduces new effects, which have direct impact on the performance of the solar cell: Thermal annealing of P3HT:PCBM devices results in drastic efficiency improvement. The relevant effect is a thermally induced ordering of the P3HT phase, accompanied with molecular diffusion of PCBM out of the polymer matrix to form isolated semicrystalline domains. Their size and concentration is correlated with the amount of PCBM available. We show that the nanoscaled morphology additionally influences the open circuit voltage V_{OC}. This is shown by comparing devices based on two fullerene derivatives with identical redox potentials, each blended with the same donor polymer. Films of both composites exhibit different morphologies, which are represented by different values of V_{OC}. Analysis of the dark diode characteristics yields different ideality factors, which reflect the dominant internal recombination mechanism, e.g., electron back transfer from the fullerene moiety into the polymer phase.

HL 31.14 Wed 18:00 POT 51

Modified quinolates for pH-probes and high performance light emitting devices — •Stephan Rentenberger[1], Stefan Kappaun[2], Alexander Pogantsch[1], Franz Stelzer[2], Egbert Zojer[1], and Christian Slugovc[2] — [1]Institute of Solid State Physics, Graz University of Technology, Petersgasse 16, 8010 Graz, Austria — [2]Institute for Chemistry and Technology of Organic Materials, Graz University of Technology, Stremayrgasse 16, 8010 Graz, Austria

Aluminum quinolates (AlQ3) were first reported by Tang and VanSlyke in 1987 to possess electroluminescent properties and are currently widely used as light emitting electron transport materials for organic light emitting devices (OLEDs). As recent studies revealed, boron compounds are in general more stable than the corresponding aluminum compounds. While ligand precursors of those complexes exhibit characteristic features that can be used for pH-sensing purposes, the corresponding boron complexes display impressive properties as emitting layers in OLEDs. In our presentation we demonstrate both, the influence of protonation on the emission characteristics of the ligand precursors, and the application of the corresponding boron complexes in highly stable OLEDs. Additionally color-tuning by controlling the extension of the pi-conjugated system is achieved.

HL 31.15 Wed 18:15 POT 51

Paracrystalline structure of P3HT thin films: X-ray studies — •Rosina A. Staneva[1,2], Thomas Haber[1], Attila J. Mozer[3], Niyazi S. Sariciftci[3], and Roland Resel[1] — [1]Institute of Solid State Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria — [2]Institute of Physics, Technical University of Ilmenau, Unterpörlitzer Srt. 38, D-98693 Ilmenau, Germany — [3]Linz Institute for Organic Solar Cells (LIOS), Physical Chemistry, Johanes Kepler University Linz, Altenbergerstr. 69, A-4040 Linz, Austria

The paracrystalline structure of poly(3-hexylthiophene) (P3HT) thin films was studied by integral breadth evaluation of X-ray diffraction patterns. The 30-40 μm thin films were cast on low reflectance Si substrate by doctor blade technique. The wide angle X-ray diffraction (WAXD) measurements were done on as-prepared films and after annealing at elevated temperatures. The crystallite size and the lattice distortions were obtained taking in account the first, the second and the third order of the (100) reflection. Two approaches were compared: the paracrystalline model of Hosemann and the method of Williamson and Hall for size and strain analysis. It was found that the method of Hoseman fits better to the most of the scattering curves. The crystallite size of as prepared films was found to be 7-9 nm. It increases to 9-12 nm for the annealed films. The lattice distortions were obtained to be 3-4%. The both parameters do not show any clear dependence on the molecular weight Mw in the range of 20000-58000.

HL 31.16 Wed 18:30 POT 51

In situ stability studies of long-life organic field-effect transistors — •M. Michelfeit, M. Leufgen, G. Schmidt, J. Geurts, and L. W. Molenkamp — Physikalisches Institut der Universität Würzburg, Experimentelle Physik III

In spite of numerous investigations, degradation of organic field effect transistors (OFETs) due to contamination, ageing and voltage stressing remains a hot issue. We report on stability studies, performed in situ in UHV in order to avoid extrinsic contamination effects. For this purpose we fabricated high-performance OFETs with UHV deposited dihexylquaterthiophene (DH4T) as active material. Using UHV-processed Au/Ti electrodes, mobility values of 0,12 cm^2/Vs are achieved and the in-situ performance data show negligible ageing effects on a time scale of at least several weeks. Thus they allow age independent measurements of the effect of applied voltage stress (both at gate/source and drain/source) on the OFET performance. We discover the carrier mobility to be independent of the voltages and the time of their application. In contrast, the threshold voltage exhibits a strong dependence on these parameters, although its shift turns out to be almost reversible. We explain this behaviour by the existence of traps at the organic/insulator interface.

HL 31.17 Wed 18:45 POT 51

High-mobility organic thin-film transistors with low operation voltage — •Günther Leising, Barbara Stadlober, Ursula Haas, Anja Haase, Valentin Satzinger, Josef Krische, Hannes Maresch, Martin Zirkl, Heinz Pichler, and Georg Jakopic — Institut für Nanostrukturierte Materialien und Photonik, Joanneum Research GmbH, Franz-Pichler Strasse 30, A-8160 Weiz

Highly integrated consumer products are the main drivers for downscaling electronic devices. We work on the miniaturization of organic thin film transistors (TFT) for its application in plastic electronics. We have produced a series of bottom-gate organic (pentacene) TFTs with channel lengths (L) in the range 0.3 - 2.4 μm by means of nanoimprinting techniques, to investigate the effects of the channel length on the device characteristics (short channel effects). Organic sub-μm TFTs showed similar characteristics as comparable long-channel devices (carrier mobilities in the range of 0.1 cm^2/Vs). Drain current saturation is observed for devices with L as small as 0.3 μm. The morphology of the pentacene domains is determined by the channel size and is studied by AFM. In the sub-μm regime we observe only a few pentacene crystallites filling the channel region. To achieve TFTs with a driving voltage below 5 Volts, we utilized a double-layer dielectric technique using a combination of inorganic and organic dielectric thin layers. Due to low leakage currents and the excellent growth of the pentacene thin films on the organic dielectric we could achieve carrier mobilities of up to 1 cm^2/Vs in our miniaturized organic TFTs.

HL 32 Photovoltaic

Time: Wednesday 14:30–19:15 Room: BEY 118

HL 32.1 Wed 14:30 BEY 118

InP-based tandem solar cell with low band gaps — •U. Seidel, H.-J. Schimper, U. Bloeck, K. Schwarzburg, F. Willig, and T. Hannappel — Hahn-Meitner-Institute, Glienicker Str. 100, 14109 Berlin, Germany

III-V multi-junction solar cells already represent a kind of third generation solar cells and are currently the most efficient photovoltaic devices worldwide. In a multi-junction solar cell multiple single p/n solar cells with different band gaps are connected in series. At the present time the world record multi-junction cell is epitaxially grown on the lattice constant of GaAs or rather Ge. However, regarding the highest theoretical efficiencies there is a lack of an appropriate material with a band gap in the range of 1eV. A monolithic tandem solar cell with optimized low band gaps was designed for its application in a four junction cell as the low band gap part. It could be combined with a high band gap tandem or triple via different techniques. Our tandem cell was grown lattice-matched to InP via metalorganic vapor phase epitaxy (MOVPE). Only alternative precursors were used, i.e. TBAs, TBP and TESb. InGaAs (Egap = 0.75eV) was used for the bottom cell and InGaAsP for the absorber material around 1eV. To connect these two sub cells a new tunnel junction was produced including n-InGaAs and p-GaAsSb.

HL 32.2 Wed 14:45 BEY 118

Ga incorporation into $CuInS_2$ solar cell absorbers fast sulfurization processes — •Roland Mainz and Reiner Klenk — Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin, Germany

It has been shown previously, that the performance of CuInS2-based (CIS) solar cells can be improved by incorporation of Ga into the absorber [1]. Industrial production requires a cheap and fast preparation method such as sulfurization of sputtered metal precursor films in a rapid thermal processor (RTP). This works well for pure $CuInS_2$ but various problems have been encountered with this particular preparation method after adding gallium to the precursor. We have therefore studied the influence of gallium on phase formation by in-situ energy dispersive x-ray diffraction (XRD) using synchrotron radiation. Results indicate that the phase formation sequence during sulfurization strongly depends on the layer sequence in the precursor as well as on the time dependence of the sulphur pressure in the reaction chamber. The information gained from these experiments is used to establish a process that works within the constraints imposed by the industrial application. Furthermore, results indicate that it is possible to influence the depth profile of the Ga in the film. Partial replacement of In by Ga increases the band gap of $CuInS_2$. Control over the Ga depth profile allows the implementation of an optimum (in terms of solar cell performance) band gap grading.

[1] R. Kaigawa A. Neisser R. Klenk M. Ch. Lux-Steiner. Improved performance of thin film solar cells based on $Cu(In,Ga)S_2$. Thin Solid Films, page 415 pp., 2002.

HL 32.3 Wed 15:00 BEY 118

Electronic Metastabilities in Cu(In,Ga)Se$_2$ Solar Cells — •Michael Reuter, Julian Mattheis, and Uwe Rau — Institut für Physikalische Elektronik, Pfaffenwaldring 47, D-70569 Stuttgart, Germany

Due to metastable electronic states, Cu(In,Ga)Se$_2$ solar cells show an electrical degeneration after being exposed to reverse voltage in the dark. While the degeneration effect first results in the shift of the dark current voltage characteristic towards larger voltages, the shift is reversed for prolonged degrading duration. This finding indicates that two competing processes with different time constants are involved in the mechanism leading to the observed metastable behavior. Subsequent illumination experiments reveal an increase of the open-circuit voltage $V_{\rm OC}$ under illumination with a power density of 100 mW/cm^2 and a decrease of $V_{\rm OC}$ under reduced illumination with 1 mW/cm^2. This intensity dependence of the change in $V_{\rm OC}$ supports the notion of two competing processes being involved in the creation and annihilation of metastable states. It points out that the injection level of minority carriers decides about whichever process will be dominant.

HL 32.4 Wed 15:15 BEY 118

Influence of grain boundaries on electric transport in chalcopyrites — •Mark Wimmer, Susanne Siebentritt, Thorsten Rissom, Tobias Eisenbarth, and Martha Lux-Steiner — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

The chalcopyrite Cu(In,Ga) Se$_2$ is successfully used as an absorber in photovoltaic devices. The chalcopyrite photoactive layers have, among others, the advantage of being useful in the polycrystalline form. Although grain boundaries, as the essential difference between single- and polycrystalline materials, may play an important role for the performance of the devices there is currently no commonly accepted model for the electronic structure of the grain boundaries. To analyze the specific influence of grain boundaries on the carrier transport we grew CuGaSe$_2$-bicrystals by metal organic vapour phase epitaxy and studied them by Hall-measurements. Hall-Measurements allow to identify the barrier height for the majority carriers which is found to be at about 100meV in polycrystalline materials. The bicrystals allow the investigations of single grain boundaries. The behaviour of the bicrystals under illumination will be discussed as well as the behaviour of annealed samples.

HL 32.5 Wed 15:30 BEY 118

Carrier recombination dynamics in 1 eV band gap (GaIn)(NAs)/GaAs solar cell material as a function of epitaxial growth conditions and post-growth annealing processes — •Swantje Horst, Kristian Hantke, Sangam Chatterjee, Kerstin Volz, Wolfgang Stolz, and Wolfgang Rühle — Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

We measure time-integrated as well as time-resolved photoluminescence (PL) at room temperature of series of as-grown and post-growth annealed $Ga_{0.92}In_{0.08}N_{0.03}As_{0.97}$/GaAs epilayers grown by metal-organic vapour-phase epitaxy (MOVPE) using either trimethylgallium (TMGa) or triethylgallium (TEGa) as Ga precursors in combination with tertiarybutylarsine (TBAs) and 1,1-dimethylhydrazine (UDMHy). The samples are nominally undoped or intentionally doped with Mg (p-doping) or Te (n-doping) with doping levels typically used for solar cell applications. Post-growth thermal annealing significantly improves the optical quality of the (GaIn)(NAs) material. The PL of the p-doped samples show, at low excitation densities, an increased initial PL intensity and a slightly faster PL decay compared to the undoped samples, whereas the n-doped samples have a reduced initial PL signal and a much faster PL decay. The p-doped layers thus have a larger minority carrier lifetime and therefore a longer minority carrier diffusion-length. In addition, the PL-characteristics in particular of the as grown (GaIn)(NAs) material is improved by annealing with intense laser light. Possible reasons for this observation will be presented and discussed.

HL 32.6 Wed 15:45 BEY 118

Influence of grain boundaries on electrical and structural properties of chalcopyrites — •Tobias Eisenbarth, Susanne Siebentritt, Sascha Sadewasser, Jürgen Albert, Ferdinand Streicher, and Martha Lux-Steiner — Hahn-Meitner-Institut, Glienicker Str.100, 14109 Berlin

Thin film solar cells made from chalcopyrites (e.g. CuGaSe$_2$) are based on polycrystalline absorber layers with grains of different orientation. The influence of grain boundaries on recombination and electrical transport is not yet completely understood. But it can be assumed, that grain boundaries have a significant effect on the efficiency. Different models are discussed for the electronic structure of grain boundaries. In the present work, we grow epitaxial (MOVPE= Metal Organic Vapour Phase Epitaxy) CuGaSe$_2$ on a bicrystal GaAs-wafer with a single grain boundary. Depending on the Cu-content of the epitaxial film the epitaxy leads to two separate crystals or to a genuine grain boundary with defined orientation. This allows the detailed analysis a single grain boundary. We present results of scanning tunnelling microscopy, giving information about the crystalline and electronic structure of the grain boundary.

HL 32.7 Wed 16:00 BEY 118

Efficiency limitations in dye-sensitized solar cells with ionic liquids — •F. Einsele[1], M. Hlusiak[1], U. Rau[1], R. Sastrawan[2], R. Kern[2], and A. Hinsch[2] — [1]Institut für Physikalische Elektronik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart — [2]Fraunhofer Institut für Solare Energiesystem (ISE), Heidenhofstraße 2, 79110 Freiburg

Dye-sensitized solar cells (DSCs) consist of a layer of nanoporous TiO_2. A monolayer of dye molecules covers the TiO_2 nanoparticles. Photoexcitation of the dye and electron transfer into the conduction band of the TiO_2 makes up the primary photovoltaic action. The I^-/I_3^- redox couple of an electrolyte (EL) oxidizes the dye molecule. Standard high-efficiency DSCs use an EL with highly volatile acetonitrile as a solvent. One major research goal is the replacement of this EL by a non-volatile EL. Here the use of ionic liquids is a major option. Unfortunately, the efficiencies, especially the short circuit current densities j_{SC}, obtained with these EL so far are much lower than those of the standard devices. The present contribution investigates possible limitations to j_{SC} by means of electrical measurements. We find that the diffusion constant D_T of I_3^- in ionic liquids is 1.8x10^{-7} cm^2/s, i.e. about two orders of magnitude smaller than 1.2x10^{-5} cm^2/s in acetonitrile. A further limitation is provided by the TiO_2 network and in an additional light-scattering ZrO_2 layer. We observe that the effective diffusion constant D_{eff} in the TiO_2 network is about 40% of the bulk value and reduces to 16% in the ZnO_2 layer. A simple model unveils that the maximum achievable short circuit current density $j_{SC,max}$ is about 8 to 10 mA/cm^2 in this case.

HL 32.8 Wed 16:15 BEY 118

1. Doping induced structural changes in CuInS2 thin films and the effects on the optical and electrical properties — •Tobias Enzenhofer, Thomas Unold, and Hans-Werner Schock — Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin

In this contribution we connect structural and optical changes induced by doping with group-II elements in CuInS2 thin films. The admixture of small amounts of zinc and/or magnesium (<1 at. %) results in significant changes of the absorber and solar cell properties of the chalcopyrite system Cu-In-S2. With Zn/Mg doping, solar cells show an enhancement of the open circuit voltage from 700mV to more than 800mV. The systematical study of the effect of incorporation of dopants into the absorber layers by annealing with Raman and photoluminescence spectroscopy reveal an increase in the Raman response of the cation-anion vibration modes accompanied with the generation of a new broad emission band at 1.35eV in the photoluminescence spectra. From photoluminescence measurements we find a change of the nature of bulk and surface defects for Zn/Mg doped samples. Moreover the electronic transport in doped and undoped absorber layers is compared by in-situ conductivity measurements during the annealing process.

HL 32.9 Wed 16:30 BEY 118

Manufacturing Photonic Crystals for Photovoltaic Applications — •Andreas Bielawny, Paul Miclea, Andreas von Rhein, Andreas Redler, Siegmund Greulich-Weber, and Ralf Wehrspohn — University of Paderborn, Department of Physics,

Inpired by the wide range of possible applications of photonic crystals, we are aiming for their contribution to the field of photovoltaics. Whether spectral photonmanagement between a multigap-cell's different layers or waveguiding in thin film cells, opaline photonic crystals offer a tempting way of producing large scale diffractive elements.

We present our work on fabrication of artificial opals made of Silica or PMMA, with focus on our experimental approaches to the main preparation methods of augmented sedimentation and vertical deposition, closely accompenied by investigation and characterization of their structural and optical properties with electron microscopy and angular resolved spectroscopy. We present some promising applications for their use in photovoltaic energy conversion.

— 15 min. break —

HL 32.10 Wed 17:00 BEY 118

Shunt Imaging and Characterization in Industrial Silicon Solar Cells using Polymer-dispersed Crystal Foils — •Stelio Correia and Jan Lossen — ErSol Solar Energy AG, Wilhelm-Wolff-Str. 23, 99099 Erfurt

Shunts reduce the efficiency of solar cells, especially under low light conditions. Besides that, shunts are responsible for the hot spot phenomena in modules under shading conditions that can result in the destruction of the device. The shunt conductance represents recombination effects and parasitic current paths parallel to the diode current. It affects the FF and Voc parameters. The identification of an increased shunt conductance, especially in large area surface state-of-the-art industrial solar cells, requires a spatial resolved analysis. Local power dissipation can be imaged with thermographic techniques. Polymer dispersed crystal foils are a simple tool to visualise temperature, when a high sensitivity is not relevant. With this method, shunts are detected by increased power dissipation under an external bias. In this work a cheap and easy-to-use system was built and used as a quality assessment and improvement tool for shunt analysis in industrial solar cells. Different types of shunts where identified. After a detailed characterization their causes could be overcome.

HL 32.11 Wed 17:15 BEY 118

Monitoring the sulfurization of (Ga,S)-Cu-In photovoltaic precursor layers by energy dispersive X-ray diffraction — •Alfons Weber, Immo Koetschau, and Hans-Werner Schock — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany

Phase transformations of Cu_xIn-(Ga,S) thin film stacks were investigated in annealing experiments under sulfur vapor using in-situ energy dispersive X-ray diffraction (EDXRD). So far the formation of $CuInS_2$ absorbers for photovoltaic applications has been studied in similar annealing experiments using metallic Cu_xIn precursor layers[1]. In the present study a (Ga,S) layer was deposited in addition to the elemental Cu and In precursor layers to study the phase formation of Cu(In,Ga)S_2 alloys. The addition of Ga is expected to enhance the Voc of $CuInS_2$-based solar cells. The sulfurization was carried out in a specially designed chamber installed at the synchrotron beamline F3 at Hasylab in Hamburg. Using the synchrotron source it is possible to get spectra with high resolution at short integration times and to trace fast structural changes during the sulfurization process. The study shows that the annealing process does not lead to a homogeneous Cu(In,Ga)S_2 alloy, but to a separation of a Ga-rich and an In-rich phase. We will discuss the effect of (Ga,S) on the electronic properties of complete devices made of these films.

[1] Djordjevic J., Rudigier E., Scheer R, Materials Research Society symposium proceedings 763, (2003) p. 383-389

HL 32.12 Wed 17:30 BEY 118

Shunt Imaging and Characterization in Industrial Silicon Solar Cells using Polymer-dispersed Crystal Foils — •Stelio Correia and Jan Lossen — ErSol Solar Energy AG, Wilhelm-Wolff-Str. 23, 99099 Erfurt

Shunts reduce the efficiency of solar cells, especially under low light conditions. Besides that, shunts are responsible for the hot spot phenomena in modules under shading conditions that can result in the destruction of the device. The shunt conductance represents recombination effects and parasitic current paths parallel to the diode current. It affects the FF and Voc parameters. The identification of an increased shunt conductance, especially in large area surface state-of-the-art industrial solar cell requires a spatial resolved analysis. Local power dissipation can be imaged with thermographic techniques. Polymer dispersed crystal foils are a simple way to visualise temperature, when a high sensitivity is not relevant. With this method, shunts are detected by increased power dissipation under an external bias. In this work a cheap and easy-to-use system was built and used as a quality assessment and improvement tool for shunt analysis in industrial solar cells. Different types of shunts where identified. After a detailed characterization their causes could be overcome.

HL 32.13 Wed 17:45 BEY 118

Electronic structure of gold- and iron-decorated dislocations in silicon — •Oliver Voss[1], Vitaly Kveder[2], and Michael Seibt[1] — [1]IV. Physikalisches Institut der Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]permanent address: Institute of Solid State Physics RAS, Chernogolovka,*142432 Moscow reg., Russia

The recombination activity of dislocations in silicon strongly depends on their decoration with transition metal impurities in different states e.g. as precipitates or as isolated point defects. In this study the influence of Au and Fe as decoration of dislocations in fz-Si was measured by deep level transient spectroscopy (DLTS). We compared the effects of different Au concentrations. In addition to the DLTS-lines of dislocated n-Si we found a line with the emission characteristics of the Au-acceptor-level but with a capture barrier only with a high Au concentration. In

dislocated p-Si we found comparable results for a defect similar to the Au-donor-level and an additional line whose amplitude depends in the same way on the Au concentration. It was shown that these lines are point-defect-like lines with a logarithmic capture dependence. We tentatively attribute this behaviour to substitutional Au atoms in the strain field of dislocations. After indiffusion of Fe into dislocated p-Si and storage of 30 hours we found two point-defect DLTS-lines: the FeB-pair-line and the intertitial Fe line. After soft annealing both lines almost disappeared, another capture dependent line appeared and the total amount of active sites was significantly reduced.

HL 32.14 Wed 18:00 BEY 118

Symmetry of defects in chalcopyrites - a polarized photoluminescence study — •Sven Augustin, Susanne Siebentritt, and Martha Lux-Steiner — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

Defects in the chalcopyrite CuGaSe_2 are analysed. CuGaSe_2 is used as an absorber in thin-film solar cells. As is known for a p-n junction, an important contribution to the efficiency is made by choosing the concentration of defects. So one way to improve efficiency is to find the optimal fraction of defects in the material. The first step in achieving this goal for CuGaSe_2 is to determine the nature of the dopants, i.e. the chemical and the structural (lattice site) character. By pursuing this aim the method of polarization resolved photo luminescence (PL) and PL excitation (PLE) spectroscopy is used to obtain information on the symmetry of the defects. The measurements of epitaxial samples of different orientation show, that the emission from two of the acceptors is polarized mainly parallel to the c-axis of the tetragonal crystal and the third acceptor on the other hand radiates with polarization predominantly perpendicular to the c-axis. Employing a classical oszillator model allows to ascertain the symmetry of the defects.

HL 32.15 Wed 18:15 BEY 118

Interface properties of Cu(In,Ga)(S,Se)$_2$ absorbers with various bufferlayers in thin film solar cells — •F. Erfurth[1], L. Weinhardt[1], T.P. Niesen[2], S. Visbeck[2], C. Heske[3], and E. Umbach[1] — [1]Experimentelle Physik II, Universität Würzburg — [2]Shell Solar GmbH, München — [3]Department of Chemistry, University of Nevada, Las Vegas

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 is of great interest. By depositing alternative layer compositions like (Zn,Mg)O or Zn(S,OH), using conventional sputter and chemical bath deposition techniques, efficiencies close to or comparable to those of CdS containing solar cells are obtained. To understand the chemical and electrical characteristics of the buffer layer and its influence on the absorber, we investigated the absorber-buffer interface using photoelectron spectroscopy and inverse photoemission. The combination of both techniques provides the determination of the chemical and stoichiometric properties as well as the alignment of the conduction and valence band at the heterojunction.
We analyze the pure and Cd-treated absorber surface and the interface to alternative buffer layers. Measurements are presented observing diffusion and accummulation processes of certain absorber elements at the interface, which depend on temperature treatments. Furthermore the alignment of both, the valence and conduction band at the interface is deduced. In conclusion, we attempt to explain differences in cell efficiencies arising from different buffer layers.

HL 32.16 Wed 18:30 BEY 118

Electrochemical grown ZnO/EosinY hybrid films on oriented substrates — •Thomas Loewenstein[1], Christian Neumann[2], Thorsten Kraemer[2], Bruno K. Meyer[2], Tsukasa Yoshida[3], and Derck Schlettwein[1] — [1]Institut für Angewandte Physik, JLU Giessen, Heinrich Buff-Ring 16, 35392 Giessen — [2]Experimentalphysik I, JLU Giessen, Heinrich Buff-Ring 16, 35392 Giessen — [3]Graduate School of Engineering, Gifu University, Yanagido 1-1, Gifu 501-1193, Japan

The sensitization of wide-bandgap semiconductors is an attractive approach to a photoelectrochemical photovoltaic cell. Porous, yet crystalline ZnO electrodes were deposited in electrochemical reactions from aqueous zinc salt solutions induced by a local pH-increase at the working electrode during the reduction of oxygen, a reaction compatible with a large number of conductive substrates. Single crystalline substrates allow to investigate the structure and texture to far higher extent than typical polycrystalline or amorphous substrates. (0001) GaN offers good possibilities of epitaxial growth of ZnO. In this study, ZnO/dye hybrid materials were electrodeposited on (0001) GaN and on (0001) ZnO. Scanning electron microscopy (SEM) revealed domains of different crystal sizes that were correlated to fluctuations in the substrate work function. Crystalline ZnO was deposited on GaN as proven by X-ray diffraction (XRD). The intensity pattern showed a preferential orientation with the c- plane of ZnO parallel to GaN (0001). XRD rocking curves indicated a high level of in-plane orientation of the grown ZnO crystalline domains. The peak position spoke in favour of a modification of the ZnO crystal lattice by the dye molecules adsorbed during the growth of ZnO.

HL 32.17 Wed 18:45 BEY 118

Analysis of Charge Carrier Dynamics in $\mathrm{Cu(In,Ga)Se_2}$ from Sub-Micron Resolved Luminesence and Photocurrent Studies — •Levent Gütay and Gottfried H. Bauer — Institute of Physics, Carl von Ossietzky University, D-26111 Oldenburg, Germany

We have analysed thin film $\mathrm{Cu(In,Ga)Se_2}$ solar cells by sub-micron resolved photoluminescence (PL) and light induced photocurrents. Respective scans show significant lateral variations of PL-yield (Y_{PL}) in the few micron scale, which correspond to locally varying quality of the photoexcited state of the absorber. PL-scans performed, both, under open and short circuit conditions (oc and sc) show differences of lateral signal profiles reflecting local variations of excess charges and consequently signalizing the influence of differences in carrier dynamics between these two modes of operation. Additionally simultaneously recorded local photocurrents (I_{sc}) exhibit a substantial local anti-correlation with PL. Since locally resolved PL quantitatively reflects local excess carrier densities and I_{sc} their respective product with their speed of extraction (perpendicular to the surface of the junction) we get experimental access to this magnitude and observe e.g. fast extraction of photoexcited carriers at the edges of the regimes with high Y_{PL} and comparatively low one in their respective centers.

HL 32.18 Wed 19:00 BEY 118

Investigation of the correlation between charge carrier lifetime of multicrystalline silicon raw wafer and solar cell efficiency — •Kevin Lauer[1], Stefan Dauwe[1], and Jan Lossen[2] — [1]SolarZentrum Erfurt, CIS Institut für Mikrosensorik, Konrad-Zuse-Str. 14, D-99099 Erfurt — [2]ErSol Solar Energy AG, Wilhelm-Wolff-Str. 23 D-99099 Erfurt

The correlation between multicrystalline silicon raw wafers and solar cell efficiency depends both on wafer quality and on the solar cell process. It is of large scientific and economic interest to understand these influencing factors in order to predict the solar cell efficiency.
In this work the electrical properties of multicrystalline silicon wafers are characterized by minority carrier lifetime measurements. We measured the lifetime of adjacent wafers from one column before emitter diffusion. Subseqeuntly, these wafers were processed to solar cells. As expected, a higher carrier lifetime of a raw wafer results in a higher solar cell efficiency. However, the position of the wafer within the column needs to be known additionally for a more precise prediction of the solar cell efficiency. We attribute this to the defect distribution across the column.
The content of one of the dominating defects, interstitial iron, was measured before and after diffusion. The standard method based on carrier lifetime measurements before and after light soaking was extended to improve the measurement sensitivity.

HL 33 GaN: Preparation and characterization

Time: Wednesday 14:30–17:15 Room: BEY 154

HL 33.1 Wed 14:30 BEY 154

Analysis of AlN/Diamond Heterojunctions by Photoelectron Spectroscopy — •Olaf Weidemann, Bernhard Laumer, Thomas Wassner, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, 85748 Garching

N-type doping of diamond still is a major problem which hinders the realization of bipolar devices like p-n-diodes. In contrast, Si-doping of AlN has been shown to result in technologically relevant n-type conductivity. The combination of both materials in a light emitting AlN/diamond hetero diode has recently been demonstrated. For a detailed understanding of carrier transport and light emission at the AlN/diamond interface, knowledge of the respective band alignment and interface structure is necessary. We have analyzed the AlN/diamond interface by X-ray and UV-photoelectron spectroscopy carried out during the sequential growth on H-terminated and O-terminated single crystalline diamond substrates. The influence of the nucleation process on the electron affinity of the diamond substrate has been analyzed and the growth mode of the AlN-film as well as the conduction band profile at the heterojunction has been determined. Complementary analysis by atomic force microscopy and electronic transport measurements has been carried out.

HL 33.2 Wed 14:45 BEY 154

Critical points of the band structure of AlN/GaN superlattices investigated by spectroscopic ellipsometry and modulation spectroscopy — •C. Buchheim[1], R. Goldhahn[1], A. T. Winzer[1], C. Cobet[2], M. Rakel[2], N. Esser[2], U. Rossow[3], D. Fuhrmann[3], and A. Hangleiter[3] — [1]Institute of Physics, Technical University Ilmenau, PF 100565, 98684 Ilmenau, Germany — [2]Institute of Analytical Sciences, Department Berlin-Adlershof, Albert-Einstein-Str. 9, 12489 Berlin, Germany — [3]Institute of Applied Physics, Technical University Braunschweig, Mendelssohnstr. 2, 38106 Braunschweig, Germany

AlN/GaN superlattices (SL) are suitable for the design of distributed Bragg reflectors and optical devices based on intersubband transitions. Applications are light emitters in the near to mid infrared region, quantum well infrared photodetectors and quantum cascade laser structures. For the design of such heterostructures and their evaluation the detailed knowledge of their optical properties over an extended energy range is essential. Three AlN/GaN SLs with different barrier and well thicknesses were investigated by modulation spectroscopy and photoluminescence to determine their ground state transition. A shift of the transition energies in dependence of the barrier and well width is found. The results are compared to quantum mechanical calculations at the Brillouin zone centre. In addition the dielectric function is determined by spectroscopic ellipsometry from the infrared to the vacuum ultraviolet spectral range (0.75 - 9.8 eV). Quantum confinement effects are observed not only for the band gap, but also for the higher energetic critical points of the band structure as can be seen from the comparison to AlGaN alloys.

HL 33.3 Wed 15:00 BEY 154

GaN-based devices on Si(001) grown by MOVPE — •F. Schulze, J. Bläsing, A. Dadgar, T. Hempel, A. Diez, A. Krtschil, J. Christen, and A. Krost — Institut für Experimentelle Physik, Otto-v.-Guericke-Universität Magdeburg, PF 4120, 39104 Magdeburg

The Si(001) substrate orientation offers an obvious approach for the integration of GaN-based devices with the standard silicon technology, because this orientation is used in silicon mainstream technology. However, the main challenges are the different lattice symmetries and crystallographic orientations of GaN and Si(001). We will present structural and optical investigations on GaN layers on Si(001) grown by metalorganic vapour phase epitaxy (MOVPE). In our approach a high temperature AlN-seed layer and 4° off-oriented substrates allow to grow c-axis oriented GaN on Si(001) with one well defined in-plane alignment. Thus, a smooth and fully closed single-crystalline GaN layer on Si(001) is obtained. The crystallographic structure is investigated by X-ray diffraction measurements. The achieved FWHM of the GaN(0002) rocking curve is 0.26° and the in-plane twist is 0.82°, determined by a GaN(10-10) ω-scan. The surface morphology was analyzed by FE-REM imaging and AFM, and the optical properties by photo- and cathodoluminescence. By growing an approx. 2.3 μm crack-free buffer layer GaN-based LEDs and FET devices on Si(001) were made and will be presented.

HL 33.4 Wed 15:15 BEY 154

Nanostructering of GaN-based semiconductors with focused ion beam — •Timo Aschenbrenner, Jens Dennemarck, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, Semiconductor Epitaxy, University of Bremen, 28359 Bremen, Germany

Nowadays quantum dots and photonic crystals take an important role for light emitting devices. The manufacturing of such nanostructures on GaN-based semiconductors is difficult because on the one hand the commonly used method of wet etching is not applicable. And on the other hand the needed structure size is below the limit of photolithography.

Therefore two different approaches to achieve nanostructures were performed: Electron beam lithography and the structuring with focused ion beams (FIB). Electron beam lithography with an acceleration voltage of 30 kV and a beam current of a few pA up to 1 nA were used to define a pattern in polymethylmethacrylate (PMMA) resist on GaN-substrates. After developing the mask was transfered to GaN by chemical assisted ion beam etching (CAIBE). The resolution is limited by the size of the polymer to above 100 nm.

A FIB can be used as a direct approach for nanostructuring. In this case the resolution is only limited by the minimum diameter of the ion-beam to hole-diameter of 30 nm. But this approach has the disadventage, that ion damaged occurs. To reduce the damage different protection layers as titanium or nickel were used. The surfaces were investigated with AFM and SEM.

HL 33.5 Wed 15:30 BEY 154

MOVPE of Cr-doped GaN — •Yong Suk Cho[1], Nicoleta Kaluza[1], Uwe Breuer[2], Vitaliy Guzenko[1], Hilde Hardtdegen[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG-1), Center of Nanoelectronic Systems for Information Technology, Research Center Jülich, 52425 Jülich, Germany — [2]Central Department of Analytical Chemistry (ZCH), Surface Analysis, Research Center Jülich, 52425 Jülich, Germany

Recently, first studies on MBE grown Cr-doped GaN revealed ferromagnetism for dilute magnetic semiconductors. Here we report for the first time on the incorporation of Cr in GaN with metalorganic vapor phase epitaxy using different hardware setups and different flow conditions. Conventional Ga and N precursors were used and bis(cylcopentadienyl)chromium (Cp_2Cr) was employed as the Cr precursor. Undoped GaN epilayer were grown to serve as a template for Cr-doped GaN. The mole fraction of Cp_2Cr used for Cr-doped GaN was varied in gas phase from 5.67×10^{-9} mol/min to 1.02×10^{-7} mol/min, while the growth temperature and V/III ratio were kept constant. Secondary ion mass spectrometry provided that the different hardware setups as well as the flow conditions strongly affect the concentration of Cr in the layer by 18%. Also a linear dependence between mole fraction of Cp_2Cr in gas phase and incorporated Cr in solid phase was found. X-ray diffraction, photoluminescence and Raman spectroscopy studies were performed as well as superconducting quantum interference device measurements carried out to study the structural and magnetic properties of the layers. The results will be presented.

HL 33.6 Wed 15:45 BEY 154

MBE Growth of cubic InN — •Jörg Schörmann[1], Stefan Potthast[1], Mark Schnietz[1], Christian Napierala[2], Rüdiger Goldhahn[2], Donat Josef As[1], and Klaus Lischka[1] — [1]University of Paderborn, Department of Physics, Warburger Strasse 100, D-33095 Paderborn, Germany — [2]Institute of Physics, TU Ilmenau, PF 100565, D-98684 Ilmenau, Germany

Among III-nitride semiconductors, InN has the highest electron drift velocity, the smallest effective mass and the smallest direct band gap. Therefore it is expected to be one promising material for high frequency electronic devices such as field effect transistors (FET). Another application for InN are InN/GaN quantum well structures for intersubband transitions. Due to the large conduction band offset (about 1.4eV 60:40) this material system allows intersubband transitions in the range of 1-10μm. 140nm thick cubic InN films were grown on top of a c-GaN buffer layer (800nm) by rf-plasma assisted MBE at different growth temperatures. X-Ray diffraction investigations show that the c-InN layers consist of a predominant zinc blende structure with a fraction of the wurtzite phase on the (111) facets of the cubic layer. The full-width at half-maximum

of the c-InN (002) reflex is less than 50arcmin. Reflection measurements show an absorption edge at ∼1.5eV. The bandgap of our c-InN layers was obtained by photoluminescence and ellipsometry.

HL 33.7 Wed 16:00 BEY 154

Nitrogen-15 and Gallium-71 nuclear magnetic relaxation measurements in GaN — •Anthony Kent, Robin Morris, Helen Geen, C Thomas Foxon, and Sergei Novikov — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK.

We have grown by RF plasma-assisted molecular beam epitaxy (PA-MBE) zinc-blende crystal structure GaN using an isotopically pure nitrogen-15 source. We have measured the nuclear spin-lattice (T_1) and spin-spin (T_2) relaxation times using pulsed NMR at 20 MHz. For Gallium-71 we found T_1 was of order seconds at low temperature, and $1/T_1$ proportional to $T^{1/2}$ where T is the temperature. This is characteristic of semiconductors in which the spin-lattice relaxation is mediated by mobile electrons and allows us to estimate the free carrier concentration. The spin lattice relaxation time was found to be much longer for nitrogen-15, of order minutes, and the temperature dependence more characteristic of an insulator. This suggests that the free electron-nuclear coupling is weaker for nitrogen-15 compared with Gallium-71. We also show that illumination of the sample by band-gap UV light with circular polarization resulted in hyperpolarization of the Nitrogen-15 and an increase in the NMR signal amplitude.

HL 33.8 Wed 16:15 BEY 154

Electrical properties of cubic $Al_xGa_{1-x}N$/GaN heterostructures — •Stefan Potthast[1], Jörg Schörmann[1], Donat Josef As[1], Klaus Lischka[1], Hiroyuki Nagasawa[2], and Masayuki Abe[2] — [1]University of Paderborn, Department of Physics, Warburger Str. 100, 33095 Paderborn, Germany — [2]HOYA Advanced Semiconductor Technologies Co., Ltd, 1-17-16 Tanashioda, Sagamihara, Kanagawa 229-1125, Japan

The absence of spontaneous and piezoelectric fields in cubic group-III nitride semiconductors enables the realization of a two-dimensional electron gas (2DEG), whose concentration is independent on the thickness and the Al-content of the barrier material and is adjusted only by the Si-doping of the AlGaN barrier. In this contribution we report on the growth of cubic $Al_xGa_{1-x}N$/GaN heterostructures by rf-plasma assisted molecular beam epitaxy on 3C-SiC substrates with an Al-mole fraction between 0.2 and 0.5. Temperature dependent Hall-Effect measurements and CV measurements between 300K and 5K were performed to estimate the electrical properties of the 2-dimensional electron gas, showing a sheet carrier density of $1.6 \cdot 10^{12} cm^{-2}$. The carrier density was quantitatively verified by a self consistent solution of the Schrödinger and Poisson equation. Detailed analysis of the electron mobility showed that interface roughness scattering is the dominating scattering process in our structures.

HL 33.9 Wed 16:30 BEY 154

Detailed analysis of the dielectric function for wurtzite In- and N-face InN — •P. Schley[1], R. Goldhahn[1], A.T. Winzer[1], G. Gobsch[1], M. Rakel[2], C. Cobet[2], N. Esser[2], H. Lu[3], W.J. Schaff[3], M. Kurouchi[4], and Y. Nanishi[4] — [1]Institut f. Physik, TU Ilmenau — [2]ISAS Berlin — [3]Cornell University Ithaca — [4]Ritsumeikan University

A detailed analysis of the dielectric function (DF) for wurtzite In- and N-face InN is presented for the first time. The experimental data cover the energy range from 0.74 up to 9.5 eV (data above 4 eV refer to the use of synchrotron radiation at the Berlin storage ring BESSY II) and were obtained by ellipsometric studies from temperatures of 440 K down to 160 K. Before the measurements, the surface quality was improved by annealing the samples for 10 minutes at 400 °C. By fitting the third derivatives of the DF's a high resolution determination of the transition energies of the high energy critical points of the band structure is achieved. All critical points shift to higher energies if the temperature is decreased. At $T = 160$ K up to seven transitions are analyzed. For both polarities the obtained transition energies show an excellent agreement within 20 meV. The experimental results are compared with recent theoretical calculations.

HL 33.10 Wed 16:45 BEY 154

Structural studies of GaN:Mn films — •Tore Niermann, Martin Kocan, Martin Röver, Jörg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We studied the effect of Mn incorporation on the microstructure of GaN films by high resolution electron microscopy and energy dispersive X-ray analysis. The GaN films were grown by molecular beam epitaxy under various conditions. It is found, that Mn can be dissolved up to nearly 5% metal content. In these films the Mn incorporation results in a columnar growth of the GaN, i.e. in a degradation of the film quality. Further properties of the incorporated Mn were studied. Higher Mn amounts result in the formation of precipitates which are identified as $GaMn_3N$ by chemical analysis and diffraction techniques. The Mn concentration in the remaining GaN matrix is below the detection limit of EDX, i.e. about 0.5 at%.

HL 33.11 Wed 17:00 BEY 154

Optical investigations of the lateral homogeneity of InGaN MQW heterostructures on 2 inch wafers — •Christoph Hums[1], Armin Dadgar[1,2], Jürgen Bläsing[1], and Alois Krost[1] — [1]Otto-von-Guericke Universität Magdeburg, Fakultät für Naturwissenschaften, Institut für Experimentelle Physik, Universitätplatz 2, 39106 Magdeburg — [2]AZZURRO Semiconductor AG, Universitätplatz 2, 39106 Magdeburg

The growth of ternary In-containing alloys is a very temperature sensitive process since small variations in temperature lead to large variations in the In-content and to a small part in the growth rate. A main source for temperature inhomogeneities of the wafer surface in MOVPE growth is the bowing of the wafer induced by strain and the vertical temperature gradient . The optical properties of the sample are effected strongly by Indium content, InGaN-QW layer thickness and overall layer thickness of the structure and have been investigated with spatially resolved photoluminescence. As sample basis we used entire 2 inch wafers from a production type and a research reactor. The peak energy, e.g., shows a standard deviation of ˜15meV at a center energy of 2.783eV. Fabry-Perot oscillations are well visible at yellow luminescence energies. These thickness interferences have an influence on the luminescence intensity and peak energies of the InGaN related luminescence. To determine the influence of the interferences the overall layer thickness has been measured spatially resolved and compared with the PL properties. We discuss the possible impact of wafer bowing on temperature and In inhomogeneities.

HL 34 Impurities/Amorphous semiconductors

Time: Wednesday 17:15–18:30 Room: BEY 154

HL 34.1 Wed 17:15 BEY 154

Measurement of the spatial extension of defect states by probing vacancy interactions — •Philipp Ebert, Ansgar Laubsch, and Knut Urban — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

The spatial extension of localized electronic states of defects in semiconductors governs to a large degree the formation of defect bands and thus the properties of semiconductor materials. Unfortunately, the spatial extension of localized defect states is largely unknown. On the one hand theory suffers from the limited size of the supercells used, where states from neighboring defects overlap. On the other hand experiments mostly rely on STM images, where defect states can be directly imaged. However, the electric field between the tip and the sample induces an extensive band bending in semiconducting surfaces, which modifies the spatial extension of the imaged defect states. Here we domonstrate for P vacancies in InP(110) surfaces that the extension of the localized defect state in the band gap can be extracted from measuring the vacancy-vacancy interaction potentials. The interaction potentials are extracted from imaging only the position of the vacancies, which remain unaffected by the electric field of the tip. We find that surface vacancies exhibit a two-dimensional repulsive screened Coulomb interaction at high vacancy concentrations, due to the formation and partial population of a vacancy-related defect band in the band gap. In contrast at low vacancy concentration no two-dimensional screening occurs, since the vacancy states do not overlap. From this we extract that the localized P vacancy state in the band gap has a spatial extension larger that 4.1 nm in diameter.

HL 34.2 Wed 17:30 BEY 154

Threshold Switching by Short Current Pulses in Phase-Change Materials — •Daniel Krebs, Michael Woda, Henning Dieker, Christoph Steimer, and Matthias Wuttig — I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Changes in the optical properties of chalcogenide alloys between the amorphous and crystalline phase are currently used in rewritable optical data storage. The pronounced optical contrast upon the phase transformation is accompanied by an even larger change in resistivity. This qualifies these materials for memory concept replacing Flash in mobile applications.
While in optical data storage the heat for the phase transition is supplied by a short laser pulse, in the so called PC-RAM current pulses are employed. While the resistance changes can exceed three orders of magnitude the voltage required to trigger the phase change (set operation) does not rise exceedingly in comparison with the read voltage, due to threshold switching of the highly resistive amorphous state.
To get a better understanding of the correlation between threshold switching, structural, optical, and electronical properties we have systematically varied the stoichiometry of the investigated phase change materials and characterised there properties by different techniques including x-ray diffraction, optical spectroscopy and electrical measurements.

HL 34.3 Wed 17:45 BEY 154

Local atomic order and optical properties in amorphous and laser-crystallized phase-change materials — •Wojciech Wełnic[1,2], Silvana Botti[2], Matthias Wuttig[1], and Lucia Reining[2] — [1]I. Physikalisches Institut IA, RWTH Aachen, 52056 Aachen, Germany — [2]Laboratoire des Solides Irradies, École Polytechnique, Palaiseau, France

Understanding the optical contrast between the amorphous and the crystalline state is one of the scientific challenges in phase change materials. In this work we present optical spectra calculations for crystalline and amorphous GeTe a prototype phase-change alloy.
Recent experimental data reveal that covalent semiconductors like GeTe or the ternary alloy $Ge_1Sb_2Te_4$ exhibit a profound change in local atomic order upon the phase transition from the crystalline to the amorphous state: Ge atoms which occupy octahedral sites in the crystalline state become tetrahedrally coordinated in the amorphous state. Based on these findings a simple structural model of amorphous GeTe was constructed to perform *ab initio* ground state and excited state calculations to reveal the change in optical properties.
The optical spectra are calculated in the Random Phase Approximation. The eigenvalues are corrected with the GW Approximation and two-particle excitations are taken into account within the framework of the Bethe-Salpeter-Equation. The results are in good qualitative agreement with experimental data and furthermore explain the profound change in absorption upon amorphization.

HL 34.4 Wed 18:00 BEY 154

Investigation of spin-dependent transport in a-Si:H/c-Si solar cells with pulsed electrically detected magnetic resonance — •Jan Behrends[1,2], Christoph Böhme[1,3], Karsten von Maydell[1], and Manfred Schmidt[1] — [1]Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Berlin, Germany — [2]Institut für Physik, Carl von Ossietzky Universität, Oldenburg, Germany — [3]Department of Physics, University of Utah, Salt Lake City, UT, USA

Spin-coherent transport of charge carriers in heterostructure solar cells based on slightly B-doped crystalline silicon (c-Si) and strongly P-doped hydrogenated amorphous silicon (n-a-Si:H) has been investigated at different bias voltages by pulsed electrically detected magnetic resonance. The analysis of the coherent spin motion provides an insight into transport through the n-a-Si:H/c-Si heterojunction involving localised states at the interface and in a-Si:H. The experiment was carried out at T = 10 K under illumination. The photocurrent changes after a coherent electron spin resonant (ESR) excitation are superimposed by Rabi oscillations that are induced by the ESR pulse. Under reverse bias of the pn-junction a general increase of the photocurrent followed by a small decrease was observed at g = 2.005(1). This signal is assumed to originate from electron hopping through conduction band tail states. Under forward bias, the signal changes its sign and a second resonance at g = 1.999(1) with different dynamics appears in addition. Line widths, intensities, and decay time constants (also of the Rabi oscillations) were determined quantitatively and will be discussed with regard to hopping and recombination time constants.

HL 34.5 Wed 18:15 BEY 154

Structuring and characterisation of electronic phase change memories — •Michael Woda, Henning Dieker, Christoph Steimer, and Matthias Wuttig — I. Insitute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Chalcogenide based phase change materials exhibit an optical contrast between their amorphous and crystalline phase which can be switched rapidly and reversibly by laser pulses. The change in reflectivity is used in optical data storage applications such as CD and DVD.
In addition phase change alloys show a remarkable change in resistivity of several orders of magnitude. Phase change memories (or PCRAM, Ovonic memory) utilize this electronic contrast and use different short current pulses for reading and writing. It is a promising candidate to compete with existing non volatile flash memory applications.
As a characteristic feature threshold switching occurs at an applied voltage when the material is in the low conductive amorphous state. Threshold switching is necessary for phase transitions at low operating voltages. For a successful choice of material and memory development a good understanding of the switching effect has to be achieved.
Different ways of structuring phase change memory bits are presented. Electric characterization methods for determining the threshold voltage are shown. An outlook how to clarify the physical origin of the threshold switching is given.

HL 35 II-VI semiconductors III

Time: Wednesday 14:30–16:15 Room: POT 151

HL 35.1 Wed 14:30 POT 151

Optical orientation and thermal relaxation of excitons in semimagnetic CdMnSe/ZnSe quantum dots — •Thomas Schmidt[1], Michael Scheibner[1,2], Lukas Worschech[1], Alfred Forchel[1], Taras Slobodskyy[3], and Laurens Molenkamp[3] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Naval Research Laboratories, Washington, DC 20375 USA — [3]EP III, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Polarization dynamics of quantum dots (QDs) represent actually an intensely studied field of research. Of special interest are semimagnetic quantum dots due to their distinct magnetic properties caused by the interaction of carrier spins with the Mn spin system. It is clear that with decreasing Mn content the semimagnetic properties are reduced. We have studied the polarization dynamics of a series of optical orientation and thermal relaxation of excitons in CdMnSe/ZnSe quantum dots for different Mn contents ranging from 0 to 2%. From the dependence of the polarization on the magnetic field strength we determined the exciton g factors of the QDs for different Mn contents and the relevant spin relaxation times. In particular, we have been able to resolve the sign reversal of the g factor. In QDs with negligible g factor the polarization properties are dominated by the optical orientation of the excited light. The spin relaxation times extracted from the thermal relaxation depend sensitively on the Mn concentration in a range of a few picoseconds.

HL 35.2 Wed 14:45 POT 151

Whispering gallery modes in ZnSe/MgZnSSe-microdiscs with CdSe quantum dots at room temperature — •Johannes Renner[1], Lukas Worschech[1], Silke Kuhn[1], Suddho Mahapatra[2], Karl Brunner[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Experimentelle Physik III, Universität Würzburg

Several approaches are currently under investigation with the aim to control the coupling between photonic modes in a cavity with three dimensional optical confinement and excited states of quantum dots. We have studied by photoluminescence spectroscopy the emission from II-VI microdiscs with self assembled CdSe quantum dots. The quantum dots were embedded in the centre of a ZnSe/MgZnSSe heterostructure,

which was grown by molecular beam epitaxy on top of a GaAs substrate. Electron beam lithography and etching techniques were applied to define microdiscs with diameters ranging from 0.5 to 5 μm. The samples were mounted on glass and the GaAs was removed. Quantum dot emission up to temperatures of 320K was detected. In addition to that we analyzed the dependence of whispering gallery modes on the disc size and for different temperatures. We were able to resolve whispering gallery modes with quality factors exceeding 1000 even at room temperature.

HL 35.3 Wed 15:00 POT 151

Oxygen in sputter-deposited ZnTe thin Films — •Stefan Merita, Thorsten Krämer, Angelika Polity, and Bruno K. Meyer — I. Physikalisches Institut, Justus Liebig Universität, Heinrich Buff Ring 16, 35392 Giessen

Bandgap-bowing has been observed in many of the zinc-group-VI compounds, when the anion is substituted with an isovalent element. Recently new results on the $ZnO_{1-x}S_x$ and $ZnO_{1-x}Se_x$ system have been presented, but so far only one report on $ZnO_{1-x}Te_x$ is known. It is to be expected that the latter system shows a particularly strong bowing behaviour. We examine the possibility of synthesizing $ZnO_{1-x}Te_x$ thin-films by sputter-deposition. Optical transmission measurements, x-ray diffraction (XRD) and energy-dispersive-x-ray-analysis (EDX) give information about the bandgap-energy, crystal structure and composition of the samples. From this data the bowing-parameter of the $ZnO_{1-x}Te_x$-system can be deduced.

HL 35.4 Wed 15:15 POT 151

Orbital- and Spin Quantization of electronic states as Origins of Second Harmonic Generation in Semiconductors — •Benjamin Kaminski[1], I. Sänger[1], D.R. Yakovlev[1], M. Bayer[1], R.V. Pisarev[2], and V.V. Pavlov[2] — [1]Experimentelle Physik II, Universität Dortmund — [2]A.A.F.Ioffe Physical Technical Institute, Russian

The application of magnetic-fields to semiconductors enables to investigate their magnetic properties and disclose the energy and spin structure. We use the nonlinear optical technique of second-harmonic generation (SHG) to study diluted-magnetic semiconductors. In the case of diamagnetic CdTe we observe an orbital quantization induced contribution to the SHG signal, whereas the SHG intensity depends quadratically on the applied magnetic field. The same mechanism was observed in GaAs (Phys. Rev. Lett. 94, 157404 (2005)). In the case of paramagnetic (Cd, Mn)Te another SHG contribution appears. The origin of this contribution is the spin quantization of the electronic states with low Mn content. It is strongly enhanced due to the giant Zeeman splitting effect (see also J. Opt. Soc. Am. B 22, 168 (2005)). The competition of the two mechanisms is investigated for (Cd, Mn)Te with a Mn concentration of 0.001, where the spin and the orbital quantization contributions are of comparable magnitude.

HL 35.5 Wed 15:30 POT 151

Carrier-density dependence of the exchange coupling between magnetic ions and conduction band electrons in heavily n-type $Zn_{(1-x)}Mn_xSe$ and optically pumped $Cd_{(1-x)}Mn_xTe$ — •M. Lentze[1], P. Grabs[1], J. Geurts[1], K. Rönnburg[2], E. Mohler[2], and H. Roskos[2] — [1]Universität Würzburg, Experimentelle Physik III, Am Hubland, 97074 Würzburg — [2]Johann Wolfgang Goethe-Universität, Physikalisches Institut, Max-von-Laue-Str. 1, 60438 Frankfurt

Diluted magnetic semiconductors (DMS) like (Zn,Mn)Se and (Cd,Mn)Te show giant magneto-optical effects. These effects originate from the strong s/p-d interaction of the magnetic ions with conduction-band electrons and valence-band holes, which induces a pronounced spin-dependent band-splitting in external magnetic fields. For undoped bulk (Zn,Mn)Se the exchange energy for the electrons amounts to $N_0\alpha$ = 260 meV.

We analyzed the doping dependence of the exchange energy $N_0\alpha$ of the conduction band electrons for n-doped bulk-like (Zn,Mn)Se samples with doping levels up to n=$4{\cdot}10^{18}$ cm^{-3} and for optically pumped (Cd,Mn)Te. Our analysis was performed by means of spin-flip Raman spectroscopy and by time-resolved Faraday rotation experiments. Our experiments show a distinct decrease of the conduction band exchange energy with increasing n-doping level. For n=$4{\cdot}10^{18}$ cm^{-3}, the decrease amounts to 30% with respect to undoped samples. The doping-induced decrease of $N_0\alpha$ is explained in terms of the increasing contribution of electronic states with finite q-vector. Their wave functions exhibit an admixture of p-like character.

HL 35.6 Wed 15:45 POT 151

Internal Drift Effects on the Diffusion of Ag in CdTe — •H. Wolf[1], F. Wagner[1], Th. Wichert[1], and ISOLDE collaboration[2] — [1]Technische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]CERN, DH-1211 Geneva 23, Switzerland

Unusual concentration profiles have been observed upon diffusion of Ag in CdTe [1]. The diffusion experiments were performed with the radiotracers ^{111}Ag implanted into one side of a typically 800 μm thick CdTe crystal at a depth of about 30 nm. The resulting diffusion profiles of Ag extending over the whole crystal critically depend on the respective external conditions during diffusion and on the sample pre-treatments. After diffusing the Ag dopant into the CdTe crystal at 800 K (60 min) under vacuum or Cd pressure the symmetrical concentration profiles show depletion layers of 100 or 300 μm below the surfaces of the crystal, whereby the depletion layers are much stronger pronounced in case of diffusion under Cd pressure. In contrast, the Ag concentration is increased at the surface and decreased in the interior of the crystal if the diffusion is performed under Te pressure. The Ag profiles are well described within a model based on an interaction of the dopant Ag atoms with the intrinsic defects of the Cd sublattice of CdTe taking into account the charge states of all participating defects. The diffusion of Ag is significantly affected by an internal drift due to the electric field generated by the distribution of the charged defects.

supported by the BMBF, contracts 05KK1TSB/7 and CZE 03/002.

[1] H. Wolf, F. Wagner, Th. Wichert, and ISOLDE Collaboration, Phys. Rev. Lett. 94, 125901, 2005.

HL 35.7 Wed 16:00 POT 151

DX-Centers in Indium doped CdTe: Electrical characterization and PAC study — •M. Türker, J. Kronenberg, M. Deicher, H. Wolf, and Th. Wichert — Technische Physik, Universität des Saarlandes, D-66041 Saarbrücken

In CdTe, donors like Indium can be electrically compensated by vacancies present in the Cd sublattice (V_{Cd}) either by the formation of A-centers (In-V_{Cd} pairs, [1]) or DX centers. For In concentrations exceeding 10^{18} cm^{-3}, DX centers are created by the relaxation of the In donor towards an interstitial lattice site thereby generating a neighboring Cd vacancy [2]. This relaxation should create an electric field gradient (EFG) observable by perturbed $\gamma\gamma$ angular correlation (PAC) using ^{111}In/^{111}Cd. An EFG assigned to the DX defect (ν_Q=21 MHz, η=0) has been observed earlier [3]. Characteristic for DX centers is a metastable state formed by illumination at low temperatures, where the In donor relaxes back to a substitutional site leading to an increased persistent photoconductivity (PPC) [2]. We performed PAC and conductivity measurements as a function of temperature with and without illumination. Below 150 K, the samples show a PPC effect with about 20% increase of the carrier concentration. This effect is not accompanied by any changes of the PAC spectra recorded with the same samples. Possible explanations of the observed EFG will be discussed.

Supported by BMBF under contract no. 05KK1TSB/5.

[1] Th. Wichert, T. Krings and H. Wolf, Physica B **185** (1993) 297
[2] C.H. Park and D.J. Chadi, Phys. Rev. B **52** (1995) 11884
[3] S.Lany, H.Wolf and Th. Wichert, Phys. Rev. Lett **92** (2004) 225504

HL 36 Optical properties

Time: Wednesday 16:15–19:15 Room: POT 151

HL 36.1 Wed 16:15 POT 151

Temperature- and size-dependence of light absorption on silicon nanoparticles — •Andreas Gondorf[1], Stephan Lüttjohann[1], Cedrik Meier[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Laboratorium für Festkörperphysik, Universität Duisburg-Essen, 47048 Duisburg — [2]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, 47048 Duisburg

Silicon nanoparticles with diameters d< 8 nm show photoluminescence in the IR-red region of the spectrum. In temperature dependent studies it is found that the PL intensity exhibits a maximum around T=80K. It has been proposed that an energy splitting of the exciton state is responsible for this. However, as silicon is an indirect semiconductor one might argue that phonon emission or absorption processes play a decisive role in the temperature behaviour of the PL. Therefore, we have studied absorption spectra of silicon nanoparticles in the temperature range between T=30K and 300K in order to clarify the phonon contribution.

HL 36.2 Wed 16:30 POT 151

Type I type II transition in optical spectra - experiments and microscopic theory — •Christoph Schlichenmaier[1], Angela Thränhardt[1], Torsten Meier[1], Jörg Hader[2], Jerome V. Moloney[2], Stephan W. Koch[1], Kristian Hantke[1], Wolfgang Rühle[1], Heiko Grüning[1], Peter J. Klar[1], and Wolfgang Heimbrodt[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, 35032 Marburg — [2]Arizona Center for Mathematical Sciences, The University of Arizona, Tucson, AZ 85721, USA

The band alignment of GaNAs in heterostructures is determined by investigating the energetically lowest optical band-to-band transition of $In_{0.23}Ga_{0.77}As/GaN_yAs_{1-y}$ samples with varying y. In a type II alignment this transition is between states located in different layers. Photoreflectance, photoluminescence, and the radiative decay of excited carrier densities are both measured and microscopically modeled. The bandstructure for every sample is computed. Based on this bandstructure all optical properties and the radiative decay are computed using the semiconductor Bloch [1] and luminescence [2] equations including electron-electron and electron-phonon interaction on scattering level. Thus the modeling is consistent and without free parameters. Overall good agreement between theory and experiment is achieved and used to explain all experimental features and to determine the band alignment [3,4].

[1] J. Hader et al., Sol. State El. **47**, 513 (2003)
[2] M. Kira et al., Prog. Quantum Electron., **23**, 189 (1999)
[3] C. Schlichenmaier et al., Appl. Phys. Lett., **86**, 081903, (2005)
[4] K. Hantke et al., Phys. Rev. B, **71**, 165320 (2005)

HL 36.3 Wed 16:45 POT 151

Theory of bosonic signatures in semiconductor luminescence — •Stefan Pfalz, Daniel Hägele, and Michael Oestreich — Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover

Much experimental and theoretical effort has been devoted to the goal of observing Bose-Einstein Condensation (BEC) of excitons in semiconductors. While this ultimate goal is still to be reached, recent experiments showed that stimulated bosonic scattering of excitons leaves a characteristic signature in the photoluminescence of direct quantum wells [1]. Luminescence at the biexciton energy is usually unpolarized due to the opposite spin orientation within the bound exciton pair. In the presence of spin polarized excitons, however, the photoluminescence exhibits a finite degree of polarization due to stimulated scattering. This signature appears already at temperatures far above the critical value for BEC. The level of theory required to explain this effect exceeds available microscopic photoluminescence theories as inclusion of exciton correlations beyond the biexcitonic level is required. Using a one-dimensional model and exact diagonalization, we calculate photoluminescence spectra for the case of high exciton densities and find good qualitative agreement with experiments. Bosonic signatures are also found in cases where the Bose-commutation relations are not perfectly fulfilled.

[1] D. Hägele, S. Pfalz, and M. Oestreich, Solid State Commun. **134**(3), 171 (2005).

HL 36.4 Wed 17:00 POT 151

1.55 μm luminescence from $InAs/In_xGa_{1-x}As_{1-y}N_y$ quantum dots grown on GaAs substrates — •Mirja Richter[1,2], Benjamin Damilano[1], Jean Massies[1], Jean-Yves Duboz[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications, CNRS, Sophia-Antipolis, F-06560 Valbonne, France — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Self-assembled InAs quantum dots (QDs) encapsulated with an $In_xGa_{1-x}As_{1-y}N_y$ (GINA) layer were grown by molecular beam epitaxy on GaAs substrates. The objective is to get efficient 1.55 μm emission from these nanostructures. The interest of adding nitrogen to the classical system $InAs/In_xGa_{1-x}As$ is that it decreases the bandgap of $In_xGa_{1-x}As$ with an enormous band bowing but also compensates parts of the strain. However, adding nitrogen introduces a high density of point defects which results in degraded photoluminescence (PL) properties. Fortunately, the density of these defects can be decreased by rapid thermal annealing (RTA). The growth process was optimized including a change in growth temperature and rate for the QDs and the GINA layer. RTA was carried out at optimized temperatures. Thereby we achieve high intensity PL emission in the 1.55 μm range with a small full width at half maximum from these InAs/GINA QDs. Finally, studies of the growth on focussed ion beam structured doping regions will be presented.

HL 36.5 Wed 17:15 POT 151

Extracting the Random Potential of Disordered Semiconductors via Directional Interference of Photoluminescence — •Peter Bozsoki[1], Walter Hoyer[1], Mackillo Kira[1], Klaus Maschke[2], Torsten Meier[1], Peter Thomas[1], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps-Universität Marburg, Germany — [2]Institut de Théorie des Phénomènes Physiques, Ecole Polytechnique Fédérale, CH-1015 Lausanne, Switzerland

We suggest a new method to gain information about the influence of disorder on the emitting electronic states in semiconductors. It uses the interference contrast of the spontaneously emitted light into different directions [1]. A microscopic expression is presented for the interference contrast in a model which includes both random disorder and Coulomb interaction. This relation gives a direct access to detailed information about the effect of disorder on the electronic states.

[1] W. Hoyer et.al. PRL 93, 067401 (2004)

HL 36.6 Wed 17:30 POT 151

Semiconductor microtubes acting as optical ring resonators — •T. Kipp, H. Welsch, Ch. Strelow, Ch. Heyn, and D. Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

We demonstrate optical modes in InGaAs/GaAs microtubes acting as an optical ring resonator. Self-supporting microtubes with a diameter of about 5 μm and a wall thickness of about 200 nm were fabricated by optical lithography and wet-etching processes utilizing the self-rolling mechanism of strained bilayers. The optical modes were probed by the photoluminescence of InAs quantum dots embedded in the tube's wall. In this novel microtube ring resonator we find a spectrum of sharp modes. They are in very good agreement with the theoretical results for a closed thin dielectric waveguide. Financial support is acknowledged by the Deutsche Forschungsgemeinschaft via the SFB 508.

HL 36.7 Wed 17:45 POT 151

Optical activation and electrical stabilization of the ultra violet electroluminescence from SiO2:Gd gate oxide layers by fluorine and potassium co-implantations — •Slawomir Prucnal, J.M. Sun, H. Reuther, and W. Skorupa — Institute of Ion Beam Physics and Materials Research,Forschungszentrum Rossendorf,POB 510119, D-01314 Dresden, Germany.

If amorphous SiO2 is bombarded with energetic ions, various types of defects are created as a consequence of ion-solid interaction and annealing processes (oxygen deficiency centres ODC, non-bridging oxygen hole centres NBOHC, E*-centres, etc.) leading to charge trapping effects during electrical excitation. Metal-Oxide-Silicon-based light emitting diodes

(MOSLEDs) with Gd implanted SiO2 layers exhibit strong ultra violet electroluminescence (EL) at 316 nm from Gd3+ ions and an enhancement of the luminescence from the aforementioned defects. Elimination or neutralisation of such defects is very important from the viewpoint of electrical stability of MOSLEDs. It will be demonstrated that (i) an additional fluorine implant into a SiO2:Gd layer leads to decrease of E*-centres and ODCs improving the efficiency of the MOSLED; and (ii), an additional potassium implant produces positive ions leading to a compensation effect for the negatively charged electron traps and, hence, to an reduced quenching of the EL efficiency and increased MOSLED lifetime .

HL 36.8 Wed 18:00 POT 151

Theory of Photoluminescence for Semiconductor Quantum Dots — •Christopher Gies, Jan Wiersig, Norman Baer, and Frank Jahnke — Institute for Theoretical Physics, Universität Bremen, Postfach 330 440, 28334 Bremen, Germany

Semiconductor quantum dots have unique properties suited for the development of new light emitting devices. Their emission properties can be controlled to a great extent by embedding in a microcavity. Enhanced spontaneous emission and ultra-low-threshold lasers are among possible applications. Direct insight into the light-matter interaction in these systems can be gained from time-resolved photoluminescence measurements.

For an analysis of these measurements we use a theory beyond the widely established two-level atom model. In a semiconductor system, electrons and holes are in general not fully correlated, and thus, the influence of correlations should be explicitly calculated.

We present results from a microscopic quantum kinetic theory. The influence of many-body effects on the photoluminescence spectrum and decay for systems in a cavity and in free space is studied. From our results we draw conclusions upon the validity of the two-level atom approach.

HL 36.9 Wed 18:15 POT 151

Optical properties and energy transfer studies of AlN doped with rare earths at high concentrations — •Gregor Öhl[1], Ulrich Vetter[1,2], and Hans Hofsäss[1] — [1]Georg-August-Universität, II. Physikalisches Institut, Göttingen — [2]Philipps-Universität, AG Oberflächenphysik, Marburg

Rare earths (RE) in AlN, e.g. AlN:Gd [1,2] or AlN:Eu [3], have increasingly been attracting interest during recent years due to their promising features, e.g. as electroluminescent light emitters.

For increasing RE concentrations, one expects energy transfer reactions between different RE ions, leading to possible changes in luminescence intensity and lifetime.

In our studies, we investigated the systems (Pm,Sm):AlN, Gd:AlN and Eu:AlN. The REs were implanted at a fluence of about $10^{13} cm^{-2}$ in the first case, in the latter cases at different energies giving a square implantation profile, with RE concentrations of the order of atomic percent. Monitoring the effect of the post-implantation annealing procedure (up to about 1600 K), the critical implantation fluence for lattice recovery was determined to be in the order of some $10^{16} cm^{-2}$.

Optical properties were investigated by temperature dependent time-resolved cathodoluminescence studies, energy transfer studies were performed on selected $intra-4f$ transitions of the implanted lanthanide ions showing concentration-related effects.

[1] U. Vetter et al., Appl. Phys. Lett. 83, 11 (2003)
[2] J.B. Gruber, U. Vetter et al., Phys. Rev. B 69 (2004)
[3] W.M. Jadwisienczak, H.L. Lozykowski et al., JAP 89 (2001)

HL 36.10 Wed 18:30 POT 151

Interband Thermoluminescence of Semiconductors and Semiconductor Nanocrystals in the Near-Infrared — •Stefan Hanna and Alois Seilmeier — Physikalisches Institut, Universität Bayreuth, D-95440 Bayreuth, Germany

Generally semiconductor luminescence is measured following electronic or optical sample excitation. In this contribution experiments are presented in which the luminescence of undoped semiconductors and of semiconductor nanocrystals near the band gap is solely thermally excited and explored by a simple and unconventional technique. Luminescence spectra are obtained at ambient conditions after slightly heating the samples to approximately 100°C *without using any additional electronic or optical means of excitation.* In our investigations, bulk GaAs, bulk InP and semiconductor doped glasses are studied. We show that absorption properties and band gap positions obtained directly from emission spectra not only correspond well to those obtained from transmission measurements, but also yield additional information about the role of defects giving rise to emission from within the band gap. This technique may be of considerable interest for online monitoring of material growth, which is generally performed at elevated temperatures, without any interference with the growth process.

HL 36.11 Wed 18:45 POT 151

Radiative Lifetime of Excitons in Multi Quantum-Well Systems — •Martin Schäfer, Marco Werchner, Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps University, Marburg, Germany

Effects like superradiance occurring in multi-quantum-well systems suggest that the radiative coupling between the quantum-wells can change the exciton lifetime with respect to a single quantum well. Therefore, a fully quantum-mechanical theory [1,2] is applied to analyze the exciton lifetime in a planar array of multiple radiatively coupled quantum wells. In the incoherent limit, the exciton lifetime of optically active excitons is independent of the homogeneous dephasing and therefore determined by the radiative lifetime.

In this talk, it is shown that the exciton lifetime in a multi-quantum-well system is enhanced compared to that in a single quantum-well. The lifetime is determined by the specific coupling between the quantum-wells and thus influenced by their spacing as well as by the background refractive-index profile of the structure. In this connection, a step-function-like refractive-index profile is investigated where the distance of the first quantum-well to the step is shown to have strong influence on the exciton lifetime. Furthermore, it is shown that an exciton population in one quantum well is able to create exciton populations in neighboring quantum wells due to the radiative coupling.

[1] M. Kira, F. Jahnke, W. Hoyer and S.W. Koch, Prog. in Quantum Electron. **23**, 189 (1999)
[2] M. Kira and S.W. Koch, E. Phys. J. D **36**, 143 (2005)

HL 36.12 Wed 19:00 POT 151

Recombination kinetics of excitons in AlN — •Barbara Bastek[1], T. Riemann[1], J. Christen[1], K. Balakrishnan[2], N. Fujimoto[2], T. Kitano[2], M. Iwaya[2], S. Kamiyama[2], I. Akasaki[2], and H. Amano[2] — [1]Otto-von-Guericke-University Magdeburg, Germany — [2]Meijo University, Nagoya, Japan

The luminescence of AlN layers is analyzed by spatially, spectrally and ps-time resolved cathodoluminescence microscopy (CL) at variable temperature. AlN was grown directly on 6H-SiC substrate by MOVPE above 1350°C. CL spectra at T=6K show bright near band edge emission (NBE) around 5.98eV and two broad defect related luminescence bands at 4.2eV and 3.2eV, respectively. The NBE peak position evidences tensile stress in the AlN layers and perfectly maps the stress relaxation at micro-cracks. The dominant NBE emission at 6K is assigned to an impurity bound exciton. At about 60K we observe the thermal activation of a high energy peak, identified as the free A-exciton X_A (Ry=59meV; E_{loc}=19meV). Periodic excitation of the AlN was performed in ps-CL by rectangular e-beam pulses. The NBE decay follows two different time scales ($\tau_1 \approx$100ps, $\tau_2 \approx$2.5ns). The slow component is preferentially found at the spectral position of X_A and vanishes at temperatures above T=15K. For the 3.2eV band a strongly non-exponential decay is found with time constants in the ms-range. The NBE recombination kinetics of different AlN layers is correlated with appearance and strength of the defect bands.

HL 37 Invited Talk Bustarret

Time: Thursday 09:30–10:15 Room: HSZ 01

Invited Talk HL 37.1 Thu 09:30 HSZ 01

Superconducting boron-doped single crystal diamond — •Etienne Bustarret[1], Jozef Kacmarcik[1], Thierry Klein[1], Benjamin Sacépé[2], Claude Chapelier[2], Christophe Marcenat[2], Emmanuel Bourgeois[3], and Xavier Blase[3] — [1]LEPES-CNRS BP166, 38042 Grenoble, France — [2]SPSMS-DRFMC CEA, 17 rue des Martyrs, 38054 Grenoble, France — [3]LPMN-UCB, 43 Bvd 11 nov. 1918, 69622 Villeurbanne, France

Although the early observation of superconductivity in semiconductors was considered in the 60's a validation of the BCS model, experimental evidence for superconductivity in boron-doped diamond came in 2004 as a major surprise to both the diamond and the superconducting materials communities. After reviewing recent literature, we focus on the growth and structural properties of homoepitaxial boron-doped layers before showing that in {001}-oriented epilayers superconductivity occurs above a critical boron density around 5 E20 cm-3 , close to the critical concentration for the metal/non metal transition. Resistivity and ac susceptibility measurements yield also the H(T) phase diagram of this type II-superconductor in the dirty limit. Since low temperature scanning tunnel microscopy shows that the local gap of excitations has a shape and a temperature-dependence compatible with a BCS-type pairing mechanism, experimental data and ab initio supercell calculations are then presented in order to discuss the strength of the electron-phonon coupling. Finally, the main properties of the vortices (core and Abrikosov lattice) imaged under a moderate magnetic field are also discussed.

HL 38 Invited Talk Meier

Time: Thursday 10:15–11:00 Room: HSZ 01

Invited Talk HL 38.1 Thu 10:15 HSZ 01

Coherent optical generation and decay of charge and spin currents in semiconductor heterostructures analyzed by microscopic theory — •Torsten Meier[1], Quang Tuyen Vu[1], Huynh Thanh Duc[1,2], Hartmut Haug[3], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg — [2]Institute of Physics, Mac Dinh Chi 1, Ho Chi Minh City, Vietnam — [3]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität Frankfurt, Max-von-Laue-Strasse 1, D-60438 Frankfurt

The coherent optical injection and temporal decay of spin and charge currents in semiconductor heterostructures is described on a microscopic basis. The approach includes excitonic effects and many-body Coulomb correlations as well as the carrier LO-phonon coupling on the second-order Born-Markov level. Furthermore, the light-field-induced intraband and interband excitations are treated nonperturbatively. Enhanced damping of the spin current relative to the charge current is obtained as a consequence of Coulomb scattering and a nonmonotonic dependence of the currents on the intensities of the two incident laser beams is predicted [1]. Additionally, the influence of memory effects on the coherent transients is investigated [2].

[1] Huynh Thanh Duc, T. Meier, and S.W. Koch, Phys. Rev. Lett. 95, 086606 (2005).
[2] Q.T. Vu, Huynh Thanh Duc, T. Meier, H. Haug, and S.W. Koch, unpublished.

HL 39 Symposium Photonic metamaterials

Time: Thursday 11:00–13:00 Room: HSZ 01

Keynote Talk HL 39.1 Thu 11:00 HSZ 01

Magnetoinductive waves in magnetic metamaterials — •Ekaterina Shamonina — Department of Physics, University of Osnabrück, D-49069 Osnabrück, Germany

Magnetoinductive waves have arisen as a by-product of the research on negative refraction and subwavelength imaging in metamaterials. Metamaterials are artificial structures comprising arrays of small resonant elements. Contrary to photonic band gap (PBG) materials, where the periodicity of the structure is comparable to the wavelength, in metamaterials both the size and the distance between the elements are much smaller than the wavelength. Consequently, the electromagnetic response of PBG materials is due to Bragg diffraction phenomena, whereas in metamaterials subwavelength phenomena are responsible for their unusual electromagnetic properties. In particular, magnetic metamaterial elements such as Split Ring Resonators are capable of propagating not only transverse electromagnetic waves but also waves due to their magnetic coupling and their resonant nature, known now as magnetoinductive waves, opening up several avenues of novell applications.

In the present talk the birth of the subject of metamaterials, including many early contributions, is briefly reviewed and the properties of magnetoinductive waves are discussed with particular reference to their dispersion characteristics, excitation and applications such as near field imaging, sensing and manipulation including waveguides, waveguide components, flux concentrators and detectors for magnetic resonance imaging.

Keynote Talk HL 39.2 Thu 11:30 HSZ 01

Photonic metamaterials: Magnetism and negative index of refraction at optical frequencies — •Stefan Linden[1], Martin Wegener[1,2], Christian Enkrich[2], Matthias. W. Klein[2], Manuel Decker[2], Gunnar Dolling[2], Nils Feth[2], Costas. M. Soukoulis[3], Sven Burger[4], and Frank Schmidt[4] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Germany — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [3]Ames Laboratory and Department of Physics and Astronomy, Iowa State University, U.S.A. — [4]Zuse Institut Berlin, Germany

We review our recent work on photonic metamaterials, comprising "artificial magnetism" in the near-infrared spectral region as well as the fabrication of square-centimeter area structures. Very recent experimental results indicate the possibility of low-loss negative-index metamaterials at $1.5 \mu m$ wavelength.

Keynote Talk HL 39.3 Thu 12:00 HSZ 01

Metamaterials: Going Optical — •Vladimir Shalaev — School of Electrical and Computer Engineering, Purdue University, West Lafayette, IN 47907, USA

In this talk I'll review our recent theoretical and experimental studies on metamaterials with a negative refractive index in the optical range.

Keynote Talk HL 39.4 Thu 12:30 HSZ 01

Negative refraction without absorption in the optical regime — •Michael Fleischhauer — Fachbereich Physik, Technische Universitaet Kaiserslautern, 67763 Kaiserslautern

Negative refraction can lead to a number of interesting effects and applications in quantum electrodynamics and laser physics. Among them are strong radiative coupling between atoms over mesoscopic distances, the modified Purcell effect or the possibility for zero-optical length resonators. These effects require however low-loss negative refraction in the

optical regime which has not been achieved so far. After a short review of QED effects in negative-index materials I will discuss a theoretical proposal for resonantly enhanced chirality and negative refraction without absorption based on electromagnetically induced transparency.

HL 40 Quantum dots and wires: Optical properties III

Time: Thursday 11:00–13:15 Room: POT 151

HL 40.1 Thu 11:00 POT 151

Quantum Theory of Quantum Dot Emission — •Lukas Schneebeli, Thomas Feldtmann, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps-Universität Marburg

The microscopic theory of semiconductor quantum dots is formulated including Coulomb interaction and quantum optical coupling effects. Several examples of optical excitations are evaluated using the generalized semiconductor Bloch and luminescence equations [1,2]. Absorption and photoluminescence spectra are discussed for several quantum dot realizations.

[1] M. Kira et al./Progress in Quantum Electronics 23 (1999) 189-279
[2] M. Kira and S.W. Koch Eur. Phys. J.D 36, 143-157 (2005)

HL 40.2 Thu 11:15 POT 151

Quantum kinetics of polarons in semiconductor quantum dots — •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

Applications of semiconductor quantum dots (QDs) require efficient carrier scattering processes. We investigate the interaction of carriers with LO phonons in semiconductor QDs, which dominates at low carrier densities and elevated temperatures and leads to fast scattering channels even in QDs where the level spacing does not match the LO-phonon energy.

A quantum kinetic theory of the interacting many-body system is presented, where carriers are described as polarons. The relaxation of a nonequilibrium carrier distribution due to optical pulse excitation is investigated within the full 2-time Green's function formalism and a 1-time approximation using the generalized Kadanoff-Baym ansatz.

It is shown that the 2-time approach leads to a thermalization in terms of the Kubo-Martin-Schwinger condition, while the 1-time approach fails in the intermediate-coupling regime, event though a steady state carrier distribution is obtained.

HL 40.3 Thu 11:30 POT 151

Exciton Aharonov-Bohm Effect in Type I and II Nanorings — •Michal Grochol, Frank Grosse, and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

The exciton Aharonov-Bohm effect (x-ABE), an oscillatory dependence on the magnetic field, in semiconductor nanorings presents an open question. Although theoretical studies on infinitely narrow nanorings [1] have predicted the x-ABE, more realistic calculations including the finite width of the rings [2] could not confirm these findings.

We present calculations of absorption spectra for realistic ring geometries and material parameters for type I and type II band alignments [3]. x-ABE oscillations are found in both types of structures. Their amplitudes are larger for type II nanorings and increase with decreasing the ring radius. In specific type II nanorings the hole position in the lowest optically active exciton state changes from the center of the ring to the outside by increasing the magnetic field. Possible strategies for observing experimentally the Aharonov-Bohm effect for excitons in semiconductor nanorings are proposed.

[1] L. G. G. V. D. da Silva, S. E. Ulloa, and T. V. Shahbazyan, B **72**, 125327 (2005)
[2] J. Song and S. E. Ulloa, Phys. Rev. B **63**, 125302 (2001)
[3] M. Grochol, F. Grosse, and R. Zimmermann, cond-mat/0511324

HL 40.4 Thu 11:45 POT 151

Optical properties of semiconductor microcavities — •J. Wiersig[1], N. Baer[1], P. Gartner[1], F. Jahnke[1], and M. Hentschel[2] — [1]Institut für Theoretische Physik, Universität Bremen,* 28334 Bremen — [2]Universität Regensburg

Optical microcavities are fundamental tools to study and tailor the emission characteristics of semiconductor quantum dots. The dielectric environment allows to enhance or inhibit light-matter interaction by modifying the optical density of states available for optical transitions, and it permits directed emission of photons by changing the spatial profile of the optical modes. Both aspects will be studied numerically for two different sorts of cavities: micropillars and microdisks with air holes. The spatial profile of the electromagnetic field, quality factors and Purcell factors of micropillars are computed using a vectorial transfer matrix approach. The influences of conical deformations of the boundary, layer-thickness fluctuations and residual absorption are investigated. Microdisks with air holes are analyzed using the extended boundary element method. Unidirectional light emission and ultra-high quality factors are observed. This surprising finding is explained by enhanced dynamical tunneling near an avoided resonance crossing.

HL 40.5 Thu 12:00 POT 151

Effect of Size and Shape on the Single-Particle Spectrum of InAs/GaAs Quantum Dots: A Tight-Binding Study — •Alexander Kleinsorge[1], Peter Kratzer[1], Matthias Scheffler[1], Roberto Santoprete[2], and Belita Koiller[2] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil

With the help of electronic structure calculations, the electronic and optical properties of quantum dots (QDs) can be related to their atomic structure. We employ the empirical sp^3s^* tight-binding approach, including second-nearest neighbor interactions and spin-orbit coupling, preceded by structural relaxation using a potential of the Abell-Tersoff type to obtain the atomic positions. The folded-spectrum method to calculate selected eigenstates of the Hamiltonian allows us to treat large systems (up to 10^6 atoms). We apply our method to buried InAs quantum dots in GaAs, comparing pyramidal shapes with {101} or {111} side facets with more realistic truncated pyramids, hut-like, or dome-like shapes. The total number of electron and hole bound states, their energy and spatial extent are determined as a function of the QD size and shape. In particular, we find that energy splitting between p-like electron states is due to the symmetry properties of the zincblende lattice, rather than the symmetry of the QD shape. Piezoelectric effects arising from shear strain (treated as an external potential) are included, but found to be small (≈ 5 meV) for the QD sizes considered. Moreover, we compare the wavefunctions in free standing dots to experimental STM images.

HL 40.6 Thu 12:15 POT 151

Exciton Dephasing in Quantum Dots: An Exactly Solvable Model — •Egor Muljarov and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, D-12489 Berlin

In quantum dots, the nondiagonal phonon coupling is responsible for the two main mechanisms of the dephasing - real and virtual phonon-assisted transitions between different excitonic states which have been recently treated in an approximate way [1]. It turns out, however, that virtual transitions alone can be taken into account by mapping the nondiagonal coupling into a level-diagonal quadratic interaction which can be solved exactly. Surprisingly, the quadratic coupling in quantum dots leads to qualitatively different results in case of acoustic and optical phonons. As shown in [2], virtual transitions with acoustic phonon assistance result in an exponential decay of the optical polarization and a broadening of the zero-phonon line. In contrast, the quadratic coupling to dispersionless optical phonons gives no dephasing at all, which rectifies an approximate treatment by Uskov *et al.* [3]. In fact, the exact solution shows that the polarization is almost perfectly periodic in time domain, and the absorption spectrum consists of an infinite set of discrete unbroadened lines.

[1] E. Muljarov, T. Takagahara, and R. Zimmermann, Phys. Rev. Lett. **95**, 155405 (2005).
[2] E. Muljarov and R. Zimmermann, Phys. Rev. Lett. **93**, 237401 (2004).
[3] A.V. Uskov *et al.*, Phys. Rev. Lett. **85**, 1516 (2000).

HL 40.7 Thu 12:30 POT 151

Microscopic Dynamics of two Coupled Quantum Dots — •Sandra Ritter, Kwang Jun Ahn, Juliane Danckwerts, and Andreas Knorr — Institut für Theoretische Physik,Nichtlineare Optik und Quantenelektronik,Technische Universität Berlin,Hardenbergstr. 36, 10623 Berlin, Germany

Within a density-matrix approach, we investigate the quantum kinetics of two Förster coupled semiconductor quantum dots. For the longitudinal Coulomb interaction, the Förster process leads to excitation energy transfer between the two quantum dots. Depending on resonant or nonresonant coupling, a qualitatively different behavior can be observed. Furthermore, we study the combined effects related to Förster transfer and dephasing processes.

HL 40.8 Thu 12:45 POT 151

Theory of Sonoluminescence of Semiconductor Quantum Dots — •Frank Milde, Kwang Jun Ahn, Valentin Flunkert, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The dynamics of resonance fluorescence spectra of acoustically excited intersubband electronic transitions in semiconductor quantum dot is discussed. Since the frequency of the used acoustic waves is well off-resonant to all electronic transitions higher-order harmonics (many phonon absorption) dominate the nonlinear excitation regime.

The derivation of the equations of motion for the photon number of the quantized field is performed in the density matrix formalism. Numerical simulations predict a conversion of incident acoustic into electromagnetic energy over a broad spectral Terahertz range.

HL 40.9 Thu 13:00 POT 151

Optical and electronic properties of self-organized wurtzite InN/GaN quantum dots — •Stefan Schulz, Norman Baer, Stefan Schumacher, Paul Gartner, Frank Jahnke, and Gerd Czycholl — Institute for Theoretical Physics, University of Bremen

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 red to ultraviolet and their potential for high-power electronic applications.

We investigate the electronic and optical properties of self-assembled InN/GaN quantum dots [1]. The one-particle states of the low-dimensional heterostructures are provided by a tight-binding model that fully includes the wurtzite crystal structure on an atomistic level. Optical dipole and Coulomb matrix elements are calculated from these one-particle wave functions and serve as an input for full configuration interaction calculations. We present multi-exciton emission spectra and discuss in detail how Coulomb correlations and oscillator strengths are changed by the piezoelectric fields present in the structure. Vanishing exciton and biexciton ground state emission for small lens-shaped dots is observed.

[1] N.Baer, S. Schulz, S. Schumacher, P. Gartner, G. Czycholl, and F. Jahnke, Appl. Phys. Lett. **87** (2005).

HL 41 Heterostructures

Time: Thursday 11:00–12:45 Room: BEY 154

HL 41.1 Thu 11:00 BEY 154

Spin transport in semiconductor heterostructures with Rashba spin-orbit interaction in an electric field — •Olaf Bleibaum — Institut für Theoretische Physik, Otto-von-Guericke Universität, 39016 Magdeburg, PF 4120

Investigations on the impact of an electric field on spin transport processes are of much current interest. Particular attention is paid to systems with Rashba spin-orbit interaction. We have derived a system of diffusion equations, which also take into account the coupling between spin transport and charge transport, to get further insight into the impact of the electric field on the transport properties of such systems. In the talk we discuss the structure of these equations and investigate special solutions. Doing so, we pay particular attention to quantum and spin-charge coupling effects.

HL 41.2 Thu 11:15 BEY 154

Electrical Spin Injection from ZnMnSe into InGaAs/GaAs Quantum Dots — •W. Löffler[1,2], D. Tröndle[1,2], J. Fallert[1], H. Kalt[1,2], D. Litvinov[3,2], D. Gerthsen[3,2], J. Lupaca-Schomber[1,2], T. Passow[1,2], B. Daniel[1,2], J. Kvietkova[1], and M. Hetterich[1,2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), D-76128 Karlsruhe (Germany) — [2]DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), D-76128 Karlsruhe (Germany) — [3]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe (TH), D-76128 Karlsruhe (Germany)

We report on efficient injection of spin-polarized electrons into InGaAs quantum dots (QDs) embedded in a p-i-n light-emitting diode structure. For electron spin alignment we made use of a semi-magnetic spin-aligner layer (ZnMnSe) on top. The spin-LEDs have been grown by molecular-beam epitaxy and show a nearly perfect III-V/II-VI interface in transmission electron microscopy. In an external magnetic field, we find a circular polarization degree of up to 75% for the electro-luminescence of the QDs. We can clearly attribute this polarization degree to be due to recombination of spin-injected electrons (with unpolarized holes) by comparison with results from reference devices without spin aligner and all-optical measurements. The robustness of this injection scheme is characterized with respect to sample temperature and current density. From that, we deduce that this combination of nearly perfect spin-alignment in ZnMnSe and ultra-long spin lifetimes in InGaAs/GaAs QDs is a very promising candidate for spintronics applications.

HL 41.3 Thu 11:30 BEY 154

Simulated strain-energy minimization in oxygen, SiO_2 and GeO_2 monolayer quantum wells in Si(001) — •D Quinlan[1] and R Tsu[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]University of North Carolina at Charlotte

We simulate the hypothetical structural feasibility of three quantum wells that could be grown in bulk Si(001). The most basic QW geometry consists of a single monolayer of oxygen forming a set of “bridge bonds” separating two volumes of silicon (i.e. [Si]−O−[Si] in the 001-direction). SiO_2 or GeO_2 can be formed by two of these oxygen monolayers enclosing a single layer of germanium or silicon ([Si]−O−X−O−[Si], where X = Si or Ge). Relaxation of the QW geometry is performed using the Keating model, which defines total strain energy as a summation of contributions based on bond-length and bond-angle deviations from equilibrium values. This yields an atomic structure that defies bulk crystalline silicon symmetry. The result is consistent with knowledge of similar (001)-terminations of crystalline silicon, including clean silicon surface reconstruction and the Si-αSiO_2 interface, where the new periodicity requires a larger pattern to properly define.

[1] PN Keating, Phys. Rev. **145**, 637 (1966).
[2] F Wooten, K Winer and D Weaire, Phys. Rev. Lett. **54**, 1392 (1985).
[3] H Over, J Wasserfall, W Ranke, C Ambiatello, R Sawitzki and W Moritz, Phys. Rev. B **55**, 4731 (1997).
[4] Y Tu and J Tersoff, Phys. Rev. Lett. **84**, 4393 (2000).

HL 41.4 Thu 11:45 BEY 154

Mesoscopic systems of cold indirect excitons in traps — •Alexei Filinov[1], Yurii Lozovik[2], Jens Boning[1], and Michael Bonitz[1] — [1]Institut fur Theoretische Physik und Astrophysik, Leibnizstrasse 15, 24098 Kiel — [2]Institute of Spectroscopy RAS, Troitsk, 142190, Russia

Experimental studies of cold excitonic gases in heterostructures attract now high interest due to the predicted possibility to observe Bose condensation of indirect excitons. If the excitons have an intrinsic dipole moment produced from specially engineered quantum well bandstructure or an applied electric field, the repulsive dipole-dipole interaction can be a dominant effect which should be taken into account in theoretical considerations. Here we study with Path Integral Monte Carlo (PIMC) simulation recent experimental realizations of indirect excitons in GaAs/AlGaAs coupled QWs [1] and in a single QW in high electric fields influenced in addition by a lateral confinement producing a 3D trap. First, using pre-compiled effective dipole moment, we consider the excitons as 2D bosonic particles. We analyze the possibility to observe an

exciton supersolid [2] in mesoscopic systems (N=10..40) and present simulation results for the condensate fraction and the superfluidity. Second, by varying exciton density and temperature we compare these results with full 3D simulations where the excitons are composed from electrons and holes. This comparison allows for a rigorous check of the applicability and limits of the bosonic model of dipoles.

[1] V.Negoita, D.W.Snoke, K.Eberl, Phys. Rev. B 60, 2661 (1999); L.V.Butov et al., Phys.Rev.Lett. 86, 5608 (2001). [2] Yu.E.Lozovik, S.Yu.Volkov, and M.Willander, JETP Lett. 79, 473 (2004).

HL 41.5 Thu 12:00 BEY 154

Resonant impurity states in quantum wells and superlattices — •Dominik Stehr[1], Claus Metzner[2], and Manfred Helm[1] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 510119, D-01314 Dresden — [2]Technische Physik I, Universität Erlangen, Erwin-Rommel-Str.1, D-91058 Erlangen

Introducing dopant atoms in quantum wells (QWs) and superlattices results in a random impurity potential in addition to the confinement in growth direction. As has recently been demonstrated, their hydrogenic levels form resonant states attached to each QW subband and finally develop into a novel type of impurity band in the case of superlattices[1]. Here we present detailed numerical studies of coupled double and quadruple QW structures with relatively low doping (few 10^{10}cm^{-2} per layer), which can be seen as precursors to superlattices. By treating impurity and QW potential in a unified framework we exactly diagonalize the fully three-dimensional Schrödinger equation and calculate the infrared absorption spectrum. We find that, by varying the lattice temperature, the absorption spectrum changes dramatically, not only in its energetic resonances but also in its electronic origin. Analyzing the 3D-wavefunctions of the electronic states contributing to the final absorption spectra shows that at room temperature mainly delocalized states (intersubband states) contribute to the spectra, whereas at low temperature they are dominated by strongly localized states (impurity states). Hitherto unexplained experimental data of a quadruple QW sample are nearly perfectly reproduced by our calculation.

[1] D. Stehr et al., Phys. Rev. Lett., in print (2005).

HL 41.6 Thu 12:15 BEY 154

Effective Hamiltonian Approach for the Magnetic Band Structure and Novel Oscillations in the Magnetization of Two-Dimensional Lattices in a Magnetic Field — •Manfred Taut, Helmut Eschrig, and Manuel Richter — Leibniz Institute for Solid State and Materials Research, IFW Dresden, POB 270116, 01171 Dresden, Germany

The one-electron Schrödinger equation in a two-dimensional **periodic potential** and an **homogeneous magnetic field** B perpendicular to the plane is solved exactly for rational flux quantum numbers per unit cell $\Phi_c/\Phi_0 = p/q$. For comparison, the spectrum around a certain flux quantum number p_0/q_0 has also been obtained by semi-classical quantization of the exact magnetic band structure (MBS) at p_0/q_0. To implement and justify this procedure, a generalized effective Hamiltonian theory based on the MBS at finite magnetic fields has been established. The **total energy** as a function of Φ_c/Φ_0 shows **series of kinks**, where each kink indicates an **insulating** state. The kinks of each series converge to a **metallic** state. The **magnetization** contains information not only about the band structure (at zero-magnetic-field), but also about the *magnetic* band structures (for finite fields). The **period of the oscillations** in $M\left(1/(B - B_0)\right)$ is determined by the Fermi surface cross sections for the MBS at B_0. The **height of the steps** in $M(B)$ provides the energy gap in the MBS at B. Unlike the standard Lifshitz-Kosevich type approaches, our theoretical de Haas-van Alphen spectra contain the effects of magnetic breakdown, forbidden orbits and inter band coupling implicitly.

HL 41.7 Thu 12:30 BEY 154

Statistics of microcavity polaritons under non-resonant excitation — •Paolo Schwendimann and Antonio Quattropani — Institute of Theoretical Physics, Ecole Polytechnique Fédérale, CH 1015 Lausanne-EPFL

In this contribution we present a model describing polariton amplification and coherence observed in non-resonantly excited polariton systems. We consider a quantum well embedded in a microcavity, excited by a continuous laser field at energy near the conduction band edge. The laser intensity is such that the exciton density in the microcavity remains much smaller than the exciton saturation density. The emission characteristics of this system are described in terms of interacting microcavity exciton-polaritons, which are admixtures of excitons and photons. As it is well known, the pump polariton state decays along the exciton-polariton dispersion curve, until the dispersion flattens. In this energy region a bottleneck effect is observed. We exploit this result by assuming that the polariton modes in the bottleneck may be considered as a thermal reservoir. Since emission is observed into the lowest energy state of the system at k = 0, we derive a master equation describing the evolution of this mode under the influence of the bottleneck reservoir. We show that this mode exhibits a threshold depending on the material parameters and on the injected exciton density. In particular we show that above threshold the statistics of the polaritons approaches that of a laser. As an example, we present the statistics for polaritons obtained in GaAs and CdTe microcavities.

HL 42 Quantum dots and wires: Preparation and characterization I

Time: Thursday 11:00–13:00 Room: POT 51

HL 42.1 Thu 11:00 POT 51

Silicon Dioxide Nanowires with Embedded Au/Si Nanoparticles — •Florian M. Kolb, Andreas Berger, Herbert Hofmeister, Eckhard Pippel, Margit Zacharias, and Ulrich Gösele — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle(Saale)

By combining SiO evaporation with the VLS mechanism (1), apart from crystalline silicon nanowires with an amorphous oxide shell, also amorphous nanowires with chains of periodically embedded nanoparticles can be observed. We found that this unusual nanowire morphology consists of pure SiO_2 with embedded Au/Si nanoparticles, using Energy-Dispersive X-Ray Spectroscopy (EDXS), Electron Energy-Loss Spectroscopy (EELS) and High-Resolution TEM (HRTEM). Experimental results suggest that the formation of the nanoparticle chains is induced by oxygen. Combined with the SiO-VLS growth, we propose a model for the formation mechanism of the nanoparticle chains, in which the nanoparticles originate from the liquid Au/Si nanowire tip. Possible applications for this special nanowire morphology are discussed.

(1) F. M. Kolb, H. Hofmeister, R. Scholz, M. Zacharias, U. Gösele, D. D. Ma, S.-T. Lee. J. Electrochem. Soc. **151** (7) G472 (2004)

HL 42.2 Thu 11:15 POT 51

Axial and radial growth of GaN-nanowires by molecular beam epitaxy — •C. Chèze[1], L. Geelhaar[1], Ph. Komninou[2], Th. Kehagias[2], Th. Karakostas[2], W. Weber[1], R. Averbeck[1], and H. Riechert[1] — [1]Infineon Technologies, D-81370 Munich, Germany — [2]Aristotle University of Thessaloniki, Department of Physics, GR-54124 Thessaloniki, Greece

GaN-nanowires were grown on c-plane sapphire substrates by solid-source molecular beam epitaxy (MBE) employing a RF plasma source for the incorporation of nitrogen. The formation of nanowires is induced by a thin layer of Ni that is sputtered onto the substrates and annealed prior to the growth of GaN. The orientation of the nanowires is perpendicular to the substrate, and their length is fairly uniform. Cross-section transmission electron microscopy (XTEM) observations reveal that the nanowires are single crystalline and have a wurtzite structure. Growth under N-rich conditions proceeds in axial direction, i.e. the nanowires become longer. In contrast, under Ga-rich conditions the nanowires grow in radial direction, i.e. they become thicker. Under both conditions, the growth rate in the dominant direction (either axial or radial) is about two orders of magnitudes greater than the growth rate in the respective other direction. Thus, both length and diameter can be controlled by choosing the appropriate N/Ga-flux-ratio and growth duration.

HL 42.3 Thu 11:30 POT 51

Thermal conductivity of gases from power-dependent Raman spectroscopy on silicon nanowires — •Harald Scheel[1], Stephanie Reich[2], Carola Nisse[1], and Christian Thomsen[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139-4307

The Raman spectra of silicon nanowires are studied as a function of laser excitation power and the molar mass of surrounding gases. We find that the thermal conductivity of a gas determines the nanowire temperature, which can be detected by a change in the Raman frequency. We can thus distinguish different gases by their thermal conductivities.

HL 42.4 Thu 11:45 POT 51

Field effect transistors with silicon nanowires as active region — •W. M. Weber[1,2], E. Unger[1], A. Graham[1], M. Liebau[1], G. Duesberg[1], C. Cheze[1], L. Geelhaar[1], H. Riechert[1], P. Lugli[2], and F. Kreupl[1] — [1]Infineon Technologies AG. 81370 Munich, Germany — [2]Technische Universität München, Institute for Nanoelectronics. 80333 Munich, Germany

The steadily increasing requirements for future electronic semiconductor applications demand large efforts in the miniaturization and performance increase of new transistors. Catalytically grown silicon nanowires (Si-NW) are promising elements for such devices combining bottom-up processing and excellent electrical characteristics. Here, we present experimental results on field effect transistors using thin Si-NWs (diameter below 25 nanometers) as the active regions. Nanowires were grown by chemical vapour deposition using Au as catalyst. Subsequently, the Si-NWs were transferred to test chips for electrical characterization. Test chips consist of a patterned electrode structure on top of an oxide layer serving as gate dielectric. 3-terminal measurements are possible by using the entire substrate as a back-gate. For NiSi, CoSi, and PdSi source and drain contacts, the output characteristic implies Schottky barriers. Although the Si-NWs are nominally undoped, they show p-type behaviour for these contact metals. The transfer characteristic can be modulated by more than 7 orders of magnitude. The on current is as high as 1 micro-ampere for a single 1 micrometer long and 23 nanometers thick wire as the active region. Also, devices with short gate lengths down to 18 nanometers were investigated.

HL 42.5 Thu 12:00 POT 51

Growth of ZnO Nanorods for Optoelectronic and Spintronic Applications — •A. Che Mofor, Andrey Bakin, Abdel-Hamid El-Shaer, Eva Schlenker, and Andreas Waag — Institute of Semiconductor Technology, Technical University Braunschweig, Hans-Sommer-Str. 66, D-38106 Braunschweig

ZnO has a wide band gap of 3.37 eV at room temperature, it is transparent, radiation resistant with lasing achievable at temperatures well above 300 K. If successfully doped with magnetic impurities, ZnO and its nanostructures would be an interesting candidate for spintronic applications. Growth of ZnO nanorods using metal catalysts and graphite at relatively high temperatures (usually above 1000° C) has been reported. These methods are associated with impurities that may not be detected by conventional crystal characterisation methods like transmission electron microscopy and x-ray diffractometry. We report on the growth of ZnO nanorods by employing a specially designed horizontal vapour transport system with elemental sources at relatively low temperatures without catalysis. We employed 6N elemental Zn carried by N2 gas and 99.995% O2 gas as reactants. The ZnO nanorods were grown directly on 6H-, 4H-SiC and (11-20)Al2O3 substrates at growth temperatures from 650 to 800° C and pressure 10-25 mbar. X-ray diffraction rocking curves with a full width at half maximum (FWHM) of 0.23° and room temperature photoluminescence peaks of high intensity and FWHM of 90 meV were obtained. ZnO nanorods with widths of 80-900 nm and lengths of 4-12 μm and density of 109 cm-2 were noted. Different approaches for nanodevice realisation shall also be presented.

HL 42.6 Thu 12:15 POT 51

Advanced and selective growth of ZnO nanopillars in wet chemical solution — •Bianca Postels, Marc Kreye, Hergo-H. Wehmann, and Andreas Waag — Institut für Halbleitertechnik, Technische Universität Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig, Germany

ZnO nanostructures have a large potential for interesting applications in optoelectronics and sensor technologies. Different methods like MOCVD, VPE and ACG (Aqueous Chemical Growth) can be used for generating a variety of nanostructures. In recent years, ACG became more and more interesting, being a low temperature (< 95°) and low cost approach. Usually, the ACG process is based on the creation of a nucleation layer followed by the growth of ZnO nanopillars in aqueous solution.

In this contribution we will show that by using ACG we are able to generate highly homogeneous and vertically aligned, densely packed (˜ 1e10 cm-2) wafer scale arrays of ZnO nanopillars on various substrate materials, e.g. Si (100, 111) and ITO coated glass as well as on polymer substrates (PEN foil, silicones). Results from detailed structural and electrical analysis will be reported. Even though grown at low temperatures in aqueous solution, the nanopillars show a surprisingly good optical quality at room temperature. To achieve selective growth, we grew on samples without nucleation layer structured with different metals on various substrate materials. We observed homogenous, densely packed arrays of ZnO nanopillars on metals, whereas on pure substrate materials only low density growth occurs.

HL 42.7 Thu 12:30 POT 51

HR-TEM characterization of InGaAs Nanowhiskers — •Daniela Sudfeld[1], Jochen Kästner[1], Günter Dumpich[1], Ingo Regolin[2], Victor Khorenko[2], Werner Prost[2], Franz Josef Tegude[2], Stephan Lüttjohann[3], Cedrik Meier[3], and Axel Lorke[3] — [1]Departments of Physics, Experimental Physics, AG Farle, University of Duisburg-Essen, Lotharstr. 1, D-47048, Duisburg, Germany — [2]Solid State Electronics Dept., University of Duisburg-Essen, Lotharstr. 55, ZHO, D-47048 Duisburg, Germany — [3]Departments of Physics, Experimental Physics, University of Duisburg-Essen, Lotharstr. 1, D-47048, Duisburg, Germany

$In_xGa_{1-x}As$ nanowhiskers were grown by metal-organic vapour-phase epitaxy (MOVPE) on (111)B GaAs substrates using the vapour-liquid-solid growth mode. The diameter of the nanowhiskers was defined by monodisperse gold nanoparticles deposited on the GaAs substrate. The whiskers have been analyzed by high-resolution X-ray diffractometry (HR-XRD), micro-photoluminescence (μ-PL) and high-resolution transmission electron microscopy (HR-TEM) including energy-dispersive X-ray spectroscopy (EDS). This study is focussed to determine the lattice structure and the composition of the nanowhiskers. A detailed analysis of the lattice structure by high-resolved bright-field images reveal a fcc (111) phase as resulting from XRD measurements. Using the law of Vegard an indium concentration of 27.6 atom% has been determined in good agreement with our EDS-studies. In addition, EDS line scans perpendicular to the growth direction indicate a homogeneous growth and the presence of indium inside the seed gold particle.

HL 42.8 Thu 12:45 POT 51

Magnetic Properties of Vanadium-doped ZnO-nanorods — •Eva Schlenker[1], Augustin Che Mofor[1], Bianca Postels[1], Marc Kreye[1], Andrey Bakin[1], Andreas Waag[1], Carsten Ronning[2], Joachim Lüdke[3], Volker Janke[3], Sibylle Sievers[3], and Martin Albrecht[3] — [1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Braunschweig, Germany — [2]II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany — [3]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

There has been much focus on the properties of the wide-bandgap semiconductor ZnO, not only for opto- but also for magneto-electronic applications. According to theoretical predictions, ZnO doped with transition metals is a promising candidate to exhibit ferromagnetism with a Curie temperature exceeding 300 K.

We report on our results concerning ZnO-nanorods grown by aqueous chemical growth and vapour phase epitaxy. The samples have been implanted with V ions, reaching concentrations up to 1.8 at.%. Photoluminescence (PL) measurements performed after the implantation process reveal a severely defective material. Subsequent annealing at 600 °C leads to a structural recovery of the matrix and therefore restores the original PL intensity. In order to clarify if the ZnVO-nanorods show ferromagnetism, we carried out Magnetic Force Microscopy (MFM) and Superconducting Quantum Interference Device (SQUID) measurements. The MFM measurements were performed either with or without application of an external magnetic field, both on ensembles as well as on single detached rods. The scans clearly display a magnetic contrast.

HL 43 GaN: Devices I

Time: Thursday 11:00–12:15 Room: BEY 118

HL 43.1 Thu 11:00 BEY 118

Biocatalytic Activity of Enzymes Immobilized on Group III-Nitride Surfaces — •Barbara Baur, Georg Steinhoff, Hans-Georg von Ribbeck, Yvonne Gawlina, Florian Furtmayr, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

AlGaN/GaN electrolyte gate field effect transistors (EGFETs) have a great potential as sensor devices for electronic detection of biochemical processes, as they combine excellent electronic characteristics with biocompatibility and long term stability in liquid electrolytes. In addition, they show a high pH sensitivity, which enables the quantitative electrical detection of enzymatic biocatalytical reactions accompanied by local pH changes. In this context, we describe the covalent immobilization of different enzymes on GaN surfaces. The influence of the pH-value in the chemical medium during the immobilization processes has been investigated. Adjustment of the pH-value results in selective covalent immobilization at crosslinker molecules on a self assembled monolayer of aminopropyltriethoxysilane (APTES) deposited on the surface. At the same time, the non-specific physisorption due to electrostatic interaction can be suppressed, as proven by fluorescence microscopy. The influence of the immobilization process on the enzyme activity and long-term stability is analyzed by photometric measurements. The biocatalytic activity of immobilized penicillinase and urease is detected electronically, employing the ion sensitivity of the underlying AlGaN/GaN EGFETs.

HL 43.2 Thu 11:15 BEY 118

Field dependent PL-spectra and emission efficiency of InGaN/GaN-LED-heterostructures — •Harald Braun[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Elmar Baur[2], Uwe Strauss[2], and Volker Härle[2] — [1]Naturwissenschaftliche Fakultät II- Physik, Universität Regensburg Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

To improve the efficiency of blue and green InGaN/GaN-based LEDs we use field-dependent photoluminescence (PL) experiments to characterize internal electric fields, carrier capture, internal efficiency, and non-radiative recombination. The shape of InGaN/GaN-QWs depends strongly on the external electric field applied to the p-n-junction. We show that applying a forward bias the comparability between PL and EL can be improved, which is important when using PL-data for optimizing EL-efficiency of InGaN/GaN heterostructures. Also, by comparing the field-dependence of the peak-position with simple one-dimensional simulations we determine the size of the piezoelectric fields in InGaN/GaN-quantum wells. From the tunnelling of carriers through the barriers, which causes a strong decrease of the PL-intensity with increasing reverse bias, we estimate the offset-ratio of the InGaN-bandgap.

HL 43.3 Thu 11:30 BEY 118

Physical Model to explain and predict performance of AlGaN/GaN-based MIS-HFETs — •Gero Heidelberger[1], Michel Marso[1], Alfred Fox[1], Juraj Bernát[1], Hans Lüth[1], and Peter Kordoš[2] — [1]Institute of Thin Films and Interfaces and cni - Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, D-52425 Jülich, Germany — [2]Institute of Electrical Engineering, Slovak Academy of Sciences, SK-84104 Bratislava, Slovakia

AlGaN/GaN-based Metal-Insulator-Semiconductor Heterostructure Field Effect Transistors (MIS-HFET) have been shown to be a promising candidate for high power and high frequency applications. Nevertheless, the underlying interface physics is not entirely understood yet. In particular, the conditions underneath the gate are unknown if it is separated by material such as SiO_2, HfO_2 or $DyScO_3$. In this work we present a model of the electrical behaviour of a MIS-HFET taking into account the problems arising from the metal-insulator-semiconductor structure. By means of this model we can predict essential DC and RF power measures knowing the geometrical and material data of the device. Furthermore, the model is suitable to explain results we gained from a comparative study of unpassivated, passivated HFETs and MIS-HFETs where we were able to demonstrate the superiority of the MIS-HFET concept with regards to DC and RF power performance.

HL 43.4 Thu 11:45 BEY 118

Dependence of exciton energy on dot size in GaN/AlN quantum dots — •David Williams[1], Aleksey Andreev[2], and Eoin O Reilly[1] — [1]Tyndall National Institute, Lee Maltings, Cork, Ireland — [2]Advanced Technology Institute, University of Surrey, Guildford GU2 7XH, UK

We show analytically that the exciton energy in nitride quantum dots (QDs) decreases linearly with increasing dot height, provided that the height to radius ratio remains constant. This behaviour is due to the strong polarization fields present in nitride dots, with the constant of proportionality given by the slope of the polarization potential. We also present a useful analytical approximation for the electron and hole wavefunctions in nitride QDs in terms of Airy functions, which provides reliable estimates for the actual energies and wavefunctions.

HL 43.5 Thu 12:00 BEY 118

Physical Model to explain and predict performance of AlGaN/GaN-based MIS-HFETs — •Gero Heidelberger[1], Michel Marso[1], Alfred Fox[1], Juraj Bernát[1], Hans Lüth[1], and Peter Kordoš[2] — [1]Institute of Thin Films and Interfaces and cni - Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, D-52425 Jülich, Germany — [2]Institute of Electrical Engineering, Slovak Academy of Sciences, SK-84104 Bratislava, Slovakia

AlGaN/GaN-based Metal-Insulator-Semiconductor Heterostructure Field Effect Transistors (MIS-HFET) have been shown to be a promising candidate for high power and high frequency applications. Nevertheless, the underlying interface physics is not entirely understood yet. In particular, the conditions underneath the gate are unknown if it is separated by material such as SiO_2, HfO_2 or $DyScO_3$. In this work we present a model of the electrical behaviour of a MIS-HFET taking into account the problems arising from the metal-insulator-semiconductor structure. By means of this model we can predict essential DC and RF power measures knowing the geometrical and material data of the device. Furthermore, the model is suitable to explain results we gained from a comparative study of unpassivated, passivated HFETs and MIS-HFETs where we were able to demonstrate the superiority of the MIS-HFET concept with regards to DC and RF power performance.

HL 44 Si/Ge

Time: Thursday 12:15–13:15 Room: BEY 118

HL 44.1 Thu 12:15 BEY 118

Polycrystalline Silicon Films Obtained from Spin-coated Dispersed Nanocrystalline Silicon Layers — •R. Lechner[1], Nuryanti[1], C. Oberhüttinger [1], M. S. Brandt[1], A. Ebbers[2], F.-M. Petrat[2], and M. Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]Degussa AG, Paul-Baumann-Str. 1, 45764 Marl

Polycrystalline silicon thin films on inexpensive substrates are of interest for thin film electronics and large area applications such as display panels or solar cells. A method known to produce continuous films of high quality polycrystalline silicon at relatively low temperatures is the aluminum induced layer exchange (ALILE). This process can be used to crystallize amorphous silicon deposited onto metal aluminum layers by simple annealing of the bilayer a-Si/Al stack at temperatures ranging from 300°C to 570°C. Here, we present first results obtained by replacing the amorphous silicon film by a layer of silicon nanoparticles spin-coated from dispersion with an organic solvent. Despite the crystalline nature of the initial nanocrystalline silicon layers and their high porosity, the growth of polycrystalline nuclei has been observed during annealing. By an appropriate choice of the sample configuration, conductive layers of

polycrystalline silicon can be obtained. The structural, optical and electrical properties of the resulting films will be discussed.

HL 44.2 Thu 12:30 BEY 118

Phase segregation in laser-crystallized polycrystalline SiGe thin films — •Moshe Weizman[1], Norbert Nickel[1], Ina Sieber[1], and Baojie Yan[2] — [1]Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Systems Corp. 1100 West Maple Road Troy, MI 48084, USA

Polycrystalline silicon-germanium (poly- SiGe) thin films on glass substrate are considered to be attractive for thin film electronic devices and for solar cells applications. The SiGe thin films investigated in this work were fabricated on glass and stainless steel substrates by the following steps. At first, amorphous silicon-germanium films (a-Si1-xGex:H) with 0.19<x<0.84 were deposited by glow-discharge decomposition of a mixture of disilane, germane, and hydrogen to a thickness of 100 to 255 nm. Secondly, the amorphous samples were crystallized employing a XeCl excimer laser. Phase segregation in the poly SiGe films was studied mainly by energy dispersive X-ray (EDX) and Raman backscattering measurements. The results show that laser crystallization of poly-Si1-xGex thin films on glass with 0.33<x<0.7 can reveal significant segregation into Ge rich and poor areas, which deviate by up to 40% from the homogeneous composition of the amorphous starting material. The Ge rich and poor areas are self assembled with a well defined periodicity length. Surprisingly, laser-crystallized SiGe thin films on stainless steel substrate under similar crystallization conditions show no detectable segregation and no self organization. These results are explained on the base of the Mullins-Sekerka instability growth model calculated for the case of SiGe alloys.

HL 44.3 Thu 12:45 BEY 118

Ultra-thin polycrystalline silicon layers on glass substrates — •Michael Scholz, Tobias Antesberger, Sebastian Gatz, Mario Gjukic, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

An emerging method for the low-temperature preparation of polycrystalline silicon (poly-Si) layers with reasonable structural and electrical properties on non-crystalline substrates is the aluminum-induced layer exchange (ALILE) process. To this end, a bilayer structure of aluminum (Al) and amorphous silicon (a-Si) is deposited e.g. on a glass substrate and heated to temperatures below the eutectic temperature of the binary Al-Si system (577 °C). If the layers a separated by a thin oxide (aluminum oxide or silicon dioxide) the two layers exchange their respective positions and a coherent poly-Si film is formed.

The preparation of these films was investigated as a function of the annealing temperature and the overall thickness of the layer system, respectively. In addition, the optical and the electrical properties will be discussed.

HL 44.4 Thu 13:00 BEY 118

MOCVD of Epitaxial Germanium Nanowires on Silicon — •Tim Echtermeyer, Stephan Senz, Volker Schmidt, and Ulrich Goesele — Max-Planck-Institute of Microstructure Physics, Weinberg 2 06120 Halle, Germany

We present results on germanium nanowires grown epitaxially on a silicon ¡111¿ substrate with the help of a metalorganic germanium precursor. The nanowires produced by this novel approach are investigated by transmission and scanning electron microscopy. In addition, preliminary results regarding silicon/germanium heterostructure nanowires are presented.

HL 45 Invited Talk Koenraad

Time: Thursday 14:30–15:15 Room: HSZ 01

Invited Talk

HL 45.1 Thu 14:30 HSZ 01

Atomic scale analysis of magnetic doping atoms and self-assembled III/V semiconductor nanostructures — •P.M. Koenraad — COBRA Inter-University Research Institute, Department of Physics, Eindhoven University of Physics, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

In the last decade we have seen the successful development of self-assembling growth techniques to produce a whole range of low-dimensional III/V semiconductor nanostructures such as wires, dots, rings and columns. Structural analysis at the atomic scale of these nanostructures is essential for the study of the self-assembly and self-organization processes forming them. For cross-sectional scanning tunnelling microscopy (X-STM) a sample is cleaved under ultra-high vacuum conditions. This cleaved surface reveals a cross-sectional image of the grown layer structure. As the STM is only sensitive to the top layers of the cleaved surface we can resolve alloy fluctuations, interfaces, doping atoms, segregation effects, etc. Using cross-sectional STM we have studied the size, shape and local composition in III/V quantum wires, dots, rings and columns that have formed by self-assembly and self-organization. Special attention will be paid to intermixing, decomposition, segregation and migration of the nanostructure material during the formation process. We have also been able to study the incorporation and segregation of (magnetic) doping atoms. Very recently we have been able to analyze impurity interaction in pairs of doping atoms.

HL 46 Quantum dots and wires: Preparation and characterization II

Time: Thursday 15:15–16:30 Room: POT 51

HL 46.1 Thu 15:15 POT 51

Charge-State and Magnetic-Field Dependence of Electron Emission from self-assembled InAs quantum dots — •Andreas Schramm, Jan Schaefer, Stephan Schulz, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstraße 11C, 20355 Hamburg

Using capacitance transient spectroscopy, we probe electron states in self-assembled InAs/GaAs quantum dots (QD). In our sample a single QD layer is embedded in a Schottky diode grown on (001) GaAs in a solid source MBE system. With a pulse bias applied at the gate we control the charge state of the QDs. The emission rate is found to be strongly dependent on the charge state. In the DLTS-spectra the peak associated to emission from the s-level is therefore split. Here we present data that demonstrate in addition fine structure in the maximum associated to the emission of p-electrons. We associate it to the emission of the four distinct charge states for p-electrons. To confirm our assignment of the DLTS-maxima we apply magnetic fields normal to the quantum dot layer. The observed behavior of the peak positions and the activation energies in the magnetic field is consistent with a harmonic oscillator model. Furthermore, in magnetic fields oriented parallel to the dot layer we clearly observe a suppression of tunneling processes.

HL 46.2 Thu 15:30 POT 51

Observation of the Aharonov-Bohm effect in self-assembled nano-volcanoes — •V.M. Fomin[1,2,3], V.N. Gladilin[1,3], N.A.J.M. Kleemans[2], I.M.A. Bominaar-Silkens[4], D. Granados[5], J.M. García[5], P. Offermans[2], U. Zeitler[4], P.C.M. Christianen[4], J.C. Maan[4], J.T. Devreese[1,2], J.H. Wolter[2], and P.M. Koenraad[2] — [1]TFVS, Departement Fysica, Universiteit Antwerpen, B-2610 Antwerpen, Belgium — [2]Department of Semiconductor Physics, TU Eindhoven, NL-5600 MB Eindhoven, The Netherlands — [3]Department of Theoretical Physics, State University of Moldova, Kishinev, MD-2009, Moldova — [4]HFML, Institute for Molecules and Materials, Radboud University Nijmegen, NL-6525 ED Nijmegen, The Netherlands — [5]Instituto de Microelectrónica de Madrid, CSIC, E-28760 Madrid, Spain

Our X-STM data indicate that self-assembled InGaAs/GaAs nanovolcanoes are characterized by an asymmetric rim and a depression rather than an opening at the center. We show that these asymmetric singly connected structures still can effectively manifest the electronic properties, like the Aharonov-Bohm (AB) oscillations, peculiar to doubly connected geometry of ideal rings. AB oscillations in the persistent current are observed in low temperature magnetization measurements using the torsion magnetometry in magnetic fields up to 15 T and are in excellent

agreement with theoretical predictions for strained nano-volcanoes. This work was been supported by the GOA BOF UA 2000, IUAP, FWO-V projects G.0274.01N, G.0435.03, the WOG WO.035.04N (Belgium), MCYT NANOSELF project (Spain) and the EC SANDiE Network of Excellence.

HL 46.3 Thu 15:45 POT 51

Transport through a (double) quantum dot fabricated with resorcinarene resist — •Monika Fleischer[1], Friedhelm Panteleit[1], David A. Wharam[1], David A. Ritchie[2], and Michael Pepper[2] — [1]Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen — [2]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK

As an alternative to the conventional split-gate approach, quantum dots can be created in the 2dim electron gas of a GaAs/AlGaAs-heterostructure by using continuous metallic gates in combination with a resist pattern. The resist marks out regions in which the gate voltage V_g is screened from the electron gas. Using this technique, multiple structures can be defined by a single gate. At high negative gate voltages, the screening breaks down and the gate region turns into a tunable barrier. We have investigated C-methyl-calix[4]resorcinarene as a novel high resolution negative resist for electron beam lithography, which has excellent properties for the envisaged applications. A single quantum dot was fabricated via a dot-shaped resist pattern crossed by three continuous gates. Transport measurements show Coulomb blockade oscillations, which at high $|V_g|$ change into the characteristics of a double dot with decreasing interdot coupling.

HL 46.4 Thu 16:00 POT 51

Theory of spin-orbit effects and spin relaxation in single and coupled quantum dots. — •Peter Stano and Jaroslav Fabian — Institut I - Theoretische Physik, Universität Regensburg

Spin-orbit effects and phonon-induced spin relaxation in laterally coupled quantum dots in the presence of magnetic field are investigated by exact numerical diagonalization. Both Bychkov-Rashba and Dresselhaus spin-orbit couplings are included. Several new phenomena are predicted. In particular, we shown that coherent tunneling between the dots depend on the spin, enabling a scheme for spin-to-charge conversion by spin separation in a *homogeneous* magnetic field. Furthermore, we show that spin relaxation is highly anisotropic, both in terms of the direction of the double-dot axis as well as the direction of the magnetic field. The anisotropy comes from spin-orbit coupling. Calculated spin relaxation rates of GaAs single dots agree with a recent experiment.

HL 46.5 Thu 16:15 POT 51

Transition from the multiple quantum dot mode to a quasi-single quantum dot mode formed in individual ropes of single-walled carbon nanotubes — •Klaus Seemann, Jens Ebbecke, and Achim Wixforth — Institut für Physik der Universität Augsburg, Universitätsstraße 1, D-86159 Augsburg

We report on conductance oscillations in a field effect device based on an individual rope of single-walled carbon nanotubes at 1.5 K. A newly developed fabrication method was employed to deposit and align carbon nanotubes onto pre-structured metal contacts of a silicon chip. Crucial for the deposition and alignment process of carbon nanotubes are micro fluidic flow fields combined with electric dipole fields being generated by surface acoustic waves within a gap filled with aqueous carbon nanotube suspension. This gap is formed, when the pre-structured silicon chip is flipped onto the piezoelectric lithium niobate substrate facilitating surface acoustic waves. The electrical characterization of the carbon nanotube junction at low temperatures exhibits very well reproducible current oscillations in the carbon nanotube rope. This indicates the formation of quantum dots between two tunneling contacts being separated by 500 nm. These quantum dots inside the carbon nanotube rope have an energy level spacing of about 10 meV. For source-drain bias beyond the height of the effective tunneling barrier the carbon nanotube junction reveals a transition to coherent tunneling akin a single quantum dot with an energy level spacing of about 1 eV. We interpret this behavior as a voltage induced transition from a multiple quantum dot system to a single larger quantum dot within the carbon nanotube.

HL 47 GaN: Devices II

Time: Thursday 15:15–16:30 Room: BEY 118

HL 47.1 Thu 15:15 BEY 118

MOVPE growth of nitride-based green LEDs — •D. Fuhrmann, T. Litte, C. Netzel, H. Bremers, U. Rossow, and A. Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, Mendelssohnstr. 2, 38106 Braunschweig, Germany

Despite the high efficiencies achieved for blue $Ga_{1-x}In_xN$ based light emitting diodes, a significant drop in efficiency occurs towards longer emission wavelengths. This behavior is commonly explained by the diminished crystalline quality of GaInN and increased piezoelectric field due to the higher In content x_{In} necessary for longer λ_{peak}. By optimizing the MOVPE growth conditions for the active region of green LEDs, we achieved thin quantum wells (QWs) of good material quality with $x_{In} \geq 25\%$. The In content was determined by XRD for thicker GaInN layers ($\approx$ 20nm) assuming that x_{In} is independent of layer thickness. The optical properties of our single QW samples were analyzed using temperature and excitation power dependent PL. It turns out that the PL linewidth, which is due to compositional fluctuations and fluctuations of the QW width, has a strong correlation with the quantum efficiency (QE). We obtained the highest values in terms of the internal QE for quantum wells showing a small PL linewidth. Hence, we find that a homogeneous In composition and smooth GaInN/GaN interfaces are of central importance for the device performance. We processed the QW structures into simple LEDs and performed "on wafer" measurements. Again, we find the highest optical output power for the structures grown under optimized growth conditions. The internal QE for QWs emitting around 525nm is only 40% lower compared to QWs emitting at 460nm

HL 47.2 Thu 15:30 BEY 118

Crack-free monolithic nitride vertical-cavity surface-emitting laser structures and pillar microcavities — •H. Lohmeyer[1], K. Sebald[1], C. Kruse[1], R. Kröger[1], J. Gutowski[1], D. Hommel[1], J. Wiersig[2], and F. Jahnke[2] — [1]Institute of Solid State Physics, University of Bremen, P.O.Box 330 440, 28359 Bremen, Germany — [2]Institute of Theoretical Physics, University of Bremen, P.O.Box 330 440, 28359 Bremen, Germany

The successful realization and optical characterization of fully epitaxially grown monolithic nitride vertical-cavity surface-emitting laser (VCSEL) structures and pillar microcavities (MCs) is presented. VCSEL structures made of InGaN/GaN λ-cavities and Bragg mirrors composed of GaN and AlN/(In)GaN superlattices have been fabricated by molecular-beam epitaxy. Airpost pillar MCs with diameters between 800 nm and 3 μm were realized by focused ion-beam etching.

The reflectivity data as well as the spontaneous emission spectra of the planar VCSEL structures show a pronounced influence of the optical-mode confinement by the cavity. The discrete mode spectrum of the pillars is studied by micro-photoluminescence measurements. The measured data for different pillar diameters show good agreement with calculations of the transmission spectra of the three-dimensional pillars based on a vectorial transfer-matrix method.

The work has been supported by the Deutsche Forschungsgemeinschaft within the framework of the research group *Physics of nitride based, nanostructured, light-emitting devices,* grant No. FOR 506.

HL 47.3 Thu 15:45 BEY 118

Study and comparison of efficiency and optical degradation of GaN/InGaN Light Emitting Diodes grown on SiC substrates — •Gianluca Tamiazzo, Ulrich Zehnder, Thomas Zahner, and Uwe Strauss — Wernerwerkstrasse 2, 93049 Regensburg

High reliability of GaN/InGaN based Light Emitting Diodes (LEDs) is of great interest. However, despite of high long-term stability, degradation mechanisms could potentially occur. In this work, we study

GaN/InGaN LEDs structures for a further improvement of their reliability and lifetime. A comparison with other commercial devices coming from different competitors was performed as well. The samples were biased in identical conditions of temperature and injected current. Electroluminescence relative intensity of LEDs was monitored in dependence of time. Dynamics of optical degradation as well as forward voltage aging during the DC-bias stress were studied. Different aging phases correspondent to as many potential failure mechanisms were identified. A model able to interpret the devices degradation behaviour is proposed. In particular, a thermally activated process is found to be responsible for long-term DC aging.

HL 47.4 Thu 16:00 BEY 118

Inhomogeneous broadened gain spectra of InGaN/GaN laser diodes — •Ulrich Schwarz[1], Georg Feicht[1], Bernd Witzigmann[2], Valerio Laino[2], Mathieu Luisier[2], Alfred Lell[3], and Volker Härle[3] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg — [3]Integrated Systems Laboratory, ETH Zürich, CH-8092 Zürich

For InGaN quantum wells (QW) indium and QW width fluctiations are a critical issue, as they cause carrier localization and affect the performance of InGaN LEDs and laser diodes (LD). We compare experimental gain spectra measured by the Hakki-Paoli mehotd with a microscopic theory including quantum-confined stark effect (QCSE) and many-body effects to analyse the contribution of homogeneous and inhomogeneous broadening to the QW gain. In particular we perform low-temperature gain spectroscopy of InGaN LDs which confirms the notion that inhomogeous broadening due to structual variations is a significant contribution to QW gain in InGaN LDs. From these measurements we can also give an estimate of the nonradiative recombination rate.

HL 47.5 Thu 16:15 BEY 118

Processing and Characterization of GaN homo-epitaxial Laser Diodes — •Jens Dennemarck, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee NW1, D-28359 Bremen

The threshold of GaN-based laser diodes is mainly determined by the geometry of the ridge wave-guide and its processing. In this work we are investigating different ridge structures to lower the threshold current density. The emission wavelength of the laser diodes, grown homo-epitaxially on GaN substrates with dislocation densities in the range of $\approx 10^6 \mathrm{cm}^{-2}$, is 395nm.
To improve the device performance, the stripe width of the devices was varied from $2-10\mu m$ and three different depths of the ridge were applied: a planar structure (no ridge), 600nm - starting at the upper wave-guide, and 900nm - penetrating the active region.
The largest impact on the threshold current density was found in the depth of the ridge, where the devices with the largest depth showed a reduction of a factor of 5 to $3\mathrm{kA/cm}^2$ in comparison to the planar structures. Duty cycles up to 50% could be applied an these devices. The width of the ridge showed also a reduction of the threshold, but not as much as the depth.
Additional to this, a better optical confinement for the deepest ridge could be seen in the far field of the laser diode.

HL 48 Preparation and characterization

Time: Thursday 15:15–16:30 Room: POT 151

HL 48.1 Thu 15:15 POT 151

Silicon Nanowire Surround-Gate Field-Effect Transistor — •Volker Schmidt[1], Heike Riel[2], Stephan Senz[1], Siegfried Karg[2], Walter Riess[2], and Ulrich Goesele[1] — [1]Max-Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle Germany — [2]IBM Zurich Research Laboratory, Saeumerstrasse 4, 8803 Rueschlikon, Switzerland

A generic process for fabricating a vertical surround-gate field-effect transistor based on epitaxially grown nanowires is presented. Exemplarily, we used Si nanowires and show a first electrical characterization proving the feasibility of the process developed and the basic functionality of this device.

HL 48.2 Thu 15:30 POT 151

Impact of Focussed Ion Beam (FIB) Preparation on the Potential Structure of Silicon Semiconductors — •Andreas Lenk[1] and Uwe Mühle[2] — [1]Institute of Structure Physics, Triebenberg Laboratory, Dresden University, 01062 Dresden, Germany — [2]Infineon Technologies Dresden GmbH & Co OHG, Germany

The electrical features of a semiconductor device are mainly determined by the dopant distribution in its matrix, which is not visible in a Transmission Electron Microscope (TEM). Electron holography, however, allows 2D mapping of electrical potentials. Since the inner electrical potential of a semiconductor is shifted in the doped regions, holography can provide 2D mappings of dopant distributions.

Because electron holography is very sensitive also against thickness variations, a homogeneously thick specimen is needed. The most efficient tool for a respective specimen preparation is the Focussed Ion Beam (FIB), which uses 30kV gallium ions for target cutting of a thin, electron transparent membrane. Unfortunately, those very ions work also as p-type dopants in silicon.

For quantitative measurement, the influence of such additional, preparation-induced dopants has to be considered. Therefore, FIB-lamellae have been cross-sectioned and investigated with electron holography. It is shown that the gallium ions of a FIB do not only amorphize the crystalline silicon laterally, but also decrease the electric potential near the surface of the lamella.

HL 48.3 Thu 15:45 POT 151

Ultra-high vacuum direct bonding of GaAs- to Si-wafer using low-energy hydrogen ion beam surface cleaning — •N. Razek, A. Schindler, and B. Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung, Permoserstr. 15, D-04318 Leipzig.

UHV-direct wafer bonding is becoming an important method to join different semiconductor materials with each other. Wafer surfaces must be prepared to be mirror-polished, flat, and clean from foreign contamination and dust for successful joining by forming chemical bonds at the interface. For applications of this bonding technique in MEMS and MOEMS technology the bonding of GaAs and Si is very interesting. We performed a study of GaAs-to-Si bonding under UHV conditions. The wafers were cleaned using low energy (<500eV) hydrogen ion beam bombardment at low temperatures (<300°C) in order to achieve an oxygen and carbon contaminant as well as near damage free surface. The cleaned wafers are transported and brought together in contact for bonding and finally annealed to increase the bonding strength in UHV. In-situ and ex-situ infrared imaging of the as-bonded wafers show directly the bonding behaviour. High-resolution transmission electron microscopy images reveal that the wafers are bonded without damage of the crystal lattice or intermediate layer and that the interface is smooth. Current-voltage measurements are used for the electrical characterization of the bonding interface of homo-type (n-Si and n-GaAs) and heterotype (p-Si and n-GaAs) material bonding.

HL 48.4 Thu 16:00 POT 151

Static and dynamic capacitance measurements on the nanoscale — •Stefan Jaensch, Christoph Henkel, Heidemarie Schmidt, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnestrasse 5, 04103 Leipzig

Using standard scanning capacitance microscopy (SCM) techniques the voltage derivative of the contact capacitance is measured with a lock-in amplifier and yields the two dimensional concentration profile of free carriers on the nanoscale. The tip-sample contact complicates the quantitative analysis of standard SCM data. Furthermore, due to the used 5-100 kHz lock-in technique, the characterisation of deep defects (emission barrier energy, capture cross section, defect distribution) by capacitance transient measurements in the μs up to s range is impossible. The presented, newly developed scanning probe technique works in the 2-2.5 GHz frequency range and facilitates quantitative temperature dependent

static and dynamic capacitance measurements with a sensitivity better than 10^{-21} F/$\sqrt{Hz}$ in combination with a standard AFM and SCM probes. The method implies frequency tuning of the integrated voltage controlled oscillator around the resonance frequency of the used coaxial resonator without and with tip-sample contact to determine the stray capacitance and the bias and time-dependent tip-sample capacitance, respectively. Assuming a bias and time independent stray capacitance, the measured transfer function of the coaxial resonator yields the static and dynamic capacitance of the sample piece being fixed to the middle pin of the coaxial resonator by an ohmic contact.

HL 48.5 Thu 16:15 POT 151

A Cryogen Free Magnet For Use In EPR — •Jeremy Good[1], Renny Hall[1], and A. I Smirnov[2] — [1]Cryogenic Ltd, 30 Acton Park Industrial Estate, London W3 7QE, UK — [2]Department of Chemistry, North Carolina State University, Raleigh, NC, 27695-8204, USA

Cryogenic has built a new type of Cryogen Free Magnet for use in EPR experiments. A novel design of sweep coil allows precise field sweeps to be made with very low inductive coupling to the main coil. Measurements using NMR at high field have confirmed the improved precision of this arrangement.

In addition, the main coil can be swept rapidly over the full range of field to detect broad resonances and without the use of any liquid helium which makes for very economic operation. For the highest feilds fo 14 Tesla, the magnets operate in dry mode with the magnet cooled directly by a Gifford McMahon (GM)cold head. Field stability of 10-7 per hour in persistent mode is now also obtained using truly superconducting joints between both the NbTi and NbSn conductors.

HL 49 Devices

Time: Thursday 15:15–16:30 Room: BEY 154

HL 49.1 Thu 15:15 BEY 154

80 GHz Passive Mode Locking of InGaAs Quantum Dot Lasers Emitting at 1.3 μm — •Gerrit Fiol[1], M. Kuntz[1], F. Hopfer[1], M. Lämmlin[1], C. Szewc[1], D. Bimberg[1], A.R. Kovsh[2], and N.N. Ledentsov[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, PN 5-2, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany

The sample structure incorporating a 15-fold stack of InGaAs QDs emitting at 1.3 μm was grown by MBE. The wafers were processed into two-sectional ridge waveguide structures with a 20 μm gap between the sections to ensure good electrical insulation. All samples were mounted p-side up and were electrically contacted with a two-channel probe head. The section lengths of the devices were 1800/200 μm for the 20 GHz device, 900/100 μm for the 40 GHz device and 450/50 μm for the 80 GHz device. An autocorrelator was used to measure the pulse width. The 20 GHz device was passively mode-locked. The shortest deconvoluted pulse width best fitted by a sech2 shaped pulse was 900 fs, which is the shortest pulse width for all devices we investigated. The 40 GHz device was hybridly and passively mode-locked. The deconvoluted pulse width ranged from 1.8 to 6 ps with a time-bandwidth-product of $\Delta\tau\Delta\nu$=0.72 for the shortest pulse width. The locking range for hybrid mode locking was 7 MHz at a RF power of 7dBm. The minimum pulse width we achieved at 80 GHz was 1.5 ps. The corresponding spectrum yields a time-bandwidth product of 1.7, which is well above the Fourier transform limit of 0.32.

HL 49.2 Thu 15:30 BEY 154

Comparison of carbon nanotube field-effect-transistor architectures: Schottky-barrier, conventional and tunneling CNFETs — •Joachim Knoch[1], Joerg Appenzeller[2], Yu-Ming Lin[2], Zhihong Chen[2], and Phaedon Avouris[2] — [1]Institute of Thin Films and Interfaces, ISG1-IT, Forschungszentrum Juelich, D-52425 Juelich — [2]IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA

Carbon nanotube field-effect-transistors (CNFETs) have recently attracted an increasing attention as building blocks of a future nanoelectronics and tremendous progress towards a real application has been made. Here, we present experimental as well as simulation results on three different CNFET device designs: the Schottky-barrier CNFET (SB-CNFET) with metallic source/drain contacts, the conventional CNFET (c-CNFET) with doped source/drain electrodes and the tunneling CN-FET (t-CNFET) based on band-to-band tunneling. While a c-CNFET, in principle, exhibits a superior on- and off-state performance if compared to SB-CNFET it is shown that ultimately scaled c-CNFETs suffer from a charge pile-up that strongly deteriorates the device's off-state. In contrast, the t-CNFET allows for an excellent off-state. Due to the smallness of nanotubes (both, in terms of geometry as well as the one-dimensionality of electronic transport properties) the t-CNFET design makes possible field-effect transistor devices with an inverse subthreshold slope significantly smaller than 60mV/dec while at the same time, an excellent on-state is achievable.

HL 49.3 Thu 15:45 BEY 154

Hydrogenated Microcrystalline Silicon Thin Film Transistors — •Kah-Yoong Chan[1,2], Eerke Bunte [1], Helmut Stiebig[1], and Dietmar Knipp [2] — [1]Research Center Jülich, Institute of Photovoltaic, 52425 Jülich, Germany — [2]International University Bremen, School of Engineering and Science, 28759 Bremen, Germany

Hydrogenated microcrystalline silicon (μc-Si:H) has recently been proven to be a promising material for thin film transistors TFTs. Electron carrier mobility of >100cm2/Vs, deconvoluted from μc-Si:H TFT characteristics has been demonstrated [1]. The high carrier mobility and good stability of the transistors is caused by the presence of crystalline silicon domains with a typical crystal diameter of 5-20nm. In our study, we developed top-gate staggered μc-Si:H TFTs on glass substrate using plasma enhanced chemical vapor deposition (PECVD). Device structures were fabricated by photolithography ranging from 10μm to 100μm channel length and 100μm to 1000μm channel width. The electrons were injected in the channel via 30nm thick n-type μc-Si:H layer. The thin n-type film prepared at ˜280°C exhibits room temperature dark conductivity of ˜10S/cm and an activation energy of ˜17meV. The channel of the transistor was formed by intrinsic μc-Si:H prepared at ˜200°C in the regime near the transition to the amorphous growth (crystalline volume fraction > 50%). The dielectric was realized by PECVD deposited SiO2 film at ˜150°C. The fabrication process together with first experimental results from the electrical characterizations of the μc-Si:H TFTs will be presented. 1. C-H. Lee, A. Sazonov, A. Nathan, Mater. Res. Soc. Symp. Proc. Vol. 862 (2005) A17.5.1-6.

HL 49.4 Thu 16:00 BEY 154

Impact of the body thickness on the performance of silicon-on-insulator Schottky-barrier metal-oxide-semiconductor field-effect-transistors — •Joachim Knoch[1], Min Zhang[1], Siegfried Mantl[1], and Joerg Appenzeller[2] — [1]Institute of Thin Films and Interfaces, ISG1-IT, Forschungszentrum Juelich, D-52425 Juelich — [2]IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA

Schottky-barrier MOSFETs are an attractive alternative to conventional MOSFETs. Due to metallic electrodes in direct contact with the channel they offer low extrinsic parasitic resistances, excellent scalability down to smallest dimensions and easy processing. However, because of the Schottky barriers, SB-MOSFETs show an inferior intrinsic performance in terms of Ion/Ioff if compared to conventional devices: A high SB not only deteriorates the transistor's on-state but also causes a poor subthreshold behavior. Here we present experimental and simulation results on ultrathin body (UTB) SOI SB-MOSFETs and show that the use of UTB SOI strongly improves the devices on- as well as off-state. An analytical approximation for the off-state is given that shows that the inverse subthreshold slope scales as the square-root of the SOI thickness. In addition, threshold voltage variations that appear in UTB SOI SB-MOSFETs will be discussed. Two different mechanisms are responsible for this, namely the above mentioned strong dependence of the device performance on the SOI thickness and vertical quantization due to the confinement of carriers between the gate and the buried oxide. Design rules are given of how to avoid too large threshold voltage variations and at the same time achieve a good device performance.

HL 49.5 Thu 16:15 BEY 154

Dynamic and static properties of quantum-dot based semiconductor optical amplifiers at 1.3 μm — •Matthias Lämmlin[1], G. Fiol[1], M. Kuntz[1], F. Hopfer[1], N.N. Ledentsov[1,2], A.R. Kovsh[2], A. Jacob[3], A. Umbach[3], and D. Bimberg[1] — [1]Institut fuer Festkoerperphysik, Technische Universitaet Berlin, PN5-2, Hardenbergstr. 36, 10623 Berlin, Germany — [2]NL Nanosemiconductor GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany — [3]u2t Photonics AG, Reuchlinstrasse 10/11, 10553 Berlin, Germany

Quantum dot (QD) based semiconductor optical amplifiers (SOAs) operating at 1.3 μm grown by molecular beam epitaxy containing InGaAs/GaAs QDs are presented. Static gain properties of SOAs based on 10 stacks of QDs are evaluated with respect to input power, wavelength and injection current. Measurements show a chip gain up to 24 dB with a signal-to-ASE ratio of 30 dB. The polarization dependence of these devices shows a TE/TM ratio of 8 dB. Gain measurements of SOAs (15 stacks of QDs, 4 mm long) are compared with a rate equation model. A chip gain of 26 dB is realized here. The modeling of the gain characteristics of these SOAs is matched to the performance of alike lasers and predicts a 40 dB amplification under ideal biasing and input power conditions. Using a hybrid mode-locked QD laser at 20 GHz with 710 fs pulse widths as input signal ultrafast amplification with no observable degradation of the amplified ultrashort pulse train is demonstrated. This work is funded by the SANDiE Network of Excellence of the European Commission, contract number NMP4-CT-2004-500101, and the State of Berlin in the framework of the Zukunftsfond Berlin (TOB).

HL 50 Poster II

Time: Thursday 16:30–19:00 Room: P3

HL 50.1 Thu 16:30 P3

Pressure-Induced Insulator-Metal Transition in (CoC10H10)0.25TiSe2 — •Sergey Ovsyannikov[1,2], Vladimir Shchennikov[2], Alexander Titov[3], and Yoshiya Uwatoko[1] — [1]The Institute for Solid State Physics, The University of Tokyo, Kashiwanoha, 5-1-5, Kashiwa, Chiba 277-8581, JAPAN — [2]High-Pressure Group, Institute of Metal Physics, Urals Division of Russian Academy of Sciences, GSP-170, 18 S. Kovalevskaya Str., Yekaterinburg 620041,RUSSIA — [3]Institute of Metal Physics, Urals Division of Russian Academy of Sciences, GSP-170, 18 S. Kovalevskaya Str., Yekaterinburg 620219, RUSSIA

In the present work we (i) have synthesized the crystals of (CoC10H10)0.25-TiSe2 by intercalation of CoC10H10 into TiS2 matrix as well as (ii) have investigated their properties at extreme conditions of ultrahigh pressure up to 20 GPa at room temperature conditions. We report the high-pressure behaviours of electrical resistance, thermoelectric power, compressibility, and thermal difference along a sample. By the changes of the above properties under pressure we have established the reversible insulator-semiconductor-metal transitions. Under pressure, the compound exhibited a change of its electrical resistance by about 8 orders and two inversions of thermopower sign. We performed six subsequent cycles of pressurisation-releasing and have established both reversibility of the changes and repeatability of the results. So, this layer crystal seemed to be a new functional material for wide applications. S.V.O. acknowledges the Japanese Society of the Promotion of Science (JSPS) for the financial support. The research was supported by the Russian Foundation for Basic Research (RFBR), Gr. No. 04-02-16178.

HL 50.2 Thu 16:30 P3

ATOMISTIC STUDY OF BULK PROPERTIES AND POINT DEFECTS IN GERMANIUM — •Henning Gessner and Matthias Posselt — FZ-Rossendorf PO-Box 510119, D-01314 Dresden

Different parameterizations for the Stillinger-Weber potential and the Tersoff potential are used to determine the elastic properties and the melting point of Ge as well as the stability, the structure and the energetics of potential vacancy and self-interstitial configurations. The results are compared with literature data obtained from experiments and by tight-binding and density-functional theory calculations. Furthermore, the vacancy and self-interstitial migration is investigated for temperatures between 600 and 1200 K. The defect diffusivity, the self-diffusion coefficient per defect and the corresponding effective migration barriers are determined. These results are compared with experimental data on self-diffusion in Ge.

HL 50.3 Thu 16:30 P3

Anisotropic Zeeman splitting of shallow impurities in Si/Ge double-barrier heterostructures — •Oleksiy B. Agafonov[1], Kai-Martin Haendel[1], Ulrich Denker[2], Oliver G. Schmidt[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, Appelstraße 2, D-30167 Hannover — [2]Max-Plank-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart

We report the results of our experimental investigations of the Zeeman splitting of shallow impurities in Si/Ge double-barrier heterostructures [1]. The impurities are located in a strained Ge quantum well with a thickness of four monolayers. The splitting was measured as a function of angle between the magnetic field and the sample growth direction. A strong anisotropy of the heavy-hole g-factor was observed. A complete suppression of the splitting takes place when the magnetic field is oriented perpendicular to the sample growth direction, while in the parallel field the observed splitting is maximal.

[1] K.-M. Haendel, R. Winkler, U. Denker, O. G. Schmidt and R. J. Haug (2005), cond-mat/0510322.

HL 50.4 Thu 16:30 P3

Mn-silicide nanoparticles formed inside Si using ion implantation — •Shengqiang Zhou, K. Potzger, A. Mücklich, F. Eichhorn, N. Schell, R. Grötzschel, B. Schmidt, W. Skorupa, M. Helm, and J. Fassbender — Institute for Ion Beam Physics and Materials Research at the Forschungszentrum Rossendorf, POB 510119, 01328 Dresden, Germany

300 keV Mn was implanted into p-Si with a fluence of 1*10ˆ15/cm2, 1*10ˆ16/cm2 and 5*10ˆ16/cm2, respectively, at 620 K. The samples were annealed at 1070 K in N2 ambient for 5 min by rapid thermal annealing. Rutherford backscattering/channeling, transmission electron microscopy and X-ray diffraction were applied for structural characterization. Mn-silicide nanoparticles were formed with the size of 5 nm already in the as-implanted samples and grew up to around 30 nm after annealing. Moreover no significant evidence is found for Mn substituting Si sites either in as-implanted or annealed samples. The virgin samples already show a ferromagnetic like behavior, and the moment is slightly increased after implantation (1*10ˆ16/cm2) and annealing by around 0.5 Bohr magneton per Mn. Therefore, the majority of Mn ions formed Mn-silicides, and some are diluted in Si matrix and develop into ferromagnetic coupling. These effects have to be properly considered for the design of Si-based diluted magnetic semiconductors.

[1] M. Bolduc, C. Awo-Affouda, A. Stollenwerk, M. B. Huang, F. G. Ramos, G. Agnello, and V. P. LaBella Phys. Rev. B 71, 033302 (2005).

HL 50.5 Thu 16:30 P3

Investigation of copper transport in silicon — •Mike Thieme and Jörg Weber — Technische Universität Dresden, 01062 Dresden, Germany

Copper transport was studied in p-type FZ-silicon using the DLTS-signal of the Cu-pairs to monitor the interstitial Cu concentration. Atomic copper was deposited at room temperature onto the sample surface from a diluted HF-solution containing ions of the metal. In the bulk, it was impossible to detect copper after the deposition (detection limit 10^{10} atoms/cm^3). Even a subsequent annealing up to 350 °C in helium atmosphere did not produce detectable copper traces. The scavenging of copper was studied in FZ-Si samples containing Cu-pairs. The dissociation energy of the pairs is 1.02 eV and an annealing step at 250 °C is necessary to break them up. Our investigations show that the amount of outdiffusing copper depends on the annealing gas. This opens a new way to control the interstitial copper contamination in silicon.

Acknowledgment: This work has been supported by the DFG (WE1319/15-1).

HL 50.6 Thu 16:30 P3

Acceptor passivation in silicon wafers under ambient conditions
— •T.D. Vo, M. Thieme, J. Bollmann, and J. Weber — Technische Universität Dresden, 01062 Dresden, Germany

Standard *p*-type silicon wafers exhibit reduced conductivity at surface-near regions after storage for months under ambient conditions. The extension of this passivated layer depends on the shallow doping density. The conductivity can be reactivated by thermal treatments at moderate temperatures. Schottky barrier diodes were prepared without wet chemical treatments to avoid any additional hydrogen contamination. All samples (0.05 to 20 Ω cm, Cz- and FZ-grown) show ion drift effects during reverse bias annealing. From temperature and time dependent capacitance measurement we identify the dissociation energy of the boron complex to be 1.3 eV. Annealed samples without passivation show transient ion drift effects very similar to the initial samples. Apparently, the annealing does not cause an out diffusion of the ions. Wet chemical etching on annealed samples was performed to study the potential role of hydrogen. We discuss a possible identification of the compensating species.

HL 50.7 Thu 16:30 P3

Isolated gold impurities in surface near regions of silicon — •J. Bollmann and J. Weber — Technische Universität Dresden, 01062 Dresden, Germany

A DLTS and PL study on silicon samples doped with gold is reported. After the implantation of Au ions (particle fluence from 10^{12} to 10^{15}cm^{-2}, energy 80 keV), a thermal treatment at 950 °C (20 min) was carried out to remove the radiation damage and to diffuse in the gold atoms. The implantation makes use of ion beams of single isotope mass and a precise amount of incorporated impurities. EXAFS studies showed that under implantation conditions most of the Au atoms occupy isolated substitutional lattice sites [J. Bollmann, D. C. Meyer , J. Weber, and H.-E. Mahnke, ICDS 23]. In the samples the already known PL line at 793meV, attributed to the neutral substitutional gold center, is identified. In contrast, the deep level centre E12 detected by DLTS does not agree with the reported energy level for the substitutional Au. The E12 defect is concentrated close to the surface.

HL 50.8 Thu 16:30 P3

Volumetric effects under pressurization and microindentation in semiconductors — •Vsevolod Shchennikov Jr[1], Sergey Ovsyannikov[2,3], Vladimir Shchennikov[2], Ivan Komarovsky[2], and Sergey Smirnov[1] — [1]Micromechanics lab., Institute of Engineering Sciences of Russian Academy of Sciences, Urals Division, GSP-207, 34 S. Komsomolskaya Str, Yekaterinburg 620219, RUSSIA — [2]High-Pressure Group, Institute of Metal Physics, Urals Division of Russian Academy of Sciences, GSP-170, 18 S. Kovalevskaya Str., Yekaterinburg 620041, RUSSIA — [3]The Institute for Solid State Physics, The University of Tokyo, Kashiwanoha, 5-1-5, Kashiwa, Chiba 277-8581, JAPAN

The results of parallel measurements of volumetric effects both under pressurization (in a region of structural transformations from 0 up to 0-20 GPa) and micro-indentation treatments in semiconductor substances are reported. For comparative characterization the single crystals of Czochralski-grown Si wafers, (i) subjected to various thermal and pressure treatments, (ii) doped with N, and (iii) irradiated with high energy particles (protons), as well as of ZnSe, and n- and p-GaAs. For the pressurization the automated was used allowing to register simultaneously several parameters of both a sample and environment. A bending has been found of the dependences of both the diamond indentor penetration depth, and contraction of sample sizes in pressure experiments, related to a drop of lattice volume at phase transitions. The model of multi-phase system has been used for analysis of the results. The work was supported by the RFBR (Gr. Ns. 04-02-16178, 04-01-00882).

HL 50.9 Thu 16:30 P3

Type-I alignment and direct fundamental gap in SiGe based heterostructures — •Michele Virgilio and Giuseppe Grosso — NEST-INFM and Dipartimento di Fisica, Universita' di Pisa, Largo Pontecorvo 3, I-56127 Pisa, Italy

We study the electronic structure of strained Si1-xGex alloys grown on (001) Si1-yGey cubic substrates. Valence and conduction band offsets at the heterointerfaces and the fundamental gap of the strained alloys are derived for all the (x,y) concentrations, adopting a first neighbors tight binding Hamiltonian description. The localized base includes sp3d5s* orbitals and spin-orbit interaction. Appropriate scaling laws for the hopping parameters are used to describe the geometrical lattice distortion induced by strain. In this way we are able to distinguish in the (x,y) plane a region characterized by robust type I alignment. Information on valence and conduction band alignment as function of alloying and strain together with suitable control of the folding mechanism along the growth direction and of the dependence of the confinement energies from the geometry, are exploited to propose a type-I SiGe quantum well. For this device electronic structure and density of states projected on each orbital and on each layer are studied by means of an iterative manipulation of the Green's function, overcoming in this way the computational difficulties related to direct diagonalization of the large period structures studied. We can therefore demonstrate that suitable choice of Ge concentrations in the substrate, spacer and active materials allows to obtain structures which are direct gap both in k- and in r space.

HL 50.10 Thu 16:30 P3

Raman spectroscopy of hydrogen molecules in germanium — •Martin Hiller, Edward Lavrov, and Jörg Weber — Technische Universität Dresden, 01062 Dresden, Germany

Single-crystal germanium wafers exposed to hydrogen and/or deuterium plasmas are studied by means of Raman scattering. The hydrogenation results in H_2 being trapped at different sites within the host lattice. Two bands at 1980 and 4155 cm^{-1} measured at room temperature are assigned to local vibrational modes of Ge–H and H_2, respectively. Polarization sensitive Raman measurements reveal that the plasma treatment results in the formation of extended planar structures called platelets, similar to the case of hydrogenated silicon. These platelets are aligned predominantly along {111} crystallographic planes and have Ge–H bonds as basic units. The signal at 4155 cm^{-1} is shown to result from molecular hydrogen trapped within these platelets. Measurements performed at a temperature of 80 K reveal two sharp Raman peaks at 3826 and 3834 cm^{-1} with an intensity ratio of 3:1, which are assigned to ortho- and para-H_2 trapped at the interstitial T site in germanium. This assignment is supported by the results of recent *ab initio* calculations. Another signal around 3930 cm^{-1} seems to be due to H_2 trapped in some other type of voids formed during the plasma treatment. The work was supported by the Deutsche Forschungsgemeinschaft (WE 1319/14).

HL 50.11 Thu 16:30 P3

Composition of Ge(Si) islands in the growth of Ge on Si(111) by x-ray spectromicroscopy — •S. Heun[1], F. Ratto[2], F. Rosei[2], A. Locatelli[3], S. Cherifi[3], S. Fontana[3], P.-D. Szkutnik[4], A. Sgarlata[4], M. De Crescenzi[4], and N. Motta[5] — [1]Laboratorio Nazionale TASC INFM-CNR, 34012 Trieste, Italy — [2]INRS-EMT, Universite du Quebec, J3X 1S2 Varennes (Quebec) Canada — [3]Sincrotrone Trieste, 34012 Trieste, Italy — [4]Dipartimento di Fisica, Universita di Roma II, 00133 Roma, Italy — [5]Dipartimento di Fisica, Universita di Roma TRE, 00100 Roma, Italy

The stoichiometry of Ge/Si islands grown on Si(111) substrates at temperatures ranging from 460 to 560 °C was investigated by x-ray photoemission electron microscopy (XPEEM). By developing a specific analytical framework, quantitative information on the surface Ge/Si stoichiometry was extracted from laterally resolved XPEEM Si 2p and Ge 3d spectra, exploiting the chemical sensitivity of the technique [1]. Our data show the existence of a correlation between the base area of the self-assembled islands and their average surface Si content: the larger the lateral dimensions of the 3D structures, the higher their relative Si concentration. The deposition temperature determines the characteristics of this relation, pointing to the thermal activation of kinetic diffusion processes.

[1] F. Ratto, F. Rosei, A. Locatelli, S. Cherifi, S. Fontana, S. Heun, P.-D. Szkutnik, A. Sgarlata, M. De Crescenzi, and N. Motta, J. Appl. Phys. 97, 043516 (2005).

HL 50.12 Thu 16:30 P3

Anisotropy of the Γ-point electron effective mass in hexagonal InN — •T. Chavdarov[1], T. Hofmann[2], V. Darakchieva[3], H. Lu[4], W.J. Schaff[4], and M. Schubert[2] — [1]Institut für Experimentelle Physik II, Universität Leipzig, Leipzig, Germany — [2]CMRA, University of Nebraska-Lincoln, Lincoln, USA — [3]Department of Physics and Measurement Technology, Linköping University, Sweden — [4]Department of Electrical and Computer Engineering, Cornell University, USA

InN recently attracted much attention due to the availability of high-quality samples. Particularly the unexpected low band gap of 0.6 to 0.7 eV has triggered new experiments, vivid debates, and many reconsid-

erations, but still information on fundamental material parameters like the anisotropy of the Γ-point wurtzite-structure effective electron mass are lacking. Only few experimentally determined values on the isotropically averaged effective mass value of hexagonal InN exist so far. In this contribution we employ generalized magnetooptic ellipsometry in the far-infrared spectral range to determine the effective mass parallel $m^*_{e,\|}$ and perpendicular $m^*_{e,\perp}$ to the c axis, the free electron concentration N, and parallel $\mu^*_{e,\|}$ and perpendicular $\mu^*_{e,\perp}$ optical mobility parameters in thin InN layers with different N in the range between 5×10^{17} cm^{-3} to 2×10^{19} cm^{-3} without electrical contacts. The samples were grown by molecular beam epitaxy on sapphire substrates. While our isotropically averaged effective mass values are in good agreement with recently reported values, we observe a distinct anisotropy of the effective mass, with $m^*_{e,\perp} > m^*_{e,\|}$, which is in good agreement with recent LDA band-structure calculation results reported by Carrier and Wei, JAP **97**, 033707 (2005).

HL 50.13 Thu 16:30 P3

Transition energies and Stokes shift analysis for In-rich InGaN and InAlN alloys — •P. Schley[1], R. Goldhahn[1], A.T. Winzer[1], G. Gobsch[1], V. Cimalla[2], O. Ambacher[2], M. Rakel[3], C. Cobet[3], N. Esser[3], H. Lu[4], and W.J. Schaff[4] — [1]Institut f. Physik, TU Ilmenau — [2]Institut f. Mikro- und Nanotechnologien, TU Ilmenau — [3]ISAS Berlin — [4]Cornell University Ithaca

We present a comprehensive optical, electrical and structural characterization of In-rich InGaN and InAlN alloys grown on sapphire substrates with either an AlN or GaN buffer layer. The absorption and emission properties of these films were studied by spectroscopic ellipsometry in the range from 0.74 up to 9.5 eV and photoluminescence spectroscopy near the band gap, respectively. Films grown on a GaN buffer layer show a much sharper increase of the imaginary part (ε_2) of the dielectric function (DF) around the band gap and a slightly reduced Stokes shift compared to layers grown directly on AlN buffers. It is attributed to a reduced electron concentration and improved structural quality of the films on GaN buffers. For the determination of the band gap values as a function of alloy composition, carrier induced band gap renormalization and Burstein-Moss shift are taken into account. By fitting the third derivatives of the DF up to 9.5 eV we determined for the first time the compositional dependences (bowing parameters) of the transition energies for at least four and three critical points of the band structure for InGaN and InAlN alloys, respectively.

HL 50.14 Thu 16:30 P3

Optical properties of GaMnN grown by MBE — •J. Zenneck, M. Kocan, M. Röver, D. Mai, J. Malindretos, R. G. Ulbrich, and A. Rizzi — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We successfully grew GaMnN on Si(111) with a plasma-assisted molecular beam epitaxy system. To incorporate the manganese it was necessary to lower the growth temperature from 760°C (optimized GaN growth) to 650°C and change the growth regime to nitrogen-rich. These conditions lead to mediocre crystal quality compared with pure GaN as measured by photoluminescence (PL), Raman and x-ray diffraction (XRD).

The XRD measurements reveal homogeneous material or a secondary phase ($GaMn_3N$), depending on the growth conditions. PL shows no excitonic luminescence at all, but a structured DAP-band the intensity of which decreases with increasing Mn-content. The yellow luminescence is only visible in lightly Mn-doped samples without a secondary phase. In Raman measurements so called disorder-activated modes are visible instead of a clear A1 mode in samples with higher Mn-content. We will discuss these findings with respect to the possible defects involved. Furthermore the effect of post growth annealing on the optical properties of GaMnN will be analysed.

HL 50.15 Thu 16:30 P3

Reaktive Ion Etching of c-GaN — •Marina Panfilova[1], Jörg Schörmann[1], Stefan Potthast[1], Donat Josef As[1], Ulrich Hilleringmann[2], and Klaus Lischka[1] — [1]Universität Paderborn, Fakultät für Naturwissenschaften, Department Physik, Warburger Str. 100, 33095 Paderborn — [2]Universität Paderborn, Institut für Elektrotechnik und Informationstechnik, Sensorik, Warburger Str. 100, 33095 Paderborn

Cubic III - nitride semiconductors have great potential for optoelectronic and electronic devices due to their wide direct band gaps and absence of piezoelectric polarization. Because GaN is chemically very stable, dry etching techniques must be established in order to fabricate devices. Reactive ion etching (RIE) of cubic gallium nitride (c-GaN) epitaxially grown on 3C-SiC substrate has been investigated using various chemistries based on $SiCl_4$, Ar and SF_6 plasmas. The influence of gas flow, pressure and RF - power on etch rate and surface morphology were studied. For RF - power in the range of 0.8 kW to 1.4 kW, the etch rate is found to increase with RF - power, attaining a maximum rate of 27 nm/min at 1.4 kW. The addition of an inert gas Ar is found to barely affect the etch rate. Surface morphology before and after etching is checked by atomic force microscopy. This show that the roughness of the etched surface is comparable to that of the unetched surface. The measurements by scanning electron microscopy show a slight overcut. The structural resolution of our method is in the order of 1 μm.

HL 50.16 Thu 16:30 P3

Molecular Beam Epitaxy of cubic $Al_xGa_{1-x}N$ and AlN — •Elena Tschumak, Stefan Potthast, Jörg Schörmann, Donat Josef As, and Klaus Lischka — University of Paderborn, Department of Physics, Warburger Strasse 100, D-33095 Paderborn, Germany

Cubic $Al_xGa_{1-x}N$ and AlN exhibit a huge potential in the fabrication of electronic and optoelectronic semiconductor devices. In comparison with the hexagonal phase, cubic nitrides show isotropic electrical properties due to the absence of spontaneous piezoelectric fields. In cubic AlN, which has band gap of 5.1eV, the gettered oxygen forms a deep donor level. Therefore, AlN is insulating at room temperature and can be used for electrical insulation of electronic devices on conductive substrate. $Al_xGa_{1-x}N$ with a high Al-content is also useful for the fabrication of cubic $Al_xGa_{1-x}N$/GaN Bragg reflectors yielding high reflectivity. $Al_xGa_{1-x}N$-layers with an Al-content between 0.2 and 1 were deposited on 200nm GaN-buffer on 3C-SiC (001) substrates by rf-plasma assisted MBE. The films were grown at temperatures of 750°C under stoichiometric growth conditions. Growth was in situ monitored by Reflection High-Energy Electron Diffraction (RHEED). Room temperature cathodoluminescence, High Resolution X-Ray Diffraction (HRXRD) and Energy Dispersive X-ray (EDX) measurements were performed to obtain the Al-mole fraction. Surface morphology was studied by Atomic Force Microscope. For the investigation of electrical properties of the $Al_xGa_{1-x}N$-layers, Hall effect was measured between 10-350K.

HL 50.17 Thu 16:30 P3

Growth of cubic Al_xIn_yN and cubic $Al_xGa_yIn_{1-x-y}N$ lattice-matched to GaN — •Mark Schnietz[1], Jörg Schörmann[1], Shunfeng Li[1], Jürgen Vogt[2], Jürgen W. Gerlach[3], Donat J. As[1], and Klaus Lischka[1] — [1]University of Paderborn, Department of Physics, D-33098 Paderborn, Germany — [2]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig,Germany — [3]Leibniz-Institut für Oberflächenmodifizierung Leipzig, Permoserstraße 15, D-04318 Leipzig, Germany

We report the first epitaxial growth of c-Al_xIn_yN/GaN and c-$Al_xGa_yIn_{1-x-y}N$/GaN heterostructures lattice-matched to c-GaN on freestanding 3C-SiC substrates by plasma-asissted molecular beam epitaxy. Cubic Al_xIn_yN alloys can be used for the realization of lattice-matched c-AlInN/GaN Bragg mirrors due to its high difference in refractive index to GaN. The c-$Al_xGa_yIn_{1-x-y}N$ alloy permits the independent control of the band gap and the lattice parameter. The ternary and quaternary films were grown at substrate temperatures of 620°C. Different alloy compositions were obtained by varying the flux of Al and Ga. The alloy composition was measured by Energy Dispersive X-ray Spectroscopy (EDS) and Rutherford Backscattering (RBS). X-ray reciprocal space map of asymmetric (-1-13) reflex were used to measure the lattice parameters and to verify the lattice match between the alloy and the c-GaN buffer layers.

HL 50.18 Thu 16:30 P3

Optical properties of InN films — •Christoph Cobet[1], Patrick Vogt[2], Munise Rakel[1,2], Rüdiger Goldhahn[3], Massimo Drago[2], Antje Vollmer[4], Wolfgang Richter[2], and Norbert Esser[1] — [1]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, D-12489 Berlin — [2]Institute of Solid State Physics, TU Berlin, Hardenbergstr. 36, D-10623 Berlin — [3]Institute of Physics, TU Ilmenau, Weimarer Straße 25, D-98648 Ilmenau — [4]BESSY-GmbH, Albert-Einstein Str. 15, D-12489 Berlin

We report on measurements of the dielectric function of hexagonal InN in a broad spectral range from 0.5-12eV by means of ellipsometry. An

a-plane InN(11-20) layer grown by MBE in the Cornell University was utilized to determine the ordinary and extraordinary part of the dielectric tensor. We find a huge anisotropy between both components, where specific absorption structures differ in energy position or disappear in the extraordinary component. All structures will be attributed to particular interband transitions in comparison with GaN. Our experiments indicate also a strong influence of surface contaminations, which finally effect the position of the measured band gap as well. In order to analyze the surface degradation, we performed SXPS before and after a thermal annealing of MOVPE-grown InN samples in UHV. The InN(0001) surface after transfer into UHV gives rise to clear C1s and O1s core-level contributions, the latter originating from hydroxides due to water contamination of the surface in air. Thermal annealing at 573K is sufficient to remove carbon and hydroxide components. But stable oxide contributions could not be removed.

HL 50.19 Thu 16:30 P3

Polarization properties of InGaN quantum wells grown on semipolar GaN {1-101} facets — •Martin Feneberg[1], Frank Lipski[1], Barbara Neubert[2], Peter Brückner[2], Ferdinand Scholz[2], Klaus Thonke[1], and Rolf Sauer[1] — [1]Abteilung Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Abteilung Optoelektronik, Universität Ulm, 89069 Ulm

Strong piezoelectric fields in InGaN quantum wells grown on {0001} surfaces reduce the radiative transition probability due to the quantum confined Stark effect. One possibility to enhance light output of such devices is to use nonpolar or semipolar crystal planes for quantum well growth. It is therefore desirable to gain a better understanding of the properties of quantum wells on nonpolar and semipolar facets.

We report on polarized photo- and electroluminescence emission of quantum wells grown on {1-101} side facets of selectively grown GaN stripes. The quantum wells emit light linearly polarized parallel to the <11-20> direction of the GaN crystal. This is explained by valence band splitting due to strain. Surprisingly defect-related emission at lower energies is also linearly polarized, but perpendicular to the quantum well emission. This is most likely due to preferential defect alignment during epitaxy.

HL 50.20 Thu 16:30 P3

Optical and electrical properties of nitride-based UV LEDs — •D. Fuhrmann, T. Retzlaff, T. Litte, H. Bremers, U. Rossow, D. Dräger, and A. Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, Mendelssohnstr. 2, 38106 Braunschweig, Germany

During the last years, the efficiency of UV light emitting diodes based on AlGaN/AlGaN or GaN/AlGaN quantum well (QW) structures was strongly improved. But still, they are about one order of magnitude less efficient compared to their GaInN/GaN-based counterparts emitting in the visible spectrum. In this contribution we show our approach in order to optimize the internal quantum efficiency (IQE) of GaN/AlGaN QWs with an emission wavelength around 350nm. The samples were grown by low pressure MOVPE. The good material quality of the AlGaN buffer layer was revealed by both XRD measurements and the low temperature PL linewidth. We used temperature and excitation power dependent photoluminescence to determine the IQE. For our structures we find IQE values as high as 26% under resonant excitation. Using a nonresonant excitation with a power density of some kW/cm^2 the IQE increases even to 38%. For optimized SQW structures we find a very similar behavior concerning the IQE dependence on temperature and excitation power for both GaN/AlGaN UV-emitting structures and GaInN/GaN blue light emitters. This indicates that in both cases similar mechanisms limiting the IQE are present. A further improvement was achieved by applying an AlN buffer layer between the sapphire substrate and the AlGaN layer. Then we observed a significant improvement of the n- and p-type doping of the AlGaN layer, which will help to realize a high power UV-LED.

HL 50.21 Thu 16:30 P3

Electro- and photoluminescence investigations of nitride-based blue and green LEDs — •T. Litte, D. Fuhrmann, C. Netzel, H. Bremers, U. Rossow, and A. Hangleiter — TU Braunschweig, Inst. f. Angew. Phys., Mendelssohnstr.2, 38106 Braunschweig, Germany

In recent years very high values of 70% and 40% for the internal quantum efficiency (IQE) of GaInN/GaN based LEDs emitting in the blue and green spectral region, respectively, have been achieved. But still all devices suffer so far from a decrease of the efficiency with increasing drive current. This effect becomes even more pronounced for larger emission wavelengths λ_{peak}. In order to understand the mechanisms limiting the quantum efficiency we present here a detailed analysis of photoluminesence (PL) and electroluminesence (EL) data for blue and green emitting LEDs. The structures were grown by low pressure MOVPE and further processed into simple LEDs. The active region consisted of single and double $Ga_{1-x}In_xN$ quantum wells (QWs) with x_{In}=0.15...0.26 and d_{QW}=1.5nm...3nm and GaN barriers. We used temperature and excitation power dependent PL to determine the IQE. For both blue and green LEDs we find a good aggrement between PL and EL spectra in terms of the linewidth. We observe a very similar shift of the PL and EL peak position with increasing excitation power. As expected the wavelength shift is more pronounced for green LEDs and becomes larger for QWs with larger d_{QW} and smaller x_{In} compared to QWs emitting at the same λ_{peak} but have smaller d_{QW} and larger x_{In}. In addition we find that the drop in efficiency at higher current is smallest for LEDs that show the smallest shift of the peak position (i.e. small d_{QW}, large x_{In}).

HL 50.22 Thu 16:30 P3

UHV-cathodoluminescence investigation of metastable light emission in GaN/GaInN quantum well structures — •Martina Finke, Daniel Fuhrmann, Carsten Netzel, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, 38106 Braunschweig

In GaN/GaInN quantum well structures, the spontaneous and the piezoelectrical fields have a strong effect on the optical properties. The spontaneous field is normally shielded by charged species on the surface. Since the spontaneous field counteracts the piezoelectrical field, a blueshift in the peak-position of the luminescence and an increased intensity is expected by a removal of the deposited particles. We investigated the cathodoluminescence for various surface conditions after etching, annealing and electron beam exposition in an UHV environment. We studied several GaInN quantum well structures with different indium concentration and layer thicknesses at room and low temperatures. From time dependent measurements we find that the intensity of the luminescence of QW samples first increases rapidly and then decreases at longer times during electron beam exposure. We attribute this to a change of the spontaneous field due to electron-stimulated-desorption or due to a stimulated chemical reaction induced by the electron beam. Using systematic experiments we try to understand how the surface conditions influence the luminescence properties of QW structures via the effect of the spontaneous polarisation.

HL 50.23 Thu 16:30 P3

Temperature- and electric field-dependence of photoluminescence spectra of InGaN/GaN-heterostructures — •Clemens Vierheilig[1], Harald Braun[1], Nikolaus Gmeinwieser[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Elmar Baur[2], Uwe Strauss[2], and Volker Härle[2] — [1]Naturwissenschaftliche Fakultät II - Physik, Universität Regensburg Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

For further enhance the efficiency of InGaN-based LEDs, it is necessary to get a good knowledge of the processes in the active layer, in particular the impact of InGaN/GaN quantum wells and barrier structure, piezoelectric fields, and indium-fluctuation induced carrier localizations. We study the influence of these effects on carrier capture and internal efficiency. We measure field-dependent electroluminescence (EL) and photoluminescence (PL) spectra in a temperature-range between 4K and room temperature with our confocal micro-Photoluminescence setup to access a wide range of excitation densities. The radiative and nonradiative carrier-recombination rates extracted from these steady-state experiments are then compared to time-resolved measurements from a macro-PL measuring station. The results allow to draw conclusions on the mechanisms of radiative and nonradiative carrier-recombination.

HL 50.24 Thu 16:30 P3

Waveguide mode dynamics of InGaN laser diodes — •Christoph Lauterbach[1], Ulrich Schwarz[1], Alfred Lell[2], and Volker Härle[2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg

We use a scanning near-field microscope (SNOM) in combination with a time resolved detection scheme to measure the evolution of the near-field and far-field of InGaN laser diode (LD) waveguide modes. We observe lateral mode competition, filamentation, and beam steering. Here

we compare the lateral mode dynamics for ridge waveguide LDs and oxide stripe LDs which are predominantly index and gain guided, respectively. We observe a distinct difference in the mode dynamics for ridge waveguide and oxide stripe LDs. For the former the spatio-temporal pattern resembles the mode behavior of a hard wall box defined by the edge of the ridge. For the latter the soft confinement defined by the gain guiding profile leads to a better centering of the mode and a more stable mode pattern. Filamentation affects both ridge waveguide and oxide stripe LDs in a similar manner.

HL 50.25 Thu 16:30 P3

AlGaN templates on sapphire — •Kai Otte, Tomohiro Yamaguchi, Stephan Figge, and Detlef Hommel — Universität Bremen, Otto-Hahn Allee 1, 28359 Bremen

To grow unstrained AlInN/GaN vertical cavity surface emitting laser (VCSEL) structures with high aluminium content one needs templates with a higher lattice constant than GaN. This can be reached by adding aluminium to the GaN template layer.
We report on the growth of AlGaN templates by metal organic vapor phase epitaxy on sapphire. The 2 μm thick AlGaN layers with an aluminium mole fraction of 0.25 were grown on low temperature AlGaN nucleation layers.
High resolution x-ray diffraction and scanning electron microscopy data showing crack-free and compressively strained ($\epsilon_{xx,yy}$ = 0.3 at room temperature) templates will be presented. The templates show no compositional fluctuation in growth direction.
Reflectometry measurements during growth show no three dimensional island growth but two dimensional growth. This points to a high defect density. To reduce this effect different nucleation layers were grown.
These templates are promising for the growth of VCSEL structures. A comparison of distributed Bragg reflectors grown on AlGaN and GaN templates will be shown.

HL 50.26 Thu 16:30 P3

Electron Blocking Layers in GaN-based Laser Diodes — •Christian Meissner, Stephan Figge, Jens Dennemarck, Timo Aschenbrenner, and Detlef Hommel — Institute of Solid States Physics, University of Bremen, Otto-Hahn-Allee, D-28359 Bremen, Germany

Several InGaN multi quantum well laser diodes with different *p*-waveguide designs were grown in a vertical MOVPE reactor. Optical and electrical properties of these structures with AlGaN electron blocking layers will be presented.
AlGaN electron blocking layers are used in laser diodes to prevent the electron overflow to the *p*-doped layers. In particular the placement in the waveguide, the width and height of the electron blocking layer has an influence on the characteristics of the devices. Furthermore the electromigration of the *p*-dopant magnesium harms the operation of the laser diodes. Therefore, we additionally varied the onset of Mg-doping in the waveguide.
The structures were investigated by photoluminescence and electroluminescence. Both spectra indicate an operating wavelengh around 390nm. Measurements of light output power and the current-voltage characteristic show the dependence of the optical properties on the structure design.

HL 50.27 Thu 16:30 P3

Enhansed Low Stressed SiO2 Phase Creation in Nitrogen Doped Cz-Si — •Sergii Zlobin — Lashkarev Institute of Semiconductor Physics of the NASU, 41, Prospekt Nauki, 03028, Kyiv, Ukraine

This presentation deals with comparative study of oxygen structural arrangement in the Cz-Si wafers of different diameter, including those doped with nitrogen. To create oxygen precipitates two-step annealing (at 750 and 1050 oC) in argon ambient was used. Absorption band connected with stretching Si-O vibrations was measured using differential spectrometer and FTIR spectrometer. Absorbance spectra were deconvoluted into Gaussian profiles, which were analyzed in the frameworks of the Random Bonding Model to estimate contribution of different kinds of SiO4 tetrahedra rings in precipitated oxide phase lattice. It was shown that presence of soluted nitrogen promotes rapid release of the interstitial oxygen and favored creation of SiO2 phase with increased content of the less-stressed 6-fold SiO4 tetrahedra rings. This effect may be principal in providing enhanced radiation hardness and mechanical stability of the Silicon of large diameter.

HL 50.28 Thu 16:30 P3

Investigation of SnSe, $SnSe_2$ and Sn_2Se_3 alloys for electronic memory applications — •Kyungmin Chung, Daniel Wamwangi, Christoph Steimer, and Matthias Wuttig — I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

This work reports on the temperature dependence of structural and electrical properties of SnSe, $SnSe_2$ and Sn_2Se_3 films studied in the search of new phase change alloys for electronic memory applications. Our results have shown large electrical contrast of a 6.0×10^5 and 3.9×10^6 for the $SnSe_2$ and Sn_2Se_3 alloys, respectively upon phase transition. The temperature window upon which these phase transition takes place is even lower than that of $Ge_2Sb_2Te_5$ (ΔT=20°C) for the case of the Sn_2Se_3 (ΔT=4°C) alloy. This could possibly suggest rapid switching. By comparing with $Ge_2Sb_2Te_5$ (ρ=1mΩcm) and $Ge_4Sb_1Te_5$ (ρ=3mΩcm), it can be seen that both $SnSe_2$ and Sn_2Se_3 have large resistivity values in the crystalline state of 26mΩcm and 23mΩcm, respectively. This means that $SnSe_2$ and Sn_2Se_3 alloys could possibly minimize the RESET current of PRAM devices. X-ray diffraction (XRD) investigations have attributed the large electrical contrast to structure transformation from the amorphous to crystalline phase. The activation energy against crystallization has also been determined for SnSe, $SnSe_2$ and Sn_2Se_3 alloys to 2.01 $\pm$ 0.11eV, 1.93 $\pm$ 0.07eV and 0.32 $\pm$ 0.04eV, respectively. Corresponding to the structural transitions we have determined a density change of 3.79%, 20.15% and 12.4% upon annealing by X-ray reflectometry (XRR).

HL 50.29 Thu 16:30 P3

The origin of high vacancy concentrations in chalcogenide alloys — •Daniel Lüsebrink, Wojciech Welnic, Christoph Steimer, and Matthias Wuttig — I. Insitute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Phase change materials that are used in rewritable CD's and DVD's show a remarkable combination of properties. They exhibit pronounced property contrast, i.e. a remarkable difference in optical properties and electronic conductivity between the amorphous and the crystalline state. This has been attributed to a considerable difference in atomic arrangement in both states. The crystalline state that is found in phase change media is a distorted rocksalt structure which is characterized by a high vacancy concentration. For example GeSb2Te4 shows a vacancy concentration of 25% at the A-site of the distorted rocksalt structure. This raises the question how structures with such high vacancy concentrations can be stabilized. To answer this question density functional theory has been employed. Calculations have been performed for both the stable crystalline state, a hexagonal atomic arrangement, as well as for metastable rocksalt structures. A reason for the surprisingly high vacancy concentration in the metastable rocksalt structure will be presented. Finally we will discuss the significance of our findings for the properties of phase change materials.

HL 50.30 Thu 16:30 P3

Indium in silicon under tensile strain — •N. Santen and R. Vianden — Helmholtz-Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, D-53115 Bonn

In the past, donor-acceptor pairs in silicon have been studied intensively using the perturbed angular correlation method (PAC) with the acceptor ^{111}In as probe [1]. In addition it was found that the remaining unpaired indium on regular lattice sites showed a reaction on uniaxial mechanical strain, which seemed to depend on the dopant species. In order to study this phenomenon more detailed we carried out further experiments which reveal that the tension induced EFG depends on the concentration of the co-implanted donors. The results will be presented and discussed.

[1] G. Tessema, Indium-impurity pairs in semiconductors and the study of the influence of uniaxial stress on defect complexes in silicon, Dissertation Universität Bonn, 2003

HL 50.31 Thu 16:30 P3

Spatially resolved characterization of bevelled InP/InGaAs/InGaAsP structures studied by Raman spectroscopy — •Janet Leschner[1], Gert Irmer[1], Peter Krcho[2], Rudolf Srnanek[2], Stanislav Hasenoehrl[3], and Jozef Novak[3] — [1]TU Bergakademie Freiberg, Institut für Theoretische Physik, D-09596 Freiberg, Germany — [2]Microelectronic Department, Slovak University of Technology, 81219 Bratislava, Slovakia — [3]Institute of Electrical Engineering, Slovak Academy of Sciences, 84104 Bratislava, Slovakia

InP/InGaAs/InGaAsP heterojunctions have a wide application in optoelectronic devices. Structures used for photodiodes were grown by MOCVD. The bevel through this structure was prepared by chemical etching with bevel angle of about 0.00001 rad. The material composition and the strain near the interfaces due to lattice misfit are analyzed spatially resolved by micro Raman scattering of the LO-phonons. The quality of the interfaces is further characterized by measurement of the LO-phonon-plasmon coupling of photoinduced carriers.

HL 50.32 Thu 16:30 P3

Optically detected resonances in n-doped quantum wells and quantum dots — •Michael Gerbracht, A. A. Dremin, D. R. Yakovlev, and M. Bayer — Experimentelle Physik II, Universität Dortmund, D-44227 Dortmund, Germany

Optically detected resonance technique was used to study energy and spin structure of n-type doped quantum wells GaAs/(Al,Ga)As and CdTe/(Cd,Mg)Te and singly-charged (In,Ga)As/GaAs quantum dots. All samples have been fabricated by molecular beam epitaxy. The technique is based on the far-infrared laser (photon energies from 2.5 up to 20 meV) radiation effect on the electrons confined in the nanostructures. Detection is provided by means of intensity changes in photoluminescence lines of neutral and negatively charged excitons (trions). External magnetic fields up to 17 T were used to bring the system into resonance conditions. We have observed cyclotron resonances and resonances related to the internal energy structure of trion complexes. These experiments allow to study electron-exciton interaction and highlight processes of spin-dependent formation of trions.

HL 50.33 Thu 16:30 P3

Photoinduced carriers in bevelled InP structures studied by micro-Raman spectroscopy — •Geoffrey Richardson[1], Gert Irmer[1], Rudolf Srnanek[2], Stanislav Hasenoehrl[3], and Jozef Novak[3] — [1]TU Bergakademie Freiberg, Institut für Theoretische Physik, D-09596 Freiberg, Germany — [2]Microelectronic Department, Slovak University of Technology, 81219 Bratislava, Slovakia — [3]Institute of Electrical Engineering, Slovak Academy of Sciences, 84104 Bratislava, Slovakia

InP and its related alloy epilayers are of great technological interest in numerous applications such as high-speed circuits, integrated optoelectronics and high-power devices. The knowledge about near-surface properties, as well as their precise control, is becoming increasingly important, especially as the dimensions of device components continue to shrink. Raman experiments were performed on bevels of layered structures with special emphasis on the study of the generation and dynamics of photoexcited carriers. Spatially resolved measurements provide information about the local distribution of free carriers and depletion layers near the interfaces. Between the TO and LO phonon of InP a band was detected which is attributed to a highly damped mode of photoinduced holes.

HL 50.34 Thu 16:30 P3

Photoluminescence studies of GaAs quantum wells in close proximity to a GaMnAs barrier layer — •Robert Schulz, Tobias Korn, Andreas Maurer, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

(Ga,Mn)As 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 a AlGaAs/GaAs heterostructure close to a GaMnAs barrier layer. The photoluminescence (PL) of two QWs at different distances to the GaMnAs layer is measured at low temperature. The circular polarized components of the PL are then analyzed as a function of the external magnetic field. The difference of the PL components for $\sigma^{\pm}$ shows different behaviour depending on the distance between the QW and the GaMnAs layer. The PL energy of the QW closest to the GaMnAs (distance 10 nm) shows a Brillouin function type dependence, indicating a paramagnetic behaviour of the QW. For the QW farther away (100 nm) from the GaMnAs layer, a weak quadratic dependence of the PL is observed, as expected for nonmagnetic QWs. Subsequent PL measurements after several months show that the PL signal from the QW close to the barrier layer is quenched. From these observations, we suggest that there is some Mn diffusion from the barrier layer into the closest QW during and after MBE growth.

HL 50.35 Thu 16:30 P3

Diamond zinc oxide heterojunction — •Peter Geithner, Jürgen Ristein, and Lothar Ley — Technische Physik, Universität Erlangen-Nürnberg, Germany

A favourable couple for a wide band gap heterojunction is p-type diamond and zinc oxide that is naturally n-type. With a band gap of 3.5 eV for zinc oxide this heterojunction has the potential for a UV emitting LED.

The growth habit of zinc oxide on the diamond (100) and (111) face is investigated. Zinc oxide layers are grown in three ways. Chemical vapour transport is performed in closed silica tubes in a nitrogen atmosphere containing 10% hydrogen. Deposition of textured zinc oxide films is achieved with a source temperature of 800°C and applying a linear temperature transient starting at 500°C and increasing to 700°C within 30 minutes to the sample. The resulting 5μm thick film is characterized by optical and scanning electron microscopy. Films of 1μm thickness are deposited by DC sputtering or by RF magnetron sputtering in an argon atmosphere with 25% oxygen content.

Crystal quality and impurity content in diamond and zinc oxide were investigated by cathodoluminescence (CL) spectroscopy. The CL spectra of the zinc oxide layers show sharp (<8 meV FWHM) exciton lines and a defect band centred around 2.48 eV photon energy.

HL 50.36 Thu 16:30 P3

Strongly correlated excitons in quantum wells — •Patrick Ludwig[1,2], Alexei Filinov[2], Michael Bonitz[2], and Heinrich Stolz[1] — [1]Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock, Germany — [2]Christian-Albrechts-Universität zu Kiel, ITAP, Leibnitzstrasse 15, 24098 Kiel, Germany

In this work we consider small ensembles of optically excited indirect excitons in a quantum well (QW). The spatial separation of electrons and holes and lateral exciton confinement is due to the quantum confined Stark effect produced by an external electric field of a single tip electrode. The typical trap size is of the order of several micrometers.

Using first principle Path Integral Monte Carlo simulations, we first compute the lateral confinement potential of the excitons and the effective exciton-exciton interaction potential in the presence of the electric field. These results are then used in classical thermodynamic Monte Carlo simulations to investigate systems of several tens to thousands of indirect excitions in GaAs-based QWs. By changing the field strength, the excitation intensity (exciton number) and temperature, the exciton-exciton correlations can be varied in broad ranges. We present results for the density distribution, correlation functions and the phase diagram in the density- temperature-field strength space. Our theoretical results allow us to predict the parameter range at which interesting many-particle states, including exciton crystallization should be observable in experiments.

HL 50.37 Thu 16:30 P3

Fine structure of the intersubband absorption in stepped quantum wells — •Pilar Aceituno[1], Antonio Hernández-Cabrera[1], and Fedir T. Vasko[2] — [1]Departamento de Física Básica, Universidad de La Laguna,La Laguna 38206-Tenerife, Spain — [2]Institute of Semiconductor Physics, NAS of Ukraine, Kiev, 252650, Ukraine

The relative intersubband infrared absorption (IIRA) of stepped quantum wells (SQWs) of GaAs-GaAlAs, when subjected to an intense THz irradiation, is theoretically studied. By using the matrix density formalism, together with the adiabatic and resonant approximations, we obtain analytical expressions for the IIRA. When the pump intensity is of the order of megawatts, it is found that the absorption peak splits in a set of satellites (fine structure) due to (n+1) order intersubband transitions with the contribution of (n) THz photons and one IR photon. The number of peaks depends on the width of the SQW and the THz field intensity. Moreover, it is also found a strong modification of the absorption, which consists on a noticeable broadening of the zero-field peak and a shift towards higher energy values. We have used in calculations multiple SQW structures formed by 10 decoupled SQWs because the IIRA is usually too weak to be detected in a single QW.

A. Hernández-Cabrera, P. Aceituno, and F.T. Vasko, Phys. Rev. B, **72** 045307 (2005).

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HL 50.38 Thu 16:30 P3

Ellipsometry on pentacene thin films OFETs. — •Daniel Faltermeier[1], Bruno Gompf[1], Matthias Fischer[1], Ashutosh Tripathi[2], Jens Pflaum[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart — [2]3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart

Pentacene with its high effective carrier mobility is one of the most promising organic semiconductors, and much work has been done in characterizing the electronic properties of thin pentacene films. Despite these efforts the correlation between morphology and function is still not well understood. We present a systematic approach by spectroscopic ellipsometry on highly purified pentacene thin films, evaporated on silicon wafers with thermal SiO_2 in the temperature range between 5 K and 350 K. There a temperature dependent shift of the optical spectra can be observed. The optical data are correlated with x-ray diffraction, atomic force microscopy and field effect measurements performed at room temperature at the same films. By tuning the evaporation parameters like substrate temperature and evaporation rate one can clearly correlate changes in the ellipsometric spectra, especially the influence of the mid-gap states acting effectively as charge-carrier traps, with mobilities extracted from I-V curves. We also compare the thin-film results with spectroscopic ellipsometry measurements obtained on pentacene single crystals, to learn more about the intrinsic properties of the material.

HL 50.39 Thu 16:30 P3

A process for screening of organic semiconductor properties based on sub micron thin film transistors — •Christian Rickert, Michael Leufgen, Georg Schmidt, and Laurens Molenkamp — Physikalisches Institut (EPIII), Universität am Hubland, 97074 Würzburg, Germany

We present a highly reproducible and fast process for the screening of electrical properties of organic thin film transistors based on various semiconducting polymers. In order to achieve a channel length of 500 nm while maintaining high throughput we have chosen a process based on all optical lithography using a thin photoresist. The transistors were fabricated in a common gate technology on silicon wafers with a 50 nm thick thermal oxide. We will present the process and results for several polymer based semiconductors. Field effect mobilities obtained in different regimes will be shown along with the influence of different contact materials. Also results on wafers with thinner oxides were carried out in order to reduce short channel effects which can occur when downscaling the transistors.

HL 50.40 Thu 16:30 P3

Investigation of electric field- and illumination intensity dependent recombination losses in polymer-fullerene bulk heterojunction solar cells — •Jörg Bösner[1], Vladimir Dyakonov[1,2], and Ingo Riedel[1] — [1]Bavarian Centre for Applied Energy Research (ZAE-Bayern e.V.), Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg, Germany — [2]Experimental Physics VI, Institute of Physics, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Organic bulk heterojunction solar cells based on P3HT:PCBM composites were studied by measurements of the current-voltage characteristics (IV) and the external quantum efficiency (EQE) under variable electrical and optical bias. In EQE measurements, the simultaneous application of a white bias light results in the partial filling of traps and accounts for the presence of bimolecular recombination losses observed at higher light intensities. Spectral changes of the EQE under variable optical bias are correlated with the scaling exponents of the integral short circuit current (J_{SC}) with light intensity. At zero bias the J_{SC} in polymer-fullerene devices is primarily driven by the internal field. Hence, the mobility-lifetime product ($\mu\tau$) of majority charge carriers determines dependence of the photocurrent J_{ph} on the applied voltage. At high reverse bias, the field-dependent J_{ph} saturates and reflects the maximum J_{SC} which can be used to estimate the $\mu\tau$-product of photogenerated charge carriers. The electrical bias dependence of the EQE used to analyze the field-dependent recombination losses observed in the current-voltage characteristics under illumination.

HL 50.41 Thu 16:30 P3

Silicon Thin Films Sensitized by Phthalocyanine Dyes — •Christian Kelting[1], Ulrich Weiler[2], Thomas Mayer[2], Wolfram Jaegermann[2], Dieter Wöhrle[3], Marinus Kunst[4], and Derck Schlettwein[1] — [1]Justus-Liebig-Universität Gießen, Institut für Angewandte Physik — [2]TU Darmstadt, Fachbereich Materialforschung, Fachgebiet Oberflächenforschung — [3]Universität Bremen, Institut für Organische und Makromolekulare Chemie — [4]Hahn-Meitner-Institut, Sektion Solarenergie

A promising way to increase the light harvesting efficiency and hence the conversion efficiency of Si thin film photovoltaic cells is the utilization of the intense optical absorption of organic dye molecules in the absorber layer. Composite materials of zinc phthalocyanine (PcZn) in Si were prepared by simultaneous physical codeposition of PcZn into growing films of amorphous or microcrystalline Si from a plasma-enhanced (hot-wire) chemical deposition reaction (CVD). Thin films of PcZn (10 nm) were also prepared as model systems by physical vapour deposition on thin Si films (100-500 nm). Spectrally resolved photoconductivity measurements of pure Si films, PcZn- coated Si films and composite Si-Pc-films were used to prove the injection of charge carriers from the dye to silicon. The photoconductivity increased, in particular at the main absorption (Q-band) of the Pc. The sensitized photoconduction was obtained in the steady state under continuous illumination and the results are therefore taken as evidence for the injection of both types of charge carriers, electrons to the conduction band and holes to the valence band of Si.

HL 50.42 Thu 16:30 P3

Temperature Dependent Bias-Stress Effects on in-situ OFET Characteristics — •B. Gburek, M. Michelfeit, M. Leufgen, G. Schmidt, J. Geurts, and L.W. Molenkamp — Universität Würzburg, Physikalisches Institut (EP III), Am Hubland, D-97074 Würzburg, Germany

It is well known that applying external voltages to an organic field effect transistor (OFET) quickly results in a performance degradation. To examine this effect more closely we fabricated OFETs with dihexylquaterthiophene (DH4T) as active material by organic molecular beam deposition in UHV and characterised their electrical properties in situ. Therefore, we applied constant gate/source and/or drain/source voltages V = ± 15 V. Besides the time of their application, we also varied the sample temperature between 150 and 360 Kelvin. Upon application of a negative gate and drain bias, a clear shift of the threshold voltage towards higher negative values was observed, strongly increasing with temperature. This shift was reversible, showing nearly full relaxation after a few minutes. The relaxation was enhanced by the application of a positive gate bias. While the charge carrier mobility remained unaffected at room temperature, the simultaneous application of gate/source and drain/source voltage at elevated temperatures induced a mobility increase beyond 50 percent. This effect also showed full reversibility.

HL 50.43 Thu 16:30 P3

Scaling behaviour of sub-μm OFETs with different active-layer materials — •O. Rost, M. Leufgen, G. Schmidt, J. Geurts, and L. W. Molenkamp — Physikalisches Institut der Universität Würzburg, Am Hubland, 97074 Würzburg

The downscaling behaviour of OFETs is influenced by the crystallinity of the organic semiconductor. Therefore, we analysed different organic semiconductors with different coating methods using templates of 20 nm thin SiO_2 dielectric with metal source/drain bottom contacts. The channel length L was varied from 5μm to 100 nm. UHV deposited dihexylquaterthiophene (DH4T) resulted in a polycrystalline thin film. The mobility was beyond 0.01cm^2/Vs. A spin coated poly-triarylamine based semiconductor (amorphous) had mobility values up to 0.01cm^2/Vs. Dithiophene-tetrathiafulvalene (DT-TTF) was drop cast from solution resulting in large single crystals. Here, mobility values up to 1 cm^2/Vs were achieved. The presentation compares the scaling behaviour of the characteristic FET-parameters: mobility, threshold voltage and on/off-ratio. It also reports on the aspect of oncoming short channel effects, which in our case took place at about L = 200 nm, regardless of the material.

HL 50.44 Thu 16:30 P3

Change of the work function of a polymer substrate by electrochemical treatments: Influence on the energy level alignment — •Heiko Peisert[1,2], Andreas Petr[2], Lothar Dunsch[2], Thomas Chassé[1], and Martin Knupfer[2] — [1]University of Tübingen, IPC, Auf der Morgenstelle 8, D-72076 Tübingen, Germany — [2]Leibniz Institute for Solid State and Materials Research Dresden, D-01069 Dresden, Germany

We studied the influence of the work function change of a polymer substrate by electrochemical treatments on the energy level alignment in layered systems using core and valence level photoemission spectroscopy. As example for a technically relevant organic/organic interfaces we chose the interface between PEDOT:PSS [mixture of poly-3,4-ethylenedioxythiophene (PEDOT) and polystyrenesulfonate (PSS)] and CuPc (copper phthalocyanine). The change of the work function by about 0.75 eV affects the interface dipole whereas the barrier between HOMO (highest occupied molecular orbital) and Fermi level remains constant.

HL 50.45 Thu 16:30 P3

Solution processed single crystal organic field-effect transistors based on tetrathiafulvalene derivates — •M. Leufgen[1], O. Rost[1], G. Schmidt[1], N. S. Oxtoby[2], M. Mas-Torrent[2], N. Crivillers[2], J. Veciana[2], C. Rovira[2], J. Geurts[1], and L. W. Molenkamp[1] — [1]Universität Würzburg, Physikalisches Institut (EPIII), Am Hubland, D-97074 Würzburg, Germany — [2]Institut de Ciencia de Materials de Barcelona(CSIS), Campus UAB, 08193 Cerdanyola, Spain

Solution processed tetrathiafulvalene (TTF) derivates as active materials in organic field effect transistors (OFETs) are electrically analysed. Dithiophene- and dibenzo-tetrathiafulvalene (DT- and DB-TTF) are drop cast from solution of toluene onto lithographically structured bottom contact FET-templates with common gate and SiO_2 dielectric. They crystallise in several micrometer size single crystals in an elongated evaporation process. A limited number of crystals hits the electrodes and thus constitutes the active channel. Here, the channel length is varied from 100 μm into the sub-micrometer regime (< 100 nm), with the use of 100 (20) nm thick SiO_2 in the first (second) case. The characteristics show the excellent properties of the materials with an on/off-ratio exceeding 10^6 and mobility values as high as 3 cm^2/Vs (in the case of DT-TTF), which is among the highest reported for solution processed crystals. The general scaling behaviour is a decrease in mobility from the 10^0 to the 10^{-1} cm^2/Vs order of magnitude, when going to sub-micrometer channel length, due to an influence of the contact resistance. The results on temperature dependant behaviour prove a thermally activated transport.

HL 50.46 Thu 16:30 P3

Topographical and electrical characterization of pentacene thin-film transistors using thiol-modified electrodes — •D.V. Pham[1], C. Bock[1], U. Kunze[1], D. Käfer[2], G. Witte[2], and Ch. Wöll[2] — [1]Lehrstuhl für Werkstoffe und und Nanoelektronik, Ruhr-Universität Bochum, D-44780 — [2]Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum, D-44780

We study the influence of thiol monolayers on the topography as well as on the electrical characteristics of pentacene thin film transistors. The electrodes are modified by dodecanethiol, heptanethiol and anthracenethiol, respectively. A sample with untreated Ti/Au (1 nm/25 nm) electrodes acts as reference sample. The roughness analysis of the films emphasizes the preferential growth of pentacene on the untreated gold layer. The best morphology of the organic film is achieved with electrodes treated with dodecanethiol for a channel length of 500 nm. Since alcanethiols are isolators, the injection of the charge carriers from the gold electrode into the active region is strongly reduced. Nevertheless the performance of pretreated OFETs is superior compared to the reference sample. The best results are obtained with anthracenethiol treatment. The morphology of the film is homogeneous and, due to its semiconducting behaviour, high drain currents are possible. The threshold voltage of this sample is 2 V and the ON/OFF ratio amounts to 10^6.

HL 50.47 Thu 16:30 P3

C-U INVESTIGATION OF BILAYER, IONIZED CLUSTER BEAM DEPOSITED, Al/PTCDA/CuPc/ITO ORGANIC SEMICONDUCTOR STRUCTURE — •Bruno Cvikl[1,2], Matjaž Koželj[2], and Dean Korošak[1] — [1]Chair of Applied Physics, Faculty of Civil Engineering, University of Maribor, Maribor, Slovenia — [2]Institute J. Stefan, Ljubljana, Slovenia

In this work the results of the room temperature C-U and I-U measurements of the ionized cluster beam deposited Al/PTCDA(0.8μm)/CuPc(1.2μm)/ITO organic bilayer structure, of two hole transporting materials, will be presented. Its room temperature C-U line shape, for larger reverse and forward values of bias, broadly resembles the Berleb et al. [1] of the thick Alq3 layer data. The C-U line shapes of the said structure, as a function of Alq3 thickness, are well described in terms of the newly derived expression for the differential capacitance [2]. It incorporates the bias dependent, at the cathode/organic semiconductor junction, induced net charge density and the bias independent electric dipole density existing within the organic mixture in the neighborhood of the Alq3/NPB region. However, within the interval between -1 V to + 2.5 V the C-U line shape of our sample is akin the cubic parabola that our expression for the differential capacitance fails to predict. The possible mechanisms that modulate the capacitance-voltage line shape of such an organic structure will be presented and discussed in details.

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HL 50.48 Thu 16:30 P3

Spin injection at metal/organic semiconductor interface — •Dean Korošak[1], Bruno Cvikl[1,2], and Matjaž Koželj[2] — [1]University of Maribor, Faculty of Civil Engineering, Chair for Applied Physics, Smetanova 17, 2000 Maribor Slovenia — [2]J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

A theoretical investigation of a possibility of using a metal/organic semiconductor interface as a spin injector, specifically considering the role of a tunneling barrier at a metal/organic semiconductor interface serving as a spin selective mechanism. The parameters of the PCTDA electronic structure are determined from the results of the analysis of the capacitance-voltage characteristics of the ionized cluster beam deposited samples. The current spin polarization is found to critically depend on the details of the disordered interlayer the width of which and the properties can be to some extent controlled in the ionized cluster beam deposition experiment. It is shown that under the assumption of the space charge limited current through the contact the crucial parameter is the effective width of the organic layer determining the spin diffusion lenght. The structure resulting from ionized cluster beam experiment in which a thin interlayer sandwiched between the metal and organic semiconductor doped with metal clusters can be obtained is considered as a numerical example.

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HL 50.49 Thu 16:30 P3

Investigations of electron transport in a contact limited methanofullerene thin film transistor — •Elizabeth von Hauff[1], Jürgen Parisis[1], and Vladimir Dyakonov[2] — [1]Institute of Physics, Energy and Semiconductor Research Laboratory, Carl von Ossietzky University of Oldenburg, 26111 Oldenburg, Germany — [2]Experimental Physics VI, Faculty of Physics and Astronomy, University of Würzburg, 97074 Würzburg, Germany

In this study the electron transport in a methanofullerene was investigated via the thin film transistor structure. The temperature dependent source-drain current and the electron field effect mobilities in [6,6]-phenyl C_{61}-butyric acid methyl ester (PCBM) were investigated in context of a model for field effect theory in amorphous materials from the literature. An initial fit led to discrepancies between experimental and predicted data at low temperatures and gate voltages, an effect which was attributed to parasitic contact resistances between the source/drain contacts and the semiconductor. The effects of the contact resistances were then investigated. Studying the temperature and electric field activated behaviour of the contact resistance was found to aid in the understanding of charge injection in the device. A form for the contact resistance based on a diffusion limited thermionic emission current was proposed. Incor-

porating the proposed form of the contact resistances into the model was found to lead to much better agreement between experimental data and that predicted by the model.

HL 50.50 Thu 16:30 P3

Optical investigation of P3HT/PCBM bulk heterojunction solar cells by photoinduced absorption spectroscopy — •Stefan Voigt[1], Uladzimir Zhokhavets[1], Harald Hoppe[1], Gerhard Gobsch[1], Maher Al-Ibrahim[2], Oliver Ambacher[2], and Steffi Sensfuss[3] — [1]Institute of Physics, Ilmenau Technical University, 98684 Ilmenau, Germany — [2]Centre for Micro- and Nanotechnologies, Ilmenau Technical University, 98684 Ilmenau, Germany — [3]TITK Inst. Rudolstadt, Dept. Functional Polymer Systems, 07407 Rudolstadt, Germany

An important parameter that determines the efficiency of organic solar cells is the product of the mobility and lifetime of generated charge carriers. This product needs to be increased by an optimized choise of the materials and balanced production processes. In this work, this mobility - lifetime product of positive polarons is determined in dependence on temperature and excitation density by dynamic photoinduced absorption experiments on the accomplished devices. In addition the recombination characteristics were regarded by studying the excitation density dependence of the signal. The influence of annealing on the recombination properties is investigated, too.

HL 50.51 Thu 16:30 P3

Field Effect Mobility of the Polymer Poly(3-Hexyl Thiophene) — •Maria Hammer[1], Carsten Deibel[1], Vladimir Dyakonov[1], and Ingo Riedel[2] — [1]Experimental Physics VI, Physical Institute, University of Würzburg, 97074 Würzburg, Germany — [2]Bavarian Centre for Applied Energy Research (ZAE Bayern e.V.), Div. Functional Materials for Energy Technology, Am Hubland, 97074 Würzburg, Germany

Semiconducting polymers are interesting materials for the use in organic electronics. We investigated the field effect mobility of regio-regular and regio-random poly(3-hexyl thiophene), in dependence of temperature and charge carrier concentration. Our data will be discussed in view of recently published models for charge carrier mobility in disordered organic materials, based on hopping transport of charge carriers in a gaussian density of states distribution.

HL 50.52 Thu 16:30 P3

Microresonators based on SOI for optical bio-sensory applications — •Dominic Dorfner, Felix Hofbauer, Andreas Kress, Marc Tornow, Jon Finley, and Gerhard Abstreiter — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany

We are investigating the potential to develop photonic biosensors that will combine high spatial resolution and detectivity. Our concept is based on probing the modification of the linear optical response of photonic crystal (PC) defect resonators upon surface bio-functionalization. PCs are fabricated from the biocompatible Silicon-on-insulator (SOI) materials system using electron beam lithography and reactive ion etching. They consist of a hexagonal lattice of air holes perforating the SOI membrane into which cavities are formed by single missing hole defects. Calculations demonstrate that the cavity mode frequency should be very strongly influenced by local changes of refractive index (n) on the surface of the PC. By simulating the attachment of bio-molecules to the surface, a ~8% absolute shift of the mode frequency is predicted as n increases from ~1.3 to ~1.5. For a PC with lattice constant a=340nm (photonic bandgap ~1.2 - 1.4 mu) this would correspond to delta~30nm, easily visible even with rather low cavity Q-factors of one thousand. First optical characterizations were performed using micro-photoluminescence spectroscopy on structures infilled with PbSb nanocrystals. These measurements reveal peaks due to filtering of the QD emission through the cavity mode spectrum, with Q~100.

HL 50.53 Thu 16:30 P3

Anisotropic Light Emission of Quantum Dots in Photonic Crystals — •Rebecca Wagner[1], Michael Barth[2], and Frank Cichos[1] — [1]Photonics and Optical Materials, Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz — [2]Nano-Optics group, Institute of Physics, Humboldt University Berlin, Hausvogteiplatz 5-7, 10117 Berlin

Photonic crystals are periodic dielectric materials, which modify light emission by means of a photonic stop band. In weak photonic systems with low dielectric contrast, the local optical density of states is only modified in certain directions of the photonic crystal therefore giving rise to an anisotropic light propagation. We study the influence of this anisotropic light propagation on the angular emission characteristics of single quantum dots within numerical calculations and experimental investigations. The numerical calculations are based on the fractional local density of states, which describes the angular redistribution of electromagnetic modes in the photonic crystal. The fractional local density of states reveals, that even in weak photonic systems strongly directional emission of emitters may occur, especially at the short wavelength edge of the photonic stop band. This calculation is combined with imaging calculations to compare the results to experimental investigations of anisotropic light propagation using defocused fluorescence wide field imaging on single quantum dots in colloidal photonic crystals.

HL 50.54 Thu 16:30 P3

Design, fabrication and characterization of microcavity OLED structures — •Hannes Gothe, Robert Gehlhaar, Hartmut Fröb, Vadim G. Lyssenko, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany, www.iapp.de

Microcavity OLEDs exhibit a directional emission and efficiency enhancement. We report on a microcavity structure consisting of a distributed Bragg reflector (DBR) and a metal mirror. The SiO_2/TiO_2-DBR is fabricated by reactive electron-beam evaporation and covered with an electrically conductive film of indium-tin-oxide (ITO). Due to the comparably high absorption, the optical properties of the microcavity are strongly dependent on the ITO layer. By annealing and structure optimization, which reduces the electromagnetic field intensity in the ITO layer, we counteract the absorbance and decrease the optical losses within the resonator. The results of linear optical measurements are explained by transfer-matrix calculations.

HL 50.55 Thu 16:30 P3

Conventional pillar-type and novel pyramidal III-V microcavities: Fabrication and characterization — •M. Karl[1], W. Löffler[1], J. Lupaca-Schomber[1], T. Passow[1], S. Li[1], F. Perez-Willard[2], J. Hawecker[2], D. Gerthsen[2], H. Kalt[1], C. Klings-hirn[1], and M. Hetterich[1] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe, D-76128 Karlsruhe, Germany

In our contribution we discuss two different approaches to realize GaAs-based micro-cavities: In the first approach conventional pillar-type resonators with AlAs/GaAs distributed Bragg reflectors (DBRs) were fabricated from MBE-grown layer structures using focussed ion beam (FIB) milling. In(Ga)As quantum dots emitting at around 950 nm served as a broad-band light source in these cavities. To assess the optical properties of individual micro-resonators a confocal micro-photoluminescence set-up with a tunable Ti:sapphire laser for excitation was used. In particular, we investigated the dependence of the observed cavity modes on the pillar diameter.

In extension to this work we have also recently started to study the potential of a new cavity design. The latter consists of a pyramidal GaAs resonator placed on top of an AlAs/GaAs DBR. It can be fabricated by combining electron-beam lithography and wet chemical etching of structures containing an AlAs sacrificial layer. First results obtained for these resonators will be presented. In particular, it will be shown that even coupled cavities can easily be realized in this approach.

HL 50.56 Thu 16:30 P3

PAC studies with LSO scintillation crystals — •Riccardo Valentini and Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn, Germany

The LSO (lutetium oxyorthosilicate, Lu_2SiO_5) scintillation crystal has been shown to improve the efficiency of PET apparatus considerably [1] [2]. This makes LSO interesting for Perturbed Angular Correlation (PAC) since today's solid state studies require appropriate PAC probes for specific purposes, like ^{77}Br, ^{187}W or ^{172}Lu, with more complicated energy spectra. We investigated the applicability of this new scintillator for PAC studies especially in experiments where the improvement of energy resolution as compared to BaF_2 is important without loosing time resolution. From these improvements we expect a larger effective anisotropy.

Further due to the high average atomic number of LSO its photopeak efficiency is considerably high. We present here test measurements with ^{172}Lu in ZnO and a comparison with measurements on a BaF_2 setup.

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HL 50.57 Thu 16:30 P3

Waveguide and sensor systems comprising metamaterial elements — •M. Shamonin[1], A. Radkovskaya[2], C.J. Stevens[3], G. Faulkner[3], D.J. Edwards[3], O. Sydoruk[4], O. Zhuromskyy[4], E. Shamonina[4], and L. Solymar[5] — [1]University of Applied Sciences Regensburg, D-93025 Regensburg, Germany — [2]M.V. Lomonosov Moscow State University, 119992 Moscow, Russia — [3]University of Oxford, Oxford OX1 3PJ, United Kingdom — [4]University of Osnabrück, D-49069 Osnabrück, Germany — [5]Imperial College of Science, Technology and Medicine, London SW7 2BT, United Kingdom

We shall report an experimental and theoretical study of periodic structures consisting of familiar metamaterial elements with a view to sensor applications. In the measurements one, two- and three-dimensional arrays of resonant elements are employed. The mechanism under investigation is the guiding, channelling, splitting and recombination of signals across (or along) perodic structures whose dimensionas are small relative to, or of the order of a wavelength. We shall present experimental and theoretical results on a variety of sensing systems in which the HF magnetic field plays a dominant role with potential applications in imaging, in the automotive industry and in antennas.

Financial support by the Royal Society (award 2004-JP) and the DFG (GK 695, Emmy Noether-Program) is gratefully acknowledged.

HL 50.58 Thu 16:30 P3

Ground State of Electron on Short-Range Potential in Two Dimensional Structure in Magnetic Field — •Tatiana Pavlova — Moscow Engineering Physics Institute, Kashirskoe sh. 31, 115409 Moscow, Russia

The exact energy spectrum of an electron in a negative ion located in a two-dimensional structure and in a magnetic field applied perpendicular to the layer surface is derived. In our calculations we used the method of the zero-range potential derived for the three-dimensional problem (Yu.N. Demkov and G.F. Drukarev, 1965). The energy of the electron located in a short-range potential of arbitrary scattering length is obtained. The dependence of the binding energy on the magnetic field is investigated in the layer with different thickness. The diamagnetic and anti-diamagnetic energy shifts from the continuous spectrum boundary are studied. In the limit of infinite layer thickness the obtained energy coincides with energy in the three-dimensional problem. The electron energy in the shallow impurity potential in a weak magnetic field agrees with the results derived previously (S.P. Andreev and T.V. Pavlova, 2005).

HL 50.59 Thu 16:30 P3

An all-Electron GW Code Based on FP-(L)APW+lo — •Ricardo I. Gomez-Abal, Xinzheng Li, and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin.

In recent years the GW approximation (GWA), typically applied as perturbation to DFT, has proven to be very successful describing quasi-particle excitations in semiconductors and insulators. Most of the existing codes are based on the pseudopotential (PP) method, which is well established for ground state DFT calculations. In this scheme, the self energy is computed for the valence states only. There is, however, no guarantee that "core-valence partitioning" done in this fashion is justified for the dynamical self energy, which is a highly non-linear functional of the total density. G_0W_0 results obtained with PP implentations are usually in better agreement with experiments than those reported from existing all-electron implementations. Self-consistent schemes improve the agreement of the all-electron calculations [1], but drastically worsen the PP results [2]. The reasons for this discrepancy and the necessity for self-consistency are still a matter of debate [1,2]. In order to address these questions, we are developing our own all-electron GW code. It is based on the FP-(L)APW+lo method, which currently provides the most reliable results within DFT. The code treats core, semicore and valence states on the same footing, which implies that it is applicable to a wide range of materials. In this poster we present a description of the code and the first results obtained for silicon.

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HL 50.60 Thu 16:30 P3

Ab initio calculation of electronic properties for dangling bond free nitridated silicon — •Philipp Plänitz, Alberto Martinez-Limia, Mohammed Bouhassoune, and Christian Radehaus — Institute for Electrical and Information Engineering, Technical University Chemnitz, 09107 Chemnitz, Germany

Silicon oxynitride is used by the semiconductor industry as Gate oxide for mordern MOSFETs. For a low nitrogen concentration the theoretical calculation of electronic properties is difficult due to large unit cells and amorphous structures.

Using ab initio density-functional theory the influcene of electrical inactive nitrogen in a silicon oxid matrix was investigated. We report the calculated values of the total energies, density of states, band gap and dielectric constant for different concentrations of nitrogen. By classical MC and CPMD approximate unit cells were obtained for the amorphous structures. The exact value for the band gap was calculated by means of the GW-method and the dielectric response was calculated in the framework of first order pertubation theory as implemented in the ABINIT program.

HL 50.61 Thu 16:30 P3

Time-dependent density functional theory in the non-adiabatic regime — •Günther Schwarz, Ilya V. Tokatly, and Oleg Pankratov — Chair of theoretical solid state physics - University of Erlangen-Nuremberg, Germany

The time-dependent density functional theory (TD-DFT) has proven to be an important scheme for the computation of dynamics of quantum mechanical systems. However, most of the work has been performed within the adiabatic local density approximation (ALDA) where the exchange-correlation potential v_{xc} is treated as a local function of electron density. Recent work [1,2] has shown that a non-adiabatic TD-DFT can be formulated most naturally in the co-moving Lagrangian reference frame. Within this approach the time evolution of v_{xc} is defined by a Cauchy deformation tensor as the basic variable rather than by the electron density or current. A differential equation for this tensor has to be solved in addition to the time-dependent Kohn-Sham equations. This imposes only modest computational effort over an adiabatic calculation.

We performed first tests of the dynamics of an electron gas in a single and double quantum well to demonstrate the similarities and differences of this generalized hydrodynamics approach as compared to adiabatic calculations. We aim to uncover the importance of non-adiabatic effects and thus to verify the applicability range of ALDA.

[1] I. V. Tokatly and O. Pankratov, Phys. Rev. B **37**, 201103(R) (2003).
[2] I. V. Tokatly, Phys. Rev. B **71**, 165105 (2005).

HL 50.62 Thu 16:30 P3

Spin-Dependent GW Approximation with Application to MnO — •Claudia Rödl, Patrick Hahn, Jürgen Furthmüller, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Determining the electronic structure of systems containing transition metals is still a challenging task. Such systems often have a nontrivial spin ordering. In order to calculate quasiparticle band structures of magnetic materials we extend the well-known Hedin equations and subsequently the GW approximation (GWA) to systems with intrinsic spin polarization and spin-orbit coupling. In the following we restrict ourselves to collinear spin polarization which is sufficient to describe a wide range of magnetic materials. Band structure calculations for the antiferromagnetic insulator MnO using spin-density functional theory (SDFT) as well as spin-polarized GW approximation are presented. Occurring effects will be critically discussed. Furthermore, we study the consequences of including collinear spin polarization in the calculation of the optical properties of magnetic materials. The Bethe-Salpeter equations and the extension of the excitonic Hamiltonian to spin-polarized systems are considered.

HL 50.63 Thu 16:30 P3

Structural and Electronic Properties of ZnO and CdO polymorphs — •Andre Schleife, Frank Fuchs, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

The group-II metal oxides ZnO and CdO are both of technological and fundamental interest. In recent years this led to a variety of proposed and

realized applications, mainly in the field of optoelectronics. However, on the theoretical side comparably little is known about their properties. Here we present results on the structural and electronic properties of various ZnO and CdO polymorphs in zincblende, wurtzite and rocksalt structure. We discuss the energetic stability, lattice parameters and bandstructures. The calculations are performed in the framework of generalized-gradient corrected density functional theory (DFT-GGA). The projector augmented plane wave (PAW) method is used to model the electron-ion interaction.

HL 50.64 Thu 16:30 P3

Energy spectrum of strongly correlated electrons and indirect excitons in quantum dots — •KARSTEN BALZER, CHRISTOPH NÖLLE, MICHAEL BONITZ, and ALEXEI FILINOV — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik, Leibnizstr. 15, 24098 Kiel, Germany

In the limit of strong correlations finite electron and exciton systems in quantum dots show Fermi liquid behavior and Wigner crystallization. Wigner crystals of electrons [1] and excitons [2] are predicted to occur in semiconductor quantum dots or in quantum wells with an external electrostatic confinement. Path integral Monte Carlo (PIMC) simulations have allowed to compute the density matrix from first principles [1,2]. However, they cannot directly yield the energy spectrum and wave functions which give access to the optical and transport properties.

Here we develop an analytical approach to the many-particle wave function and energy spectrum of electrons and indirect excitons in the strong-coupling limit which is based on an expansion in terms of collective eigenmodes [3]. Exact solutions are obtained for small particle numbers by direct diagonalization. For larger systems, a new method is introduced which allows one to reconstruct the energy spectrum and wave function from first principle PIMC results for the density distribution.

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HL 50.65 Thu 16:30 P3

CYLINDRIC RESONATORS WITH COAXIAL BRAGG-REFLECTORS — •R. SCHMIDT-GRUND[1], T. GÜHNE[2], H. HOCHMUT[1], B. RHEINLÄNDER[1], A. RAHM[1], V. GOTTSCHALCH[2], J. LENZNER[1], and M. GRUNDMANN[1] — [1]Uni Leipzig, Inst. für Exp. Physik II — [2]Uni Leipzig, Fak. für Chemie und Mineralogie

Lateral confinement for cylindrical micro-resonator light emitters improves the ratio of the number of the axial resonant modes to the number of the spontaneous emitting lateral modes. We have observed resonator behaviour of cylindrical micro-structures, whose surfaces were coated with coaxial MgO/ZrO_2 and a-Si/SiO_x Bragg-reflectors (BR).

Glass rods with circularly shaped basal planes ($\oslash$=5μ...100μm) and ZnO wires with hexagonally shaped basal planes ($\oslash$=0.8μm...10μm) were used as cavity material. The optical properties were investigated using a micro-reflectometer (μR), spatially resolved spectroscopic ellipsometry, and cathodoluminescence (CL) measurements. The Bragg-stop-band (SB) of the BR deposited on the free standing ZnO-wires was found to be uniform for all hexagonal lateral facets. In contrast, the SB of the BR deposited on the horizontally mounted glass rods varies with the azimuthal position on surface. The μR measurements were performed perpendicular to the axis of the ZnO wires. In the wavelength range of the SB spectral structures due to multiple-reflection induced interferences of the ZnO cavity are visible. This indicates resonator behaviour of the coated ZnO-wires. CL measurements confirm these results.

Calculations of the electromagnetic field distribution within the cylindrically layered structures will be presented.

HL 50.66 Thu 16:30 P3

FIR spectroscopy of single quantum dots fabricated by AFM — •STEFFEN GROTH[1], KEVIN RACHOR[1], CARSTEN GRAF VON WESTARP[1], CAN-MING HU[2], and DETLEF HEITMANN[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]Department of Physics and Astronomy University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

We study charge excitations in single quantum dots fabricated on semiconductor heterostructures by *a*tomic *f*orce *m*icroscope (AFM) nanolithography. For this purpose we have established the technique of anodical oxidation to pattern a split gate directly on a GaAs/AlGaAs heterostructure with a two-dimensional electron system confined 35 nm below the sample surface. This technique enables us to prepare barriers with a geometrical thickness of less than 200 nm. The dot geometry and size (down to a few 100 nm) are both tunable by changing the applied gate voltage. We monite the tunneling conductance of the single quantum dot which oscillates as a function of the gate voltage due to the Coulomb blockade. We perform the measurement at a temperature of 250 mK using a He3 cryostat with a 10 tesla magnet connected to a far-infrared (FIR) spectrometer. We expect that under the influence of FIR radiation, the Coulomb blockade peaks will be shifted due to the charge redistribution caused by collective excitations.

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HL 50.67 Thu 16:30 P3

Coherence properties of the resonance fluorescence from GaAs Quantum Wells — •GEROLF BURAU, BIRGER SEIFERT, and HEINRICH STOLZ — Institut für Physik, Universität Rostock, 18051 Rostock

We study the spectral coherence properties of the resonance fluorescence from excitons in GaAs quantum wells under coherent resonant excitation. The distinction between the coherent and the incoherent component of the radiation emitted from excitons is experimentally challenging. Therefore a new setup for spectral speckle analysis has been developed for precise measurement of the secondary emission intensity distribution. We considerably improved the quality of the quantitative analyzed speckle distribution due to the improved optical imaging and the higher spectral resolution. A single frequency laser with 4 neV (1 Mhz) bandwidth was used for excitation.

HL 50.68 Thu 16:30 P3

Optical beam indal npn-structure junction devicesuced current measurements at planar two-dimension — •C. WERNER, D. REUTER, and A.D. WIECK — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum

By overcompensating a p-doped $GaAs/In_{0.19}Ga_{0.81}As/Al_{0.33}Ga_{0.67}As$ pseudomorphic heterostructure we have fabricated two-dimensional npn-junction devices. The molecular beam epitaxy grown base material has a hole density of 7×10^{11} cm^{-2} and the mobility of the holes is 200 cm^2/Vs at room temperature.

By implanting silicon ions we locally overcompensate the heterostructure, as described in [1, 2], and obtain n-doped areas. The implantation consists of two rectangles with a non-implanted area in between. We expect the resulting photocurrent to be linearly dependent on the position of a light spot for this type of sample. Therefore we made OBIC-measurements (optical beam induced current) by scanning a modulated focused laser beam (635 nm) across the sample perpendicular to the junctions and measuring the voltage drop over a resistance connected to the device by a lock-in amplifier.

This project is gratefully acknowledged by the Evangelische Studienwerk "Haus Villigst" within the "Promotionsschwerpunkt Wechselwirkungen".

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HL 50.69 Thu 16:30 P3

Resonant Raman scattering in Cu_2O — •JAN BRANDT[1], DIETMAR FRÖHLICH[1], CHRISTIAN SANDFORT[1], MANFRED BAYER[1], and HEINRICH STOLZ[2] — [1]Institut für Physik, Universität Dortmund, D-44221 Dortmund, — [2]Fachbereich Physik, Universität Rostock, D-18051 Rostock

We present results on exciton phonon polariton scattering in Cu_2O. We study by high resolution spectroscopy (ΔE< 10neV) resonant Raman scattering on the yellow 1S orthoexciton for optical phonons of different symmetry (Γ_3^-, Γ_4^-, Γ_5^-). The Γ_4^- phonon of 19meV is optically active and has thus to be considered as a polariton with TO and LO components split by 0.3meV. For forward Raman scattering the polariton character of the TO components has to be taken into account. We present the Raman selection rules for quadrupole excitation of the threefold Γ_5^+ exciton. The splitting in up to three components by k-dependent exchange interaction is also taken into account[1].

[1] Dasbach et al. PRB 70, 045206 (2004)

HL 50.70 Thu 16:30 P3

Calculation of optical mode energies and field distributions in micron-sized semiconductor ring resonators — •Ch. Strelow, T. Kipp, and D. Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany

We calculate the mode structure and field distributions of micrometer-sized semiconductor ring resonators with very thin walls and compare it to experimental spectra.

Using polar coordinates and a radial stepwise arrangement of refractive index we get an exact solution of Maxwell's equation by matching Bessel functions at the boundaries. The mode energies and their field distributions sensitively depend on the thickness of the wall, its refractive index and radius. We compare these exact results to a simplified model of a planar dielectric wave guide applying periodic boundary conditions. The theoretical results show a very good agreement to experiments on a novel kind of microcavity, namely a InGaAs/GaAs microtube ring resonator, which we prepared using the self-rolling mechanism of strained bilayers. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508.

HL 50.71 Thu 16:30 P3

Transport investigation on ZnO Nanowires — •T. Lüdtke[1], J. M. Becker[1], R. J. Haug[1], B. Postels[2], M. Kreye[2], and A. Waag[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]TU-Braunschweig, D-38106 Braunschweig

We report on fabrication and transport measurements on ZnO nanowires. The nanowires are grown vertically onto a highly doped SiO_2 substrate and have a diameter of 50nm - 200nm and a length up to $2\mu m$. We use a method to contact this array of nanowires vertically. The sample is completely coated with an insulating polyimid whereas the tips of some wires are uncovered in several etching steps. Gold pads of a few tenth μm are located above the uncovered tips to connect the wires to leads.

The sample is measured inside a He^4 cryostat allowing temperatures down to 1.5 K and magnetic fields up to 15T. I-V characteristics shows an asymmetric diode like behaviour and the current rises while increasing the temperature. By illuminating the sample the conductivity is increasing by a factor of 2. Further temperature dependent measurements have been performed to analyze possible piezoelectric effects of the ZnO.

HL 50.72 Thu 16:30 P3

Self-Assembly of Nitride Nanowires grown by MBE — •Ratan Debnath[1], Ralph Meijers[1], Thomas Richter[1], Toma Stoica[1,2], Raffaella Calarco[1], Michel Marso[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich,52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest,Romania

Among different types of nanostructures, semiconductor nanowires and nanotubes are extremely interesting as building blocks for nanoelectronics, due to their suitability for fabricating both nanoscale devices and interconnects. Although there have been a lot of investigations on these semiconductor nanowires, fundamental physical properties are still unclear. The growth mechanism and especially the nucleation of the wires, which is very important for producing ordered arrays of nanowires is not understood in detail. The self-assembled growth of GaN, InN as well as $In_xGa_{1-x}N$ nanowires on Si(111) substrates by molecular beam epitaxy (MBE) was investigated by means of several characterization methods. Scanning electron microscopy (SEM) images showed the influence of growth parameters on column shape and density whereas, optical methods (photo- (PL) and cathodoluminescence (CL)) provided the information about the quality of the grown wires. It was even possible to get spatially-resolved information by combining SEM and CL. By introducing doping materials (Si and Mg) in the nanowires, column morphology can be changed considerably, depending on the concentration of the dopants.

HL 50.73 Thu 16:30 P3

Structural and electronic properties of morphological transformed InAs quantum dots — •Andreas Schramm, Jan Schaefer, Fabian Wilde, Tobias Kipp, Stephan Schulz, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstraße 11C, 20355 Hamburg

We study the structural and electronic properties of morphological transformed InAs-quantum dots embedded in Schottky diodes using atomic force microscopy (AFM), photoluminescence (PL), capacitance (CV) and deep level transient spectroscopy (DLTS). The samples were grown on (001) GaAs in a solid-source MBE system. We find that we can control the shape of the dots by an annealing step after growth of an AlAs cap layer. Both AFM data as well as the electronic properties show that the dots size increases with the AlAs cap layer thickness. Furthermore, we observe a strong lateral shape anisotropy in quantum dots grown beneath AlAs cap layers. The influence on the electronic properties like threshold voltages and energies as well as number of observed DLTS-maxima will be briefly discussed.

HL 50.74 Thu 16:30 P3

Constant capacitance deep level transient spectroscopy on InAs quantum Dots — •Jan Schaefer, Andreas Schramm, Stephan Schulz, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstraße 11 20355 Hamburg

The thermionic emission of charge carriers from self-assembled quantum dots embedded in Schottky diodes is found to strongly depend on the electric field at the location of the quantum dots. So far, the emission rates have been studied with transient capacitance spectroscopy. However, in such measurements (conventional deep level transient capacitance spectroscopy, DLTS) the electric field does not remain constant while the transient is recorded. It is thus very desirable to have a method at hand, that allows to probe the carrier emission at constant field condition. Here we report about the implementation of such a method: The so-called constant capacitance deep level transient spectroscopy (CC-DLTS). We present first CC-DLTS measurements on InAs quantum dots and compare the results obtained with this and the conventional DLTS method.

HL 50.75 Thu 16:30 P3

Deposition and epitaxial overgrowth of colloidal nanocrystals on ZnSe surfaces — •Dirk Mügge[1], Christof Arens[1], Detlef Schikora[1], Klaus Lischka[1], Oliver Schöps[2], Ulrike Woggon[2], and Mikhail V. Artemyev[3] — [1]Dep. Physik, Universität Paderborn, Warburger Str. 100, 33098 Paderborn, Germany — [2]FB Physik, Universität Dortmund, Otto-Hahn-Str. 4, 44227 Dortmund, Germany — [3]Institute for Physico-Chemical Problems of Belarussian State University, Minsk, Belarus

The incorporation of colloidal Nanocrystals (NCs) in an epitaxial grown ZnSe Matrix is an alternative production technology of Quantum Dot (QD) structures adverse to the self organized Stranski Krastanow (SK) QD growth. The advantages of such hybrid epitaxial-colloidal structures are the production of QD layer with variable QD densities (theoretically from 10^0 cm^{-2} to 10^{14} cm^{-2}) and the possible incorporation of different colloidal NCs into the same QD layer (e.g. different materials, size, shape). The NCs are kept in Pyridine and transmission measurements allow the determination of the absolute NC density in the carrier solvent. We will present optical and structural properties of core(shell) CdSe(ZnS) NCs with different NC densities on epitaxial grown ZnSe surfaces treated by standart deposition technologies (e.g. spin coating, dip coating) and investigations of optical and structural properties of integrated NCs in an epitaxial grown ZnSe Matrix.

HL 50.76 Thu 16:30 P3

Constant capacitance deep level transient spectroscopy on InAs quantum Dots — •Jan Schaefer, Andreas Schramm, Stephan Schulz, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, D-20355 Hamburg, Germany

The thermionic emission of charge carriers from self-assembled quantum dots embedded in Schottky diodes is found to strongly depend on the electric field at the location of the quantum dots. So far, the emission rates have been studied with transient capacitance spectroscopy. However, in such measurements (conventional deep level transient capacitance spectroscopy, DLTS) the electric field does not remain constant while the transient is recorded. It is thus very desirable to have a method at hand, that allows to probe the carrier emission at constant field condition. Here we report about the implementation of such a method: The so-called constant capacitance deep level transient spectroscopy (CC-DLTS). We present first CC-DLTS measurements on InAs quantum dots and compare the results obtained with this and the conventional DLTS method.

HL 50.77 Thu 16:30 P3

Raman study of CdSe core/shell nanorods — •N. Tschirner[1], M. Machon[1], U. Woggon[2], M.V. Artemyev[3], and C. Thomsen[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Fachbereich Physik der Universität Dortmund, Germany — [3]Minsk State University, Belarus

CdSe nanorods were studied using Raman spectroscopy. The spectra reveal an LO peak which is shifted from the bulk Raman frequency by $\approx 3\,\mathrm{cm}^{-1}$. The linewidth and lineshape are also affected. We discuss our results on nanorods without and with ZnSe shells of different sizes.

HL 50.78 Thu 16:30 P3

Modeling the growth of quantum dot stacks via kinetic Monte Carlo simulations — •Roland Kunert and Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

We study the heteroepitaxial growth of self-assembled quantum dot stacks, grown in the Stranski-Krastanov growth mode, using kinetic Monte Carlo simulations.

The focus of our investigations is the effect of the three-dimensional anisotropic strain field induced by the lattice mismatch, which is computed self-consistently in the framework of elasticity theory. With this approach we can explain the seemingly contradictory predictions about the positions of anticorrelated stacks of quantum dots in theory[1] and experiment[2].

Using a hybrid method, we simulate the growth of the quantum dot arrays, taking into account the strain field generated by the layers beneath.

[1] V. Holý, G. Springholz, M. Pinczolits, and G. Bauer, Phys. Rev. Lett. **83**, 356 (1999).
[2] X.-D. Wang, N. Liu, C. K. Shih, S. Govindaraju, and A. L. Holmes, Jr., Appl. Phys. Lett. **85**, 1356 (2004).

HL 50.79 Thu 16:30 P3

Positioning of self-assembled InAs quantum dots by focused ion beam implantation — •Minisha Mehta, Alexander Melnikov, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik,Ruhr-Universtät Bochum, Universitätstraße 150, D-44780 Bochum,Germany

Self-assembled quantum dots (QDs) have attracted great interest in the last years for realization of novel nanoelectronic devices based on single quantum dots. For such devices, well controlled positioning of the InAs QDs is necessary.

We have studied a selective positioning method for self-organized InAs quantum dots (QDs) on patterned GaAs substrate by a combination of in-situ focused ion beam implantation (FIB) and self-organized molecular beam epitaxy (MBE) technology. We have proposed square lattice of nanoholes by FIB-implantation of Ga and In ions respectively. These arrays were overgrown with InAs to induced preferred QD formation at the hole positions. The shape and position of the QDs were investigated by scanning electron and atomic force microscopy. We studied the influence of the ion dose, an in-situ thermal treatment and the In amount deposited. By optimizing these parameters, we could achieve a minimum of approximately 7 QDs per hole without having QDs in the unpatterned areas.

Financial support from the DFG GRK384 and the BMBF contract BM451 NanoQuit is gratefully acknowledged.

HL 50.80 Thu 16:30 P3

Top-down fabrication of GaAs/AlAs nanocolumns with lateral dimensions in the sub-100nm range — •Jakob Wensorra[1], Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten and Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

We report on a top-down fabrication technique for vertical GaAs nanocolumns with embedded AlAs barriers.

Layer stacks with double barrier resonant tunneling structures have been grown by MBE. Precise plasma etching of nanocolumns with lateral dimensions down to the sub-100nm range was achieved by using electron beam lithography and high resolution Hydrogen Silsesquioxan (HSQ) negative resist as the mask material. HSQ is also employed to planarize and physically isolate the devices. A novel non-alloyed ohmic contact based on a very thin low-temperature-grown GaAs (LT-GaAs) top layer is used for contacting the nanostructures.

HL 50.81 Thu 16:30 P3

Synthesis and characterization of CdS nanowires — •Jens Böttcher, Marko Burghard, and Klaus Kern — Max-Planck-Institut für Festkörperforschung, Stuttgart

Cadmium sulphide (CdS) nanowires with an average diameter of 30 nm and lenghts of up to 10 μm have been synthesized via a novel solvothermal method that uses a single-source precursor and ethylenediamine as coordinating solvent. Investigations by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), transmission microscopy (HRTEM), thermal gravimetric analysis (TGA), and photoluminescence (PL) studies indicate that the described synthesis approach yields pure, structurally uniform, and single crystalline nanowires. Furthermore, spatially resolved photoconductivity measurements were used to determine the mechanism of photocarrier transport in individual CdS nanowires.

HL 50.82 Thu 16:30 P3

Optical properties and structure of CdP4 nanoclusters in zeolite Na-X and fabricated by laser ablation — •Oleg Yeshchenko — Physics Department, National Taras Shevchenko Kyiv University, 2 Akademik Glushkov prosp., 03022 Kyiv, Ukraine

CdP4 nanoclusters were fabricated by incorporation into the pores of zeolite Na-X and by deposition of the clusters onto a quartz substrate using laser ablation-evaporation technique. Absorption and photoluminescence (PL) spectra of CdP4 nanoclusters in zeolite were measured at the temperatures of 4.2, 77 and 293 K. Both absorption and PL spectra consist of two blue shifted bands. We performed DFT calculations to determine the most stable clusters configuration in the size region up to size of the zeolite Na-X supercage. The bands observed in absorption and PL spectra were attributed to emission of (CdP4)3 and (CdP4)4 clusters with binding energies of 3.78 eV and 4.37 eV per atom respectively. The Raman spectrum of CdP4 clusters in zeolite proved the fact of creation of (CdP4)3 and (CdP4)4 clusters in zeolite pores. The PL spectrum of CdP4 clusters produced by laser ablation consists of single band that was attributed to emission of (CdP4)4 cluster.

HL 50.83 Thu 16:30 P3

Excitons and band behavior in ultrasmall nanoclusters. — •Anton Grygoriev and Vladimir Litovchenko — V. Lashkarev Institute of Semiconductor Physics NASU 45 Prospect Nauki, Kyiv 03028, Ukraine

We present experimental and theoretically investigation of nanosized effects: transformation of the energetic structure of quantum dots in oxide matrix. Calculations were performed taking into account the electron-hole Coulomb interactions, expanded interface area, leakage of electronic density from quantum dot, increasing the effective mass and experimental values of barrier high. The interactions of electrons and holes are strongly enhanced in ultrasmall *quasiopen* quantum dots because of decreasing effective permittivity, which lead to very stable exciton (at T room). Dependences of exciton binding energy, work function (electron affinity), effective mass and energy of optical transfers from quantum dot diameter have been obtained. The achieved results demonstrate notably difference to the parameters achieved from well-established idealized case (sharp and infinite barriers) to the ultrasmall (˜1-3 nm) dots. Comparison cluster calculations with revised effective mass approximation prove correctness developed approach up to 1 nm. Using of renewed by us effective media approximation allows us to predict some principal new physical effects, such as negative electron affinity (electrons localization outside the dot), which can be useful for electron photo and field emission applications

HL 50.84 Thu 16:30 P3

Coherence time of single photons from laterally coupled InGaAs/GaAs quantum dot molecules — •Serkan Ates[1], Sven M. Ulrich[1], Mohamed Benyoucef[2], Armando Rastelli[2], Lijuan Wang[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]5. Physikalisches Institut,Universität Stuttgart, Pfaffenwaldring 57 D - 70550 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung Heisenbergstr. D-70569 Stuttgart

In this work, we report detailed investigations on the coherence length of single photons from laterally coupled InGaAs/GaAs quantum dots. The lateral coupled QDs were grown on GaAs substrates by a unique combination of molecular beam epitaxy and in-situ layer precise etching [1]. The samples were cooled to 4 K and optically pumped by a

continuous-wave Ti:sapphire laser at a pump wavelength of 800 nm. Our measurements were performed using a Michelson interferometer combined with a micro-photoluminescence (μ-PL) setup and a Hanbury Brown and Twiss setup. The visibility of the interferometer setup was over 90 % with the Ti:sapphire laser. We have observed excitonic and biexcitonic transitions and the visibility curve of the transitions showed a Gaussian behavior. We get the coherence length of transitions in the range of 30 - 40 ps, corresponding to a linewidth of approx. 40 μeV by using the Gaussian fitting. These results indicate that decoherence processes are present even at low temperatures. [1] R. Songmuang, S. Kiravittaya, and O. G. Schmidt, APL 82,2892 (2003)

HL 50.85 Thu 16:30 P3

Theory of Optical Dephasing in Semiconductor Quantum Dots — •Carsten Weber, Matthias Hirtschulz, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Within a density matrix approach, the nonlinear quantum kinetic dynamics of semiconductor quantum dots is investigated. We consider different dephasing mechanisms, e.g. electron-phonon interaction and the interaction with the underlying wetting layer, in order to describe in a realistic manner the damping mechanisms. Non-Markovian dynamics as well as scattering processes lead to a damping of the Rabi oscillations, which can be compared to single-quantum dot experiments.

HL 50.86 Thu 16:30 P3

The role of non-equilibrium phonons for the optically induced dynamics in quantum dots — •Annette Krügel, Vollrath Martin Axt, and Tilmann Kuhn — Institut für Festkörpertheorie, Westfälische Wilhelms-Universität, 48149 Münster, Deutschland

For GaAs type quantum dots it has been shown that pure dephasing due to the coupling to longitudinal acoustic (LA) phonons gives a major contribution to the initial dephasing on picosecond time scales. For high density excitation also the phonon system is driven out of its equilibrium state and coherent phonon amplitudes and non-equilibrium phonon coherences and occupations act back on the carrier system. We study the exciton dynamics in a quantum dot coupled to LA-phonons. The carriers are excited by Gaussian laser pulses of arbitrary duration. For the electron-phonon interaction we concentrate on pure dephasing processes described by the independent boson model. Numerical results are obtained by using a correlation expansion within the density matrix formalism. We account for all single and double assisted density matrices as well as for the coherent phonon amplitudes and non-equilibrium phonon occupations and correlations. A pronounced influence of these non-equilibrium phonons on the carrier dynamics is observed. We find that especially for low temperatures and longer pulses of several picoseconds non-equilibrium phonons play an important role and cannot be neglected.

HL 50.87 Thu 16:30 P3

Multiphonon Raman scattering of spherical PbSe quantum dots — •J. T. Devreese[1,2], S. N. Klimin[1,3], V. M. Fomin[1,2,3], and F. W. Wise[4] — [1]TFVS, Universiteit Antwerpen, B-2610 Antwerpen, Belgium — [2]Department of Semiconductor Physics, TU Eindhoven, NL-5600 MB Eindhoven, The Netherlands — [3]State University of Moldova, Kishinev, Republic of Moldova — [4]Department of Applied Physics, Cornell University, Ithaca, New York 14853, USA

Multi-phonon resonant Raman scattering in spherical PbSe quantum dots is investigated using a non-adiabatic approach. The optical phonons in quantum dots are treated within the multimode dielectric continuum model, taking into account both the electrostatic and mechanical boundary conditions for the relative ionic displacement. The exciton-phonon interaction is considered for all phonon modes specific for these quantum dots. Our multimode dielectric continuum model, which includes, as a substantial ingredient, the realistic dispersion of optical phonons, adequately describes the optical-phonon spectra of spherical PbSe quantum dots. The non-adiabaticity leads to a substantial enhancement of the relative intensities of multi-phonon peaks with respect to the intensity of the one-phonon peak. The peak positions and intensities of the calculated Raman scattering spectra for spherical PbSe quantum dots are in good agreement with recent experimental results on the Raman scattering in oleic-acid-capped colloidal PbSe nanocrystals.

This work was supported by the GOA BOF UA 2000, IUAP, FWO-V projects G.0274.01N, G.0435.03 and the WOG WO.035.04N (Belgium).

HL 50.88 Thu 16:30 P3

Single electron quantum dot in a spatially periodic magnetic field — •Daniel Buchholz[1] and Peter Schmelcher[1,2] — [1]Theoretische Chemie, Institut für Physikalische Chemie, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany — [2]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

A general overview of the electronic properties of a harmonically confined single electron quantum dot inside a spatially periodic magnetic field is presented. The energy spectrum, magnetization, probability density and current density are calculated for varying parameters (i.e. amplitude, wavelength and phase) of the periodic magnetic field. For wavelengths comparable to the oscillator length of the dot, we observe a rich spectral behavior. Avoided and exact level crossings dominate the spectrum and ground state degeneracies occur for particular values of the field. The probability and current densities are very sensitive with respect to the phase of the magnetic field. Differently to the dot inside a homogeneous magnetic field, the magnetization, as a function of the field amplitude, has a minimum, depending on the phase and wavelength of the field. For wavelengths being small compared to the oscillator length, the impact of the field on the lowest eigenenergies is almost zero, thus the obtained spectrum is approximately that of a pure harmonic oscillator. The eigenfunctions take up a spatial dependent phase yielding a non-vanishing probability current.

HL 50.89 Thu 16:30 P3

Single photon emission from CdSe/ZnSe quantum dots — •Christian Peitzmeyer, Steffen Michaelis deVasconcellos, Patrick Ester, Christof Arens, Dirk Mügge, Artur Zrenner, Detlef Schikora, and Klaus Lischka — Universität Paderborn, Department Physik, Warburger Strasse 100, D-33095 Paderborn

We have studied the correlation of the photon emission from a single selfassembled CdSe/ZnSe Stranski-Krastanow quantum dot under cw excitation from a blue-emitting laser diode. The quantum dot surface density was 10^{10} to 10^{11} cm^{-2}. Spectra were taken on mesa structures at T = 4.2K, which contain only a small number of dots. The emission of the CdSe dots was measured by a micro-photoluminescence setup, using a LN_2-cooled CCD camera. In the single dot emission antibunching is observed. Therefore a single CdSe dot can be used for the generation of single photons on demand. Stranski-Krastanow-grown quantum dots as used within this work have advantages in comparison to other emitters in the green spectral range, because photobleaching, blinking and spectral diffusion do not occur.

HL 50.90 Thu 16:30 P3

Energy transfer processes in ensembles of CdSe quantum dots of different sizes — •M. Rohe[1], M. Grau[1], P.J. Klar[1], W. Heimbrodt[1], M. Yosef[2], and S. Schlecht[2] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]Institute of Chemistry and Biochemistry, FU Berlin, Germany

Bimodal random ensembles of CdSe quantum dots containing two distinct sizes (e.g. 3 nm and 9 nm) and mixed different ratios were studied by cw and time-resolved photoluminescence (PL) techniques. Due to different quantum confinement situations in the two subsystems of dots, the corresponding PL spectra show two spectrally resolved bands of which the high-energy band corresponds to the 3 nm dots whereas the low-energy band corresponds to the 9 nm dots. A coupling between the two subsystems of dots is revealed by time-resolved PL where the decay time of the 9 nm dots is significantly increased in the presence of 3 nm dots compared to an ensemble of solely 9 nm dots. This demonstrates that, in addition to energy transfer processes within each of the two subsystems, an energy transfer takes place from the 3 nm dots to the 9 nm dots. We study these energy transfer processes in dependence on the mixing ratios.

HL 50.91 Thu 16:30 P3

Influence of an in-plane electric field on the photoluminescence of single InGaAs/GaAs quantum dots — •Moritz Vogel[1], Sven M. Ulrich[1], Lijuan Wang[2], Armando Rastelli[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany

We present a systematic investigation of the quantum confined Stark effect in (In,Ga)As/GaAs quantum dots. For this purpose lateral static electric fields have been applied via lithographically defined Schottky

contact structures on top of our low-density sample structures. The quantum dots were cooled to 4 K and optically pumped using a cw or a mode-locked Ti:Sapphire laser with a repetition rate of 76 MHz and a pulse width of 2 ps tuned to 800 nm. We adopt the technique of scanning Fabry-Perot interferometry to perform high-resolution spectroscopy on the biexcitonic (XX) and excitonic (X) radiative transitions. From studies on numerous quantum dots we typically observe narrow emission lines with a full width at half maximum as low as 13 *eV which is significantly below the resolution limit provided by conventional single-stage spectrometers. Within a small bias range a strong nonlinear dependence of the emission energy due to the quantum-confined Stark effect has been observed which allows for a stable and reversible control of the emission energy. In conjuction with field-dependent measurements, the polarization properties of the emission will also be discussed.

HL 50.92 Thu 16:30 P3

Observation of Multi-exciton Transitions in Individual Quantum Dot Molecules — •Emily Clark[1], Hubert J. Krenner[1], Toshihira Nakaoka[1,2], Matthias Sabathil[1], Max Bichler[1], Yasuhiko Arakawa[2], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut and Physik Department, Technische Universität München, Germany — [2]University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8505, Japan

We present investigations of single, charged and multi-exciton states in individual quantum dot molecules (QDMs). The samples investigated consist of pairs of self assembled, vertically stacked InGaAs-GaAs QDs embedded in an n-type Schottky photodiode. This device geometry enables us to control the coupling between excitonic states in the upper and lower dots via the electric field. Previously, we demonstrated an anticrossing of spatially direct (e,h in the same dot) and indirect (e,h in different dots) excitons with an average coupling energy of 2E=1.6±0.3meV. By comparing these findings with realistic calculations of the single exciton spectrum, we confirm that the observed anticrossing is due to hybridization of the electron component of the exciton wavefunction. New emission peaks emerge at higher excitation levels, the intensity of which increases quadratically on the excitation intensity, identifying them as biexcitons in the QDM. Both spatially direct (two excitons in upper dot) and separated (single exciton in upper and lower dot) biexcitons are identified. Comparison between quasi resonant and non-resonant excitation, separates between charged and neutral excitons.

HL 50.93 Thu 16:30 P3

Lateral and vertical electric field applied to Self-Assembled QDs — •V. Stavarache[1], D. Reuter[1], A. D. Wieck[1], R. Oulton[2], and M. Bayer[2] — [1]Lehrsthul für Angewandte Festkörperphysik, Ruhr Universität Bochum, Universitätstrasse 150, D-44780, Bochum — [2]Experimentele Physik II, Otto-Hann Strasse 4, D-44221 Dortmund

The effect of an in-plane (lateral) and a vertical electric field on self-assembled InAs -quantum dots (QDs) by photoluminescence (PL) and time-resolved spectroscopy will be presented. For this purpose, we have fabricated a double p-i-n device with application of an electric field in the lateral and vertical directions. Combining techniques such as, electron beam lithography (EBL), focus ion beam implantation (FIB), and standard optical lithography we are able to define small p-i-n structures, which allow us the realization of fields higher than $\sim 10^5 V m^{-1}$. By applying an external electric field, a redshift of the wavelength emission is expected due to the Stark effect, as well as an increase in the radiative lifetime of the exciton accompanied by a decrease in the PL intensity.

HL 50.94 Thu 16:30 P3

Highly resonant Raman spectroscopy of InAs quantum dots — •Tim Köppen, Thomas Brocke, Tobias Kipp, Andreas Schramm, Christian Heyn, and Detlef Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung der Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

We investigate the electronic properties of InAs quantum dots grown with Indium flush technique [1] using resonant inelastic light scattering. These quantum dots allow for highly resonant excitation with near-infrared laser light near the E_0 gap. Photoluminescence measurements show this gap to be at approximately 1.2 eV. In previous Raman experiments on InAs quantum dots grown without flush technique we used the $E_0 + \Delta$ gap ($\sim$1.65 eV) for resonant excitation [2]. With technical improvements and the stronger resonance we get an increase in the electronic Raman signal of a factor of $\sim$250. We now observe signatures of single quantum dots in our spectra.

This project is supported by the Deutsche Forschungsgemeinschaft via SFB 508 "Quantenmaterialien".

[1] S. Fafard et al., *Phys. Rev. B* **59**, 15368
[2] T. Brocke et al., *Phys. Rev. Lett.* **91**, 257401

HL 50.95 Thu 16:30 P3

Engineering the multi-exciton spectra in wurtzite InN/GaN quantum dots — •Norman Baer, Stefan Schulz, Stefan Schumacher, Paul Gartner, Gerd Czycholl, and Frank Jahnke — Institute for Theoretical Physics, University of Bremen

The emission spectra of nitride based quantum dots (QDs) differ dramatically from those known from other III-V material systems. We use an atomistic description of the single-particle properties in InN/GaN QDs and combine them with a microscopic calculation of the Coulomb interaction effects. Details of a tight-binding (TB) study that fully incorporates the underlying wurtzite lattice structure and the induced electrostatic fields are presented. In the TB-model we use a sp^3 basis set and calculate the internal fields via the solution of the Poisson equation. From the resulting TB-wave functions Coulomb- and dipole matrix elements are evaluated and enter the Full Configuration Interaction calculations. The effects of Coulomb correlations on the optical properties of the nitride system are investigated. In particular we study in detail the influence of the QD geometry and the effect of the strong built-in fields on the emission spectra. The dependency of the ground state symmetry as a function of the QD size and the resulting changes in the optical spectra are discussed, which allow to tailor the emission spectra.

HL 50.96 Thu 16:30 P3

Size dependence of quantum confinement effects in HgTe nanocrystals determined by spectroscopic ellipsometry — •Veronika Rinnerbauer[1], Maksym Kovalenko[2], Ventsislav Lavchiev[1], Wolfgang Heiss[2], and Kurt Hingerl[1] — [1]Christian Doppler Labor für oberflächenoptische Methoden, Universität Linz, 4040 Linz, Austria — [2]Institut für Halbleiter- und Festkörperphysik, Universität Linz, 4040 Linz, Austria

We have explored the optical properties of HgTe nanocrystals which were prepared from a colloidal solution. These nanocrystals show strong luminescence in the near infrared (λ=1550 nm), which makes them an interesting material for the telecommunication area. The emission wavelength can efficiently be tuned by controlling the size of the nanocrystals.

We report spectroscopic ellipsometry measurements, which show clearly an energy shift of the critical points in the dielectric function of these HgTe nanocrystals when compared to the HgTe bulk properties. This shift δ of the E1 and E1+ Δ1 transitions to higher energies is caused by the quantization effect due to the small size of the crystals. The exact peak energies of the transitions were fitted with line-shape models for critical points (CP). We observe not only a shift of the oscillator energies, but also the inhomogeneous broadening of the peaks due to the size distribution of the nanocrystals. The size dependence of the energy shift was studied for samples with nanocrystals of different sizes (3-10 nm). It can be seen that the energy of the CPs shifts from near bulk level for the biggest nanocrystals to higher energies with decreasing size.

HL 50.97 Thu 16:30 P3

Lateral Features of Cu(InGa)Se_2-Heterodiodes by Submicron Resolved Simultaneous Luminescence and Light Beam Induced Currents — •Levent Gütay, Tim Jürgens, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, F.R.G.

Polycrystalline Cu(InGa)Se_2-absorbers and hetero-diodes show lateral variations in optoelectronic magnitudes like luminescence yield (pl) and short circuit current density (j_{sc}) in the few micrometer range (3-8 μm) whereas structural features such as grain sizes lie in the 1μm-scale or even below. From the dependence of pl-yield and j_{sc} on temperature of regimes with high and with low signals we estimate activation energies for non-radiative optical transitions and for minority transport and relate these numbers to potential fluctuations for which we got evidence from the dependence of spectrally resolved pl versus exitation level. Variations of the lateral extension of j_{sc}-patterns will be discussed in terms of the influence of a circuitry model of non illuminated diodes in the neighborhood of an illuminated junction.

HL 50.98 Thu 16:30 P3

Computer modelling of gettering under conditions of rapid thermal processing — •Carsten Rudolf[1], Michael Seibt[1], and Vitaly Kveder[2] — [1]IV. Physikalisches Institut der Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Goettingen — [2]Institute of Solid State Physics RAS, Chernogolovka, 142432 Moscow reg., Russia

We modelled phosphorous-diffusion-gettering of iron in monocrystalline p-Si under the conditions of a 2-step rapid thermal processing by using our gettering simulator software tool. The applied thermal treatment consists of a preceding step at 1100°C and a subsequent step at 800°C. The step at higher temperature enables dissolution of precipitates whereas the actual gettering takes place during the step at lower temperature.

Results of two sets of simulations are presented: 1) time at 800°C is varied while the time at 1100°C is kept constant. 2) times at both temperatures are varied in such a way that a constant sheet resistance is yielded.

Gettering after dissolution step of appropriate duration reduces the total amount of metal in the bulk of the wafer significantly compared to gettering without prior dissolution step. For RTP at constant sheet resistance gettering is limited by incomplete dissolution of precipitates for too short times at 1100°C and by incomplete outdiffusion of the mobile Fe species for too short times at 800°C.

HL 50.99 Thu 16:30 P3

Study of bulk defects in $CuIn_{1-x}Ga_xSe_2$ based solar cells — •Verena Mertens[1], Jürgen Parisi[1], Robert Kniese[2], Marc Köntges[3], and Rolf Reineke-Koch[3] — [1]University of Oldenburg , Institute of Physics, Energy and Semiconductor Research Laboratory, 26111 Oldenburg — [2]Center for Solar Energy and Hydrogen Research (ZSW), Heßbrühlstr. 21c, 70565 Stuttgart — [3]Institut für Solarenergieforschung Hameln/Emmerthal (ISFH), Am Ohrberg 1, 31860 Emmerthal

$CuIn_{1-x}Ga_xSe_2$ based solar cells with different molar gallium to gallium plus indium ratio (GGI) are investigated concerning the bulk defects of the absorber material using admittance spectroscopy (AS) and deep level transient spectroscopy (DLTS). The study aims to clarify why in devices with GGI larger than 0.3 the open circuit voltage does not increase linearly with the band gap of the material as it does in those with gallium poor absorber layers. We find that in samples with mixed absorber composition, i.e. those containing both indium and gallium, the same bulk defects are detected. The devices with $CuInSe_2$ and $CuGaSe_2$ absorbers show some additional trap signals. As no principle difference in defect spectra of gallium poor and gallium rich samples is found, we conclude that the bulk defects of the absorber material do not play an important role concerning the "open circuit voltage problem“ of the gallium rich devices.

HL 50.100 Thu 16:30 P3

Lattice parameters of CuAu- and chalcopyrite-phase of epitaxial CuInS2 on silicon substrates — •Janko Cieslak[1], Thomas Hahn[1], Jürgen Kräusslich[2], Heiner Metzner[1], Jens Eberhardt[1], Mario Gossla[1], Udo Reislöhner[1], and Wolfgang Witthuhn[1] — [1]Institut für Festkörperphysik, Friedrich Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena — [2]Institut für Optik und Quantenelektronik, Friedrich Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena

Epitaxial thin films of CuInS2 (CIS) were grown on Si(111) and Si(100) substrates using molecular beam epitaxy from elemental sources. Their lattice parameters were measured by means of x-ray diffraction at the European Synchrotron Radiation Facility in Grenoble in reflection as well as transmission geometry, respectively. The epitaxial films show a coexistence of the CuAu- and the chalcopyrite-phase with different lattice constants and tetragonal distortions. The volume fractions of both phases were determined. The lattice parameters for both substrate orientations are compared with values of single crystals and discrepancies and their implications for CIS thin film growth are discussed.

HL 50.101 Thu 16:30 P3

Hillock formation in epitaxial Cu(In,Ga)S2 thin films — •Thomas Hahn, Janko Cieslak, Jens Eberhardt, Mario Gossla, Heinrich Metzner, Udo Reislöhner, Kristian Schulz, and Wolfgang Witthuhn — Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Max-Wien-Platz 1, 07743 Jena, Germany

Epitaxial thin films of the ternary chalcopyrite semiconductor Cu(In,Ga)S2 are grown epitaxially on Si substrates by molecular beam epitaxy from elemental sources. The samples are analyzed according to their morphological and structural properties utilizing electron diffraction, Rutherford backscattering spectroscopy, and atomic force microscopy. A strong tendency for the formation of hillocks, achieving heights of nearly a magnitude larger as compared to the underlying film thickness, is observed. The influences of deposition parameters and metastabilities during film growth on the occurence of these hillocks are investigated. The possibility of hillock formation being due to internal stresses during film growth is discussed.

HL 50.102 Thu 16:30 P3

2. A comparative photoluminescence study on CuInS2 absorber layers for solar cell applications from a rapid thermal process and from RF reactive sputtering — •Tobias Enzenhofer, Thomas Unold, Klaus Ellmer, and Hans-Werner Schock — Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin

This contribution reports detailed temperature and intensity dependent photoluminescence measurements on CuInS2 thin films deposited by RF reactive sputtering and from a rapid thermal process and relates several commonalities and differences in the defect structure of the films prepared by the two different techniques. First, we compare the various luminescence transitions in absorber layers from reactive sputtering and from a rapid thermal process. Second, we propose a model concerning the role of the deep level luminescence emission which occurs in the high temperature region in both types of absorber layers at about 1.15eV but vanishes for sputtered Cu-rich absorbers at about T<140K. Third, we correlate the properties and quality of photovoltaic devices with the investigation of the deep level in CuInS2 thin films.

HL 50.103 Thu 16:30 P3

SILAR conditioning of TiO_2 / In(OH)_xS_y / PbS(O) structures — •Ilona Oja[1], Sergej Gavrilov[2], Bianca Lim[3], Abdelhak Belaidi[3], Larissa Dloczik[3], Martha Ch. Lux-Steiner[3], and Thomas Dittrich[3] — [1]Tallinn University of Technology, Department of Materials Science, Ehitajate tee 5, Tallinn 19086, Estonia — [2]Moscow Institute of Electron Technology, 124498 Moscow, Russia — [3]Hahn-Meitner-Institute, Glienicker Str. 100, D-14109 Berlin, Germany

In(OH)_xS_y and PbS(O) films and ultra-thin inter-layers were deposited by SILAR (successive ion layer adsorption reaction, this is a wet chemical deposition technique in aqueous solution) and TiO_2 / In(OH)_xS_y / PbS(O) / PEDOT:PSS solar cell structures were prepared to investigate photoelectrical properties of the layers. Investigations were carried out by spectral surface photovoltage in the Kelvin-probe and capacitor arrangements, current-voltage and quantum efficiency analysis. The band gap of In(OH)_xS_y was tuned between 2.6 and 1.9 eV by changing the annealing temperature of In(OH)_xS_y in air between 50 and 350°C. The open circuit voltage of the solar cell structures correlated well with the band gap and the work function of the In(OH)_xS_y. Surprisingly, excess charge carriers generated in the PbS(O) layer do not contribute significantly to the short circuit current. The interface between the In(OH)_xS_y and the PbS(O) layers has been modified by introducing ultra-thin layers which are important for high open circuit potentials.

HL 50.104 Thu 16:30 P3

III-V materials for multi-junction solar cells on the lattice constant of InP — •Ulf Seidel, H.-J. Schimper, U. Bloeck, K. Schwarzburg, F. Willig, and T. Hannappel — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

At present, the world record solar cell is a monolithic triple junction cell epitaxially grown on the lattice constant of GaAs or rather Ge. Considering the thermodynamic limit of the theoretical efficiencies of multi-junction cells with more than two band gaps there is a need of an appropriate material with a band gap in the range of 1eV.
For that, different III-V compound semiconductors were tested for application in multi-junction solar cells based on the lattice constant of InP, in particular InGaAs, GaAsSb (E_{gap} = 0.75eV) and InGaAsP, InAlGaAs (E_{gap} around 1.0eV). Solar cells consisting of these materials were grown via metalorganic vapor phase epitaxy (MOVPE) using the alternative precursors TBAs, TBP and TESb. An InP n/p cell was prepared as a reference and showed that highest internal quantum efficiencies were achieved using these nongaseous less toxic precursors. Single n/p cells with different absorber materials and nearly the same band gaps (0.75eV and 1.0eV) were compared to each other concerning short-circuit cur-

rent, open-circuit voltage, FF, and quantum efficiency. Accordingly, a monolithic tandem solar cell was designed employing these sub cells for its application in a four or five junction cell as the low band gap part. Our tandem cell consists of an InGaAs bottom cell (Egap = 0.75eV) and an around 1eV InGaAsP sub cell. Connecting these two sub cells a new tunnel junction was produced including n-InGaAs and p-GaAsSb.

HL 50.105 Thu 16:30 P3

The Prospects of Development of Photoelectric Convertors by Using Solar Energy in Georgia — •Ia Trapaidze, Rafiel Chikovani, Tengiz Mkheidze, and Gela Goderdzishvili — Georgian Technical University, Dep. of Physics,Tbilisi, Georgia

Georgia together with use of traditional energy resources attaches a very large importance of using renewable energy sources. The location of Georgia, the annual duration of solar radiation in the majority of areas ranges from 250 to 280 days, approximately 1900-2200 hours in a year. The prospects of development of solar photoenergetic devices in Georgia are analyzed. It is noted that the photoelectric method of conversion of the solar energy based on semiconductor materials is especially promising. It would be expedient to realize the production and application of solar photoelectric convertors in Georgia by stages in the scope of a complex research, technical and industrial program for 10-12 years. We have ve studied photoelectric converters on the base silicon, also GaAlAs. After research we observed that convertor obtained on the base of semiconductive compound of GaAlAs is more effective (2-2.5 times), than converter with silicon.

HL 50.106 Thu 16:30 P3

Memory effects in MOS-structures containing nanoclusters — •M. Allardt[1], R. Pietzsch[1], J. Bollmann[1], J. Weber[1], and V. Beyer[2] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]Forschungszentrum Rossendorf, 01314 Dresden, Germany

Memory devices based on embedded silicon nanoclusters are prepared by implantation of Si ions into SiO_2 and subsequent annealing [K. H. Heinig, T. Müller, B. Schmidt, M. Strobel, and W. Möller, Appl. Phys. A 77, 17 (2003)]. The charge retention of the metal-oxide-semiconductor (MOS) structures is investigated by capacitance–voltage (CV) measurements. The devices exhibit almost ideal MOS-CV-behavior indicating a low density of interface states. Positive and negative charges can be stored depending on the applied voltage. The programming voltages generate a memory window which seems to be suitable for future device applications. We compare these results to electrical properties of alternative SONOS-memory devices.

HL 50.107 Thu 16:30 P3

Calculation of the direct tunneling current in a Metal-Oxide-Semiconductor structure with one-side open boundary — •Ebrahim Nadimi — Technische Universität Chemnitz, Fakultät für Elektrotechnik und Informationstechnik, Reichenhainer Straße 70, D-09126 Chemnitz, Deutschland

The leakage current through the oxide of an n-channel Metal-Oxide-Semiconductor (MOS) structure with one-side-open boundary is numerically computed by applying an one-dimensional Schrödinger-Poisson self-consistent solver. By embedding the n-channel MOS in a well, which prevents the penetration of particles into the metallic gate, the potential profile, the bounded energy levels and spatial distributions of electrons in the quantized levels are calculated in the inversion regime. Penetration of electrons into the metallic gate with open boundary results in a broadening of the discrete bound states at the interface of the substrate with the oxide, transforming the bounded energy levels to the quasi- bound states. Starting from the continuity equation, a qualitative formula for the current in terms of the electrons* lifetime in the quasi-bound states is derived. Based on the determination of the energy level width by means of wave functions, we suggest a method to compute the lifetime, and subsequently, the tunnelling current across the potential barrier. The tunnelling current is computed for a MOS structure with Silicon oxide and Silicon nitride gate oxides. The computation results are compared against results obtained experimentally for similar structures, yielding an excellent agreement.

HL 50.108 Thu 16:30 P3

Realization of logic circuits with in-plane gate transistors written using focused-ion-beam implantation — •M. Draghici, D. Reuter, and A. D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

In-plane gate (IPG) transistors realized by writing insulating lines with focused ion beam (FIB) implantation technique [1] are promising devices for logic devices due to the fact that this technique requires no alignment between gate, source and drain. Considering this aspect, the fabrication of IPG transistors is a very reliable single step process. The drawback of this method consists in impossibility to realize complementary device structures on the same sample because only one carrier type is available depending on the heterostructure doping. In order to overcome this problem, we use FIB implantation doping to fabricate n- and p-type channel IPG transistors by implantation of Si and Be, respectively [2].

We present here the realization of logic devices based on IPG transistors realized by insulating lines (negative writing) or overcompensation doping by FIB implantation (positive writing). Different geometries and implantation doses will be studied and analyzed especially for the circuits realized by positive writing.

We gratefully acknowledge financial support from the DFG GRK384.

[1] A. D. Wieck and K. Ploog, Appl. Phys. Lett. 56, 928 (1990).
[2] D. Reuter, A. Seekamp, A. D. Wieck, Physica E 21, 872 (2004).

HL 50.109 Thu 16:30 P3

Optical response of Ag-induced reconstructions on vicinal Si(111) — •Sandhya Chandola[1], J Jacob[1], K Fleischer[1], P Vogt[2], W Richter[2], and J McGilp[1] — [1]Physics Department, University of Dublin, Trinity College, Dublin 2, Ireland — [2]Technische Universität Berlin, Institut für Festkörperphysik, Sekr. PN 6-1, Hardenbergstr. 36, D-10623 Berlin, Germany

The optical response of the Si(111)-3x1-Ag surface has been studied for the first time with reflectance anisotropy spectroscopy (RAS). A single domain surface was obtained by depositing < 1 ML of Ag onto a vicinal Si(111) substrate at 870 K. A significant optical anisotropy develops around 2.2 eV which is related to the formation of the 3x1 structure. This surface was then used as a template to grow one-dimensional (1D) arrays of Ag nanodots, and also 3D Ag islands, by depositing 0.5 ML, and higher, coverages of Ag at room temperature. RAS of these structures showed a different response in the 2.2 eV region, with a broadened and reduced anisotropy. By extending the RA spectra into the infra-red region (0.5-1.5 eV), substantial differences between the structures were observed below 1 eV, which may be linked to a difference in the metallic character of the nanodots and islands.

HL 51 Invited Talk Eroms

Time: Friday 10:15–11:00 Room: HSZ 01

Invited Talk

HL 51.1 Fri 10:15 HSZ 01

Andreev reflection in Nb-InAs structures: Phase-coherence, ballistic transport and edge channels — •Jonathan Eroms[1,2] and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Kavli Institute of Nanoscience, TU Delft, The Netherlands

In this talk we present our experimental work on transport in superconductor-semiconductor structures. Using high-quality contacts, Andreev reflection dominates the transport properties in a range of experimental parameters, including high magnetic fields.

We investigated periodic arrays of Nb filled stripes or antidots in an InAs-based 2DEG. Depending on the geometry and magnetic field, Andreev reflection modifies transport in different ways. At magnetic fields up to a few flux quanta per unit cell, we observe phase-coherent behavior, such as flux-periodic oscillations. At slightly higher fields, the Andreev reflection probability is determined by induced superconductivity in the 2DEG, which is gradually suppressed by an increasing magnetic field. The impact of Andreev reflection on the ballistic motion in antidot lattices is particularly intriguing: the commensurability peaks commonly found in the magnetotransport in those lattices are strongly suppressed. At fields of several Tesla we enter the regime of the quantum Hall effect in the 2DEG, and we find a pronounced increase of the amplitude of $1/B$-periodic magnetoresistance oscillations. The latter can be traced to an enhanced backscattering of Andreev-reflected edge channels, which contain both electrons and holes .

HL 52 Quantum dots and wires: Optical properties IV

Time: Friday 11:00–14:00 Room: POT 151

HL 52.1 Fri 11:00 POT 151

Optical absorption and gain of Quantum Dots - Influence of Coulomb and carrier-phonon correlations — •Michael Lorke, Jan Seebeck, Torben R. Nielsen, Paul Gartner, and Frank Jahnke — Institute for Theoretical Physics, University of Bremen

In recent years, semiconductor quantum dots have been studied extensively due to possible applications in optoelectronic devices like LEDs or lasers. An important ingredient for the modeling of these devices as well as for practical applications is the knowledge of dephasing processes. They determine the homogeneous linewidth of the quantum dot resonances and limit the coherence properties of quantum dot lasers.

We use a microscopic theory to to study the optical absorption and gain properties of semiconductor quantum dot systems. The excitation-induced dephasing and the line-shifts of the quantum dot resonances are determined from a quantum kinetic treatment of correlation processes which includes non-Markovian effects due to Coulomb and carrier-phonon interaction. A special focus of these investigations is the clarification of the importance of various scattering channels due to the Coulomb interaction.

We observe a pronounced damping of the quantum dot resonances accompanied by strong line-shifts with increasing carrier density. Our results are compared to recent photoluminescence spectroscopy measurements of single QDs in which linewidths of several meV at room temperature are found.

HL 52.2 Fri 11:15 POT 151

Co-dependence of electron and nuclear spin systems and ultra-long spin lifetimes in self-assembled QDs — •Ruth Oulton[1], A. Greilich[1], S. Verbin[1,2], R.V Cherbunin[1,2], I.V. Ignatiev[1,2], D.R. Yakovlev[1], M. Bayer[1], I. Merkulov[3], V. Stavarache[4], D. Reuter[4], and A. Wieck[4] — [1]Experimentelle Physik II, Universität Dortmund, 44221 Dortmund, Germany — [2]Institute of Physics, St.Petersburg State University, St.Petersburg, Russia — [3]A.F. Ioffe Physico-Technical Institute, RAS, St.Petersburg, 194021, Russia — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

The hyperfine interaction between electrons and randomly orientated nuclei in QDs is predicted to lead to fast electron spin decoherence over a timescale of nanoseconds. An aligned nuclear and electron spin system, however, is predicted to be ultra-stable, with spin lifetimes much larger than that of either the electron or the nuclei in isolation. We demonstrate an accumulation of PL polarization and subsequent preservation of spin memory in n-doped QDs over a millisecond timescale, indicative of a strong co-dependence of the resident electron and nuclear spins. Application of small (10 -100microT) external fields demonstrate that the weak effective electronic magnetic field on the nuclei is the key to achieving and maintaining the co-aligned system.

HL 52.3 Fri 11:30 POT 151

Direct Observation of Inter-level Phonon Relaxation in Individual Quantum Dot Molecules — •T. Nakaoka[1,2], H. J. Krenner[1], E. C. Clark[1], M. Sabathil[1], M. Bichler[1], Y. Arakawa[2], G. Abstreiter[1], and J. J. Finley[1] — [1]Walter Schottky Institut and Physik Department, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany — [2]RCAST, University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8505, Japan

We present an optical study of relaxation between tunnel coupled excitonic states in individual self-assembled InGaAs/GaAs QD-molecules embedded in Schottky photodiodes. Radiative lifetimes and temperature evolution of the emission intensities of the coupled states are probed close to the point of maximum coupling. The interdot coupling ($2E$) is tuned by detuning (Δ) away from the anticrossing [$E_{direct} - E_{indirect} = (\Delta^2 + (2E)^2)^{1/2}$] using static electric field perturbations. The results obtained clearly demonstrate that the radiative lifetimes of the coupled excitonic states can be tuned from $\tau = 0.3$ ns to 1.3 ns, as the fraction of direct character of the exciton wavefunction is varied. Furthermore, close to the anticrossing ($\Delta \sim 0$) where the electron component of the wavefunction hybridizes into symmetric and antisymmetric orbitals, the lifetimes of both transitions tend to the same value confirming the fully mixed nature of the states. Temperature dependent measurements demonstrate that relaxation from the antibonding to bonding state can occur during the radiative lifetime. Analysis of the temperature dependent data indicates that such inter-level relaxation proceeds over timescales faster than ~ 100 ps for $2E = 3.1$ meV mediated by acoustic phonon scattering.

HL 52.4 Fri 11:45 POT 151

Optical control of spin coherence in singly charged (In,Ga)As/GaAs quantum dots — •Alex Greilich[1], R. Oulton[1], E.A. Zhukov[1], I.A. Yugova[1], D.R. Yakovlev[1,2], M. Bayer[1], A. Shabaev[3], Al.L. Efros[3], I.A. Merkulov[2], V. Stavarache[4], D. Reuter[4], and A. Wieck[4] — [1]Experimentelle Physik II, Universität Dortmund, D-44221, Germany — [2]A.F. Ioffe Physico-Technical Institute, RAS, St. Petersburg, 194021, Russia — [3]Naval Research Laboratory, Washington, DC 20375, USA — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Electron spin coherence has been studied in n-type modulation doped (In,Ga)As/GaAs quantum dots (QDs) which contain on average a single electron per dot. The coherence arises from resonant excitation of the QDs by circularly polarized picosecond laser pulses, creating a coherent superposition of an electron and a trion state. Time dependent Faraday rotation is used to probe the spin precession of the optically oriented electrons about a transverse magnetic field. Spin coherence generation can be controlled by the pulse intensity, being most efficient for $(2n+1)\pi$ pulses.

HL 52.5 Fri 12:00 POT 151

Tailored quantum dots for entangled photon pair creation — •Thorsten Berstermann[1], Alex Greilich[1], Matthias Schwaab[1], Thomas Auer[1], Ruth Oulton[1], Dimitri Yakovlev[1], Manfred Bayer[1], Victorina Stavarache[2], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimentelle Physik 2, Universität Dortmund, D-44221 Dortmund, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Entangled photon pairs from quantum dots (QD) are the key requirement for quantum-cryptography and quantum teleportation [1]. Lowering the symmetry of a QD leads to an asymmetry-induced exchange splitting δ between the two bright exciton energy levels. In order to obtain polarization entangled photon pairs from the biexciton radiative decay cascade, this splitting should be smaller than the homogeneous linewidth γ of each level. In this talk we compare the asymmetry-induced exchange splitting δ of the bright-exciton ground-state doublet in self-assembled (In,Ga)As/GaAs quantum dots, determined by Faraday rotation with its homogeneous linewidth γ, obtained from the radiative decay in time-resolved photoluminescence and differential transmission. Post-growth thermal annealing of the dot structures leads to a considerable increase of the homogeneous linewidth, while a strong reduction of the exchange splitting is simultaneously observed. The annealing can be tailored such that the asymmetry-induced exchange splitting becomes even smaller than the homogeneous linewidth.

[1]D.Bouwmeester, A.Ekert, A.Zeilinger, The Physics of Quantum Information, Springer, Berlin(2000)

HL 52.6 Fri 12:15 POT 151

Systematic size-dependence of anisotropic exchange interaction in InAs/GaAs quantum dots — •Robert Seguin, Sven Rodt, Andrei Schliwa, Konstantin Pötschke, Udo W. Pohl, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A comprehensive study of the exchange interaction of charge carriers in self-organized InAs/GaAs quantum dots (QDs) is presented. Single QDs are examined by means of cathodoluminescence applying metallic shadow masks. The spectra reveal a systematic dependence of the anisotropic exchange interaction on QD size.

The exchange interaction in nanostructures has been subject of a lively debate in recent years. Its anisotropic part governs the excitonic fine-structure splitting (fss), the key parameter determining the suitability of QDs for quantum cryptography, and the degree of polarization of excited charged excitons (trions) in QDs. While the number of participating particles varies between two (excitons) and three (trions), the underlying physical effect is the same. We show that the magnitude of the excitonic fss and the degree of polarization of excited trions are indeed correlated.

They both increase with decreasing exciton recombination energy and thus increasing with quantum dot size.

HL 52.7 Fri 12:30 POT 151

Demonstration of intrinsic non-exponential quantum dot emission dynamics due to reduced electron-hole correlation — •Thomas Auer[1], Matthias Schwab[1], Manfred Bayer[1], Thorsten Berstermann[1], Jan Wiersig[2], Norman Baer[2], Christopher Gies[2], Frank Jahnke[2], Viktorina Stavarache[3], Dirk Reuter[3], and Andreas Wieck[3] — [1]Experimentelle Physik II, Universität Dortmund, 44221 Dortmund — [2]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum

The emission dynamics of self-assembled quantum dots has been studied using time-resolved photoluminescence (TRPL) spectroscopy. Quantum dot emission dynamics are normally described using the picture of quantum dots as two-level systems, where electron-hole-pairs are fully correlated, resulting in a predicted exponential decrease of the emission. Non-exponential decay of the TRPL has been reported in the literature, but is normally attributed to various factors, such as dark excitons or ensemble variations. However our calculations show that reduction of e-h pair correlation leads to intrinsically non-exponential dynamics. In agreement with these calculations, our measurements of the radiative exciton decay clearly show a non-exponential behaviour with non-resonant excitation. A study of the temperature dependence of the decay and comparison with measurements on n-doped quantum dots reveal the intrinsic nature of the non-exponentiality. By exciting resonantly, a fully correlated two-level system may be prepared which displays an exponential decay as expected.

HL 52.8 Fri 12:45 POT 151

Quantum light emission of two lateral tunnel-coupled InGaAs/GaAs quantum dots controlled by a tunable static electric field — •Claus Hermannstädter[1], Gareth J. Beirne[1], Lijuan Wang[2], Armando Rastelli[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max-Planck Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

We present the observation of lateral quantum coupling between two self-assembled InGaAs/GaAs quantum dots (QDs). Each single lateral quantum dot molecule (QDM) exhibits a distinctive photoluminescence spectrum consisting of neutral and charged excitonic, as well as biexcitonic emission. Photon statistics measurements between the dominant emission lines display strong antibunching, confirming the presence of quantum coupling within the QDM, and cascaded emission between corresponding biexcitonic and excitonic emission. We also show that the coupling can be controlled using a static electric field, and that the relative intensities of the two neutral excitonic transitions can be reversibly switched between the two emission energies. Subsequently, the QDM can be used as a tunable single-photon emitter simply by applying a small electric field.

HL 52.9 Fri 13:00 POT 151

Optically Probing Hole Spin Dynamics in InGaAs Quantum Dots — •Stefan Schaeck, Dominik Heiss, Miro Kroutvar, Max Bichler, Dieter Schuh, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

Recently, we presented an optically driven spin memory device that enables selective generation, storage and readout of single electron spins in InGaAs self assembled quantum dots (QDs). This device operates via optical charging of a sub ensemble of dots via polarized optical excitation and selective exciton ionisation using an internal electric field. Using such techniques we studied the electron spin lifetime (T_1) as a function of Zeeman energy and lattice temperature and deduced the dominant relaxation mechanisms for self assembled QDs.
Lately, we have extended our investigations to a modified device design that enables investigation of the dynamics of optically generated *holes*. In strong contrast to electron storage experiments, hole storage samples reveal no optical polarization memory effect for storage times of $0.5\mu s$ and magnetic fields up to $\sim 12T$. These findings contrast strongly with our findings for electrons, indicating that the hole spin decays over much faster timescales. The hole (T_1) time in QDs has been controversially discussed in the literature; some theories indicating that it can be comparable to electrons whilst others predict orders of magnitude faster relaxation. Our results provide, much needed, experimental data for comparison with theory.

HL 52.10 Fri 13:15 POT 151

Wavelength- and spin-selective addressing of self-organized InAs/GaAs quantum dots by means of spectral hole burning — •Till Warming[1], Witlef Wieczorek[1], Martin Geller[1], Victor Ustinov[2], Alexey Zhukov[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin — [2]A.F. Ioffe Physico-Technical Institute RAS, St. Petersburg, Russia

Semiconductor quantum dots (QDs) with their possibility to confine one single carrier only, representing one quantum bit of information, are potential candidates for future memory devices. Here, spectral hole burning is used for wavelength-selective addressing of a subensemble of QDs from the large inhomogeneously broadened QD ensemble. Resonant laser excitation and controlled tunneling leads to QDs charged with single carriers. Such charging manifest itself in photocurrent spectra as increased absorption due to the formation of negatively charged trions. Spin-selective addressing by polarized excitation is demonstrated at low temperatures and sufficiently high magnetic fields when pure spin states prevail. The formation of trion depends on the polarization of the primary and secondary pump wi9th respect to each other, in order to take account of Pauli blocking. Spin-selective readout of the carriers is realized. Parts of this work are funded by the European SANDiE NoE, contr. no. NMP4-CT-2004-500101 and SFB296 of DFG.

HL 52.11 Fri 13:30 POT 151

Lasing effects in high quality AlAs/GaAs micropillar cavities — •Carolin Hofmann[1], Stephan Reitzenstein[1], Steffen Münch[1], Anatolly Bazhenov[1,2], Alexander Gorbunov[1,2], Andreas Löffler[1], Johann Peter Reithmaier[1,3], Martin Kamp[1], Leonid Keldysh[1,4], Vladimir Kulakovskii[1,2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Germany — [2]Institute for Solid State Physics, Russian Academy of Science, Chernogolovka, Russia — [3]Physik, Universität Kassel, Germany — [4]Lebedev Physical Institute, Russian Academy of Science, Moscow, Russia

We report on studies performed on optically pumped high quality micropillar laser-structures. The pillars are based on planar microcavity structures grown by molecular beam epitaxy. The planar structures consist of a GaAs λ-cavity sandwiched between DBR with up to 27 quarter-wavelength layer pairs of AlAs and GaAs. In the center of the cavity a low density layer of InGaAs quantum dots is embedded. Micropillars with diameters as low as a few hundred nanometers were patterned. By microphotoluminecence measurements at low temperatures we have studied the transition from spontaneous emission to laser operation for pillars of different diameter and quality factors of up to 35000. Lasing was observed for pillars which contain less than 100 quantum dots. Laser operation is identified by a nonlinear increase of the output intensity versus excitation power. We will discuss the influence of the pillar diameter and the quality factor on the lasing characteristics of the micropillar laser-structures and give an estimation of the influence of single quantum dots on the lasing behaviour.

HL 52.12 Fri 13:45 POT 151

Lifetime of localized excitons in InGaN quantum dots — •M. Dworzak, M. Winkelnkemper, A. Hoffmann, and D. Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

At low temperature indium-rich fluctuation islands in a 2 nm thick InGaN layer form a quantum dot (QD) ensemble of ultra-high density. Regarding the recombination dynamic of localized excitons these QDs differ extremely from other QD systems. Spatially resolved investigations on single InGaN QDs by means of time-resolved photoluminescence (TRPL) showed a broad distribution of the exciton lifetimes, even for QDs with similar transition energy. [1]

On one hand this behavior is causes by different electron/hole wavefunction overlaps due to the disordered distribution of QD size, shape and indium content inside the QD ensemble. This is modeled by 8-band kp theory. On the other hand TRPL studies showed redistribution of carriers between the QDs. Thus, also different transfer probabilities inside the QD ensemble lead to different time constants.

[1] Bartel et al., Appl. Phys. Lett. 85, 1946 (2004)

HL 53 Hybrid systems

Time: Friday 11:00–11:15 Room: BEY 154

HL 53.1 Fri 11:00 BEY 154

Electrical tuning of resonant energy transfer from semiconductor nanoantennae to single molecules — •Klaus Becker[1], John M. Lupton[1], Josef Müller[1], Andrey L. Rogach[1], Dmitri V. Talapin[2], Horst Weller[2], and Jochen Feldmann[1] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität, Munich, Germany — [2]Institute of Physical Chemistry, University of Hamburg, Hamburg, Germany

Advances in technology often occur by bringing together different branches of materials science to form novel heterostructures or hybrid compounds. The combination of semiconductor nanoparticles and organic dye molecules constitutes a particularly powerful route to creating novel functional properties. The large absorption cross section of the nanocrystals provides an efficient route to concentrating excitation energy and funneling it to single dye molecules with much weaker absorption cross sections. By introducing a small number of nanoparticles into a film of dye acceptors, we show the feasibility of addressing single emitters in a large ensemble by resonant energy transfer, thus demonstrating the extremely high sensitivity of this approach. Such hybrid exciton coupling is complicated by the requirement of substantial spectral overlap between donor and acceptor. We employ the exceptional quantum confined Stark effect of rod-like heterostructure nanocrystals [1,2] to drive the particle in and out of resonance with a single absorbing molecule. This electrical control of energy transfer illustrates a novel single molecule switch.

[1] J. Mueller et al., Nano Letters 5, 2044 (2005). [2] J. Mueller et al., Phys. Rev. Lett. 93, 167402 (2004).

HL 54 Metal-insulator transitions

Time: Friday 11:15–11:30 Room: BEY 154

HL 54.1 Fri 11:15 BEY 154

Scanning tunneling spectroscopy of magnetic-field -induced localization in InSb — •Katsushi Hashimoto[1], Focko Meier[1], Jens Wiebe[1], Markus Morgenstern[2], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, D-20355 Hamburg — [2]Institute of Physics, RWTH Aachen University, D-52056 Aachen

Using scanning tunneling spectroscopy (STS), we study the microscopic nature of localization in three dimensional metallic n-InSb with a low carrier concentration of 1.4 $\times 10^{14} cm^{-3}$. First, we confirmed by transport measurements that extreme quantum limit (EQL) and a metal-insulator (MI) transitions caused by magnetic-field-induced localization occur at $B_{EQL} \approx 150$ mT and $B_{MI} \approx 280$ mT. The microscopic measurements using STS are performed on cleaved InSb (110) in ultra high vacuum at 0.3 K. When the B-field is set to 0 mT, dI/dV maps at a sample bias voltage (V_s) of 0 mV show two-lobe-like maxima in the local density of state (LDOS), which are merged at a negative V_s. The observed LDOS features are interpreted as quantized states confined by the potential valley, such as p-like and s-like states. They, however, abruptly vanish at B_{EQL}. This can be correlated to enhanced electron-electron interactions with respect to the potential disorder. Furthermore, we find that the confined states are recovered above B_{EQL} and diminish as the B-field approaches B_{MI}, suggesting that localization due to enhanced electron-donor interactions modifies the confined states.

HL 55 Photonic crystals

Time: Friday 11:30–13:15 Room: BEY 154

HL 55.1 Fri 11:30 BEY 154

Probing Photonic Crystals with Single CdSe/ZnS Quantum Dots — •Frank Cichos[1], Michael Barth[2], Roman Schuster[3], and Achim Gruber[1] — [1]Photonics and Optical Materials, Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz — [2]Nano-Optics Group, Institute of Physics, Humoldt University Berlin, Hausvogteiplatz 5-7, 10117 Berlin — [3]Leibniz Institute for Solid State and Materials Research Dresden, PF 27 01 16, 01171 Dresden

Within this presentation we demonstrate for the first time the application of single quantum dots to measure local optical properties of a 3D photonic crystal (PC). We have doped artificial polystyrene opals with a low concentration of core-shell CdSe/ZnS quantum dots, which emit in the region of the photonic stop band. With the help of fluorescence microscopy we demonstrate, that individual quantum dots can be imaged with high quality even though they are more than 30 lattice planes inside the PCs. Based on a comparison of defocused fluorescence images with numerical calculations, we show that the angular radiation characteristics of single quantum dots is modified by the photonic stop band. The variation of the photonic stop band position with the orientation of the crystal prevents light emission from the quantum dot in certain directions. This is to our knowledge the first measurement of photonic stop band effects based on a single emitter inside a PC and opens up a new class of experiments studying the local optical properties of 3D PCs. The results of this study can be advantageously used to manipulate the angular radiation characteristics of single photon sources.

HL 55.2 Fri 11:45 BEY 154

Dynamics of Optical Wavepackets in Coupled Microcavities — •Markas Sudzius, Vadim G. Lyssenko, Robert Gehlhaar, Marco Swoboda, Michael Hoffmann, and Karl Leo — Institut für Angewandte Photophysik, TU Dresden, D-01062 Dresden, Germany

We investigate the oscillating amplitudes and phases of a 150 fs laser pulse, transmitted through coupled microcavities, using time- and spectrally-resolved cross-correlation techniques. Careful monitoring of the upconverted signal allows the determination of frequencies, amplitudes, damping rates, and relative phases of spectral components of the wavepacket. The experimental observations can be explained by a Fourier-transform-based analytical model, leading to a better understanding of the origin of the temporal and spatial terahertz oscillations (optical Bloch oscillations) and allowing to reconstruct their evolution in coupled microcavities. In particular, we investigate how the real time evolution of the upconverted signal depends on the interplay between central laser wavelength, laser halfwidth and cavity mode splitting. These parameters are of crucial importance for both qualitative and quantitative behavior of the signal.

HL 55.3 Fri 12:00 BEY 154

Cavity-polariton interaction mediated by coherent acoustic phonons — •Mauricio de Lima[1], Rudolf Hey[1], Paulo Santos[1], Mike van der Poel[2], and Jørn Hvam[2] — [1]Paul-Drude-Institut für Festkörperelektronik — [2]Research center COM, Technical University of Denamark

The strong coupling between excitons in a quantum well (QW) and photons inserted in a semiconductor microcavity leads to the formation of quasi-particles known as cavity-polaritons. In this contribution, we investigate the interaction of the polaritons with coherent acoustic phonons in the form of surface acoustic waves (SAWs). The studies were performed in a GaAs QW embedded in a (Al,Ga)As/AlAs microcavity. The periodic modulation introduced by the phonons folds the cavity-polariton dispersion within a mini-Brillouin zone (MBZ) defined by the phonon wave vector (k_{SAW}). The appearance of well-defined mini-gaps at the edge of the MBZ as well as folded modes in the center of the MBZ are observed for different phonon densities and different cavity polariton detuning energies. The experimental results are in good agreement with calculations that take into account the modulation of the the band-gap and of the optical thickness of the microcavity spacer layer by the SAW strain field.

HL 55.4 Fri 12:15 BEY 154

Polarization splitting and terahertz oscillations from a single planar Fabry-Perot microcavity — •R. Gehlhaar[1], M. Swoboda[1], M. Sudzius[1], H. Wendrock[2], M. Hoffmann[1], H. Fröb[1], V. G. Lyssenko[1], and K. Leo[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany, www.iapp.de — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, PF 27 01 16, 01171 Dresden, Germany

We report the experimental observation of polarization splitting and terahertz oscillations of transmitted coherent light from a single planar optical microcavity consisting of two SiO_2/TiO_2-dielectric mirrors. The samples are prepared by reactive electron-beam deposition. Optical anisotropy leads to two perpendicularly polarized transmission modes at ~ 800 nm with a splitting of 2.5 nm. We ascribe the anisotropy to oblique columnar structures in the dielectrics, resulting from off-axial growth of the microcavity structure. Therefore the beating frequency is widely tunable in the GHz and THz range by variations in the fabrication process. We apply an up-conversion setup for temporally and spectrally resolved measurements and obtain a corresponding beating of 0.8 ps period or 1.25 THz oscillation frequency. Time resolved measurements yield a cavity photon lifetime of 0.65 ps, corresponding to a Q-value of 1600. To explain our observations, we introduce a Fourier-transform-based analytical model.

HL 55.5 Fri 12:30 BEY 154

Coexistence of Left- and Righthanded Propagation in Photonic Crystals — •Ronald Meisels[1], Rados Gajic[1,2], Friedemar Kuchar[1], Javad Zarbakhsh[3], and Kurt Hingerl[3] — [1]Institute of Physics, University of Leoben, Austria — [2]Institute of Physics, University of Belgrade, Serbia and Montenegro — [3]CDL of Surface Optics, Johannes Kepler University, Linz, Austria

Photonic Crystals (PhC) are structures with a periodic spatial modulation of, e.g., the dielectric constant causing a photonic band structure. These PhC show peculiar phenomena, e.g. negative refraction (NR). For NR the directions of incident and refracted beams (parallel to $\mathbf{v}_g = \partial\omega/\partial k$), when projected on the interface, are opposite. NR and positive refraction (PR) can be both accomponied by righthanded (RH) or lefthanded (LH) behavior of the wave in the PhC. In this work, the PhC consists of a square lattice of alumina rods. For this structure we present results of band structure calculations demonstrating the coexistence of a) NR and RH (1st band), b) NR and LH (2nd band), c) two waves with the same frequency and same angle of incidence showing NR with LH and RH, respectively (2nd band). These results are compared with FDTD simulations. An analysis using only field values at lattice points eliminates the periodic parts of the Bloch waves and shows only the envelopes. This allows to separate two coexisting waves as in case c).

Supported by MNA Networking Project.

HL 55.6 Fri 12:45 BEY 154

Negative Refraction in Ferromagnet/Superconductor Superlattices — •A. Pimenov[1], P. P. Przyslupski[2], B. Dabrowski[3], and A. Loidl[1] — [1]Experimentalphysik V, Center for Electronic Correlations and Magnetism, Universität Augsburg, 86135 Augsburg, Germany — [2]Institute of Physics, Polish Academy of Sciences, 02-668 Warszawa, Poland — [3]Department of Physics, Northern Illinois University, 60115 DeKalb, Illinois, USA

Negative refraction, which reverses many fundamental aspects of classical optics, can be obtained in systems with negative magnetic permeability and negative dielectric permittivity. During the last five years this negative refraction has been experimentally verified in a number of metamaterials and photonic crystals. In this work we demonstrate an experimental realization of negative refraction at terahertz frequencies and finite magnetic fields utilizing a multilayer stack of ferromagnetic and superconducting thin films [1]. In the present case the superconducting $YBa_2Cu_3O_7$ layers provide negative permittivity while negative permeability is achieved via ferromagnetic (La:Sr)MnO_3 layers for frequencies and magnetic fields close to the ferromagnetic resonance. In these superlattices the refractive index can be switched between positive and negative regions using external magnetic field as tuning parameter.

[1] A. Pimenov, P. P. Przyslupski, B. Dabrowski, and A. Loidl, Phys. Rev. Lett., in print

HL 55.7 Fri 13:00 BEY 154

Realization of Electrically Active Photonic Crystal Nanocavities — •Simon Grimminger, Felix Hofbauer, Michael Kaniber, Susanne Dachs, Hubert J. Krenner, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institute, TU München, 85748 Garching, Germany

We present investigations of electrically tunable InGaAs self-assembled quantum dots (QDs) embedded in 2D photonic crystal (PC) defect nanocavities. The samples consist of (Al)GaAs p-i-n diodes with a single layer of dots in the intrinsic region. Low mode volume ($V < (\lambda/n)^3$), high-Q ($\sim$2000) nanocavities are formed by etching a hexagonal lattice of air holes through the p-i-n junction and introducing defects to produce reduced symmetry H1-cavities. A 180nm thick freestanding membrane containing the p-i-n diode is then realized by selective wet etching and electrical contacts to the p and n-doped regions enable us to apply static electric field perturbations to QDs in the cavity.

Such active PC nanocavities were studied using spatially resolved luminescence and photocurrent absorption spectroscopy. The experiments show that the electric field is uniform over the $200 \times 200\mu m$ diode structure. Furthermore, quenching of the PL is observed for fields >50kV/cm due to carrier tunneling escape from the dots that occurs faster than the radiative lifetime. By measuring the PL quenching as a function of position on the PC and nanocavity we electrically probe the local density of photonic states. Furthermore, the devices have the potential to study cavity-single QD coupling in an electrically tunable system.

HL 56 Quantum dots and wires: Preparation and characterization III

Time: Friday 11:00–13:15 Room: POT 51

HL 56.1 Fri 11:00 POT 51

Understanding Growth of InAs/GaAs Quantum Dot Nanostructures in Atomic Detail — •Thomas Hammerschmidt, Peter Kratzer, and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

The experimental and theoretical investigations of the last decade lead to a good understanding of many aspects of quantum dot (QD) growth. One of the remaining challenges is the discrimination of kinetic and thermodynamic effects. We focus on the question which aspects of QD growth can be understood within thermodynamic reasoning. In particular, we identify the driving force for the experimental findings of a sequence of shapes with increasing QD size, and of growth correlations in QD stacks. Recently, we developed an interatomic potential of the Abell-Tersoff type that accounts for the energetic balance of strain relief and QD side-facet formation during QD growth, and enables us to systematically study the energetics and atomic structure of realistic QD nanostructures. Based on recent atomically resolved STM images we set up InAs QD nanostructures in atomic detail, apply our potential to relax them, and compare the resulting total energies. We find that the experimentally observed critical coverage for the 2D to 3D growth transition and the shape sequence of 'hut'-like QD's dominated by {317} facets and 'dome'-like QD's dominated by {101} can be attributed to three distinct stability regimes. Furthermore, we can explain the vertical growth correlations in QD stacks by quantitatively calculating the size of the critical nucleus in different lateral positions.

HL 56.2 Fri 11:15 POT 51

Strain-enhanced charge carrier confinement in nanostructures fabricated by cleaved edge overgrowth — •Jörg Ehehalt[1], Robert Schuster[1], Christian Gerl[1], Harald Hajak[1], Elisabeth Reinwald[1], Matthias Reinwald[1], Dieter Schuh[1], Werner Wegscheider[1], Max Bichler[2], and Gerhard Abstreiter[2] — [1]Universität Regensburg — [2]Walter-Schottky-Institut TU München

The Cleaved Edge Overgrowth technique was used to fabricate quantum wires and quantum dot systems with precisely controlled sizes and positions. Conventionally two intersecting GaAs quantum wells lead to the formation of a quantum wire at the T-shaped junction with confinement energies of up to 54 meV.

However, a larger confinement is needed in order to examine excited states and observe quantum effects at higher temperatures. This can

be achieved by introducing tensile strain between materials with different lattice constants. Micro-photoluminescence spectroscopy of purely strain-induced quantum wires shows confinement energies of up to 52 meV. By combining conventional T-shaped wires with strain-induced confinement, much larger confinement energies are possible. Simulations predict confinement energies of up to 108 meV.

These results are now to be applied to fabricate quantum wire lasers working at higher temperatures and lower threshold currents as well as quantum dot system, which will be used to study generation, detection and lifetimes of spin-polarized charges.

HL 56.3 Fri 11:30 POT 51

Atomic structure of GaSb/GaAs quantum rings and dots studied by cross-sectional scanning tunneling microscopy — •Rainer Timm[1], Andrea Lenz[1], Lena Ivanova[1], Holger Eisele[1], Ganesh Balakrishnan[2], Diana Huffaker[1,2], and Mario Dähne[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, D-10623 Berlin — [2]Center for High Technology Materials, University of New Mexico, Albuquerque, New Mexico 87106, USA

GaSb quantum dots in a GaAs matrix show a staggered type-II band alignment and are promising nanostructures for storage devices due to their large hole confinement energy [1]. Cross-sectional scanning tunneling microscopy is a powerful tool to obtain both structural and electronic information on such buried quantum dots with atomic resolution [2].

Here we present data on self-assembled GaSb/GaAs nanostructures, grown by molecular beam epitaxy. Independent of the amount of deposited GaSb ranging from 1 to 3 monolayers, we found distinctive quantum dots with truncated pyramid-like shapes with base lengths between 10 and 30 nm and 2 to 6 nm height as well as quantum rings, which have evolved from the dots by segregation of antimony out of the dot center. While the rings consist of nearly pure GaSb, strongly intermixed stoichiometries were obtained for the dots. Additionally, a shape unisotropy between the [110] and the $[\bar{1}10]$ direction was observed for all structures.

This work was supported by the EU in the SANDiE Network of Excellence and by projects Da 408/8, and SFB 296 of the DFG.

[1] M. Geller et al., Appl. Phys. Lett. **82**, 2706 (2003)
[2] R. Timm et al., Appl. Phys. Lett. **85**, 5890 (2004)

HL 56.4 Fri 11:45 POT 51

Stacking of InGaAs/GaAs-based quantum dots for long-wavelength laser diodes — •Tim David Germann, André Strittmatter, Thorsten Kettler, Kristijan Posilovic, and Dieter Bimberg — Institute of Solid State Physics, Sekr. PN 5-2, Hardenbergstr. 36, Technical University of Berlin, D-10623 Berlin, Germany

Currently, only a few reports exist on quantum dot (QD) based laser diodes with emission wavelengths beyond 1240 nm grown by MOCVD on GaAs(100) substrates. Stacking of several QD planes is generally proposed in order to increase the gain at the target wavelength. However, the stacking of QD planes for long-wavelength emission around 1300 nm is not much investigated with respect to the chosen material combination. For example, an $In_{0.65}Ga_{0.35}As$ QD layer overgrown by an $In_{0.15}Ga_{0.85}As$ layer shows photoluminescence emission around 1310 nm with comparable intensity to a similar QD layer overgrown by an $In_{0.08}Ga_{0.92}As$ layer which peaks at 1250 nm. In contrast, upon stacking of the $In_{0.65}Ga_{0.35}As/In_{0.15}Ga_{0.85}As$ combination the photoluminescence intensity starts to deteriorate already when the third QD plane is deposited, while the latter combination could be stacked up to the fifth QD plane without degradation. Furthermore, using an $In_{0.65}Ga_{0.35}As$-QD/$In_{0.13}Ga_{0.85}As$-QW combination for 1290 nm emission only a triple stack could be grown without degradation. Presently, we realized QD laser diodes at a wavelength of 1246 nm with ultra-low threshold current densities of 66 A cm^{-2}, transparency current densities as low as 10 A cm^{-2} per QD plane, and high internal quantum efficiencies of 94 %.

HL 56.5 Fri 12:00 POT 51

Growth and characterization of self-assembled CdSe quantum dots in MgS barriers — •Arne Gust, Carsten Kruse, Henning Lohmeyer, Kathrin Sebald, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee, 28359 Bremen, Germany

Up to now it's only possible to achieve single quantum dot emission from CdSe QDs at low temperatures, which is bleached out for temperatures above 200 K due to the thermal emission of carriers [1]. By embedding the QDs in wide band gap materials such as MgS (5.5 eV) the stronger confinement should stabilize the emission up to room temperature (RT). Samples with additional 5 nm thick MgS barriers surrounding the QD region and a reference sample without barriers have been prepared.

Photoluminescence (PL) measurements were performed at RT in order to be close to the application. The PL spectrum of the reference sample shows a peak with a full-width at half-maximum around 110 meV at RT (emission at 2.38 eV). The emission of the sample including the MgS barriers is shifted by 240 meV to higher energies (2.62 eV) due to the increased confinement. Furthermore the activation energy raised by a factor of 2.5 compared to sample without MgS barriers. Micro-PL measurements on single QDs in dependence on the temperature will be presented in order to quantify the activation energy for different kinds of QD samples.

[1] K. Sebald *et al.*, Appl. Phys. Lett. **81**, 2920 (2002).

HL 56.6 Fri 12:15 POT 51

Influence of Indium-free sublayers on the formation of self-assembled quantum dots on InP (001) substrates — •Roland Enzmann, Susanne Dachs, Ralf Meyer, and Markus-Christian Amann — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching

The deposition of InAs quantum dots on a lattice-matched AlGaInAs matrix material on (001) InP substrate leads to a prolate configuration known as "quantum dashes"oriented along the [1-10] direction. This effect is possibly caused by the indium atoms located in the uppermost layer of the matrix material of which the quantum dots are deposited. This layer is in the following called sublayer. To avoid this direction-dependent growth we investigate the influence of indium-free sublayers to grow self-assembled quantum dots on InP (001) substrates. To this end, we first prepared InAs quantum dots on a GaAs sublayer with 0,55nm thickness. In this way a reduction of the asymmetry has already been obtained. Since indium is known to segregate, thicker indium free sublayers might be instrumental to avoid "quantum dashes". Because of the heavy strain, a GaAs sublayer has to be very thin. Thicker sublayers can be achieved by the substitution of GaAs by GaAsSb, which principally can be grown lattice matched to InP. Accordingly, a further reduction of the asymmetry can be expected for InAs-GaAsSb-AlGaInAs quantum dots.

HL 56.7 Fri 12:30 POT 51

Self-organization of InAs-quantum dots: kinetics, strain, and intermixing — •Christian Heyn — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

The basic mechanisms of the self-assembly process which leads to the formation of InAs quantum dots will be addressed. Our goal is to develop a simple model of strain-induced quantum dot formation, that allows to directly determine correlations between structural features of the quantum dots and the growth parameters applied. In doing so, the major task is to identify and model the key processes controlling quantum dot formation such as the kinetics of rearrangement of material by surface diffusion, intermixing of the deposit with substrate material, and the influence of the strain energy. This presentation discusses results calculated with a rate equations based growth model and the related experimental behavior.

HL 56.8 Fri 12:45 POT 51

Growth-related structure of InAsN/GaAs quantum dots studied by cross-sectional scanning tunneling microscopy and spectroscopy — •L. Ivanova[1], H. Eisele[1], R. Timm[1], A. Lenz[1], M. Dähne[1], O. Schumann[2], L. Geelhaar[2], and H. Riechert[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Infineon Technologies, Corporate Research Photonics, 81730 München, Germany

We investigated the influence of nitrogen on the growth of quantum dots (QD) in the $GaInN_{0.012}As_{0.988}$ system using cross-sectional scanning tunneling microscopy (XSTM). The incorporation of nitrogen into the InAs/GaAs QD leads to a dissolution of the dots and the formation of cluster-like structures of InAs intermixed with N at the anionic sublattice as well as Ga at the cationic sublattice. This observation is in very good agreement with photoluminescence spectra, showing a strong decrease of the dot signal with increasing nitrogen content within the InAs layer. The nitrogen-induced dissolution of the InAs QD occurs due to the highly localized perturbation caused by N atoms.

These InAs/GaAsN heterostructures we studied further by cross-sectional scanning tunneling spectroscopy, monitoring the local density

of states. The nitrogen definitely changes the band structure of the matrix material with a reduction of the fundamental band gap by about 0.2 eV and the appearance of an additional state at 0.4 eV above the conduction band minimum, as compared to pure GaAs.

This work was supported by the EU in the SANDiE Network of Excelence and by SFB 296 of the DPG, and Da 408/8.

HL 56.9 Fri 13:00 POT 51

Atomic structure of unstrained GaAs/AlGaAs quantum dots — •Andrea Lenz[1], Rainer Timm[1], Lena Ivanova[1], Dominik Martin[1], Vivien Vossebürger[1], Holger Eisele[1], Armando Rastelli[2], Oliver Schmidt[2], and Mario Dähne[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

GaAs/AlGaAs quantum dots (QD), formed by a combination of self-assembled growth and atomic-layer etching technique, are a novel and promising structure [1]: The material is ideally unstrained and can be designed to emit light in the optical spectral range. For improving the epitaxial growth a detailed knowledge of the interfaces and the quantum dot structure after overgrowth is essential.

Cross-sectional scanning tunneling microscopy (XSTM) is a powerful method to investigate the shape and size of buried semiconductor nanostructures with atomically resolution. We present XSTM images of the GaAs/AlGaAs interface and of the inverted quantum dot structures, indicating that the unstrained QDs have a truncated cone shape and a relatively large base length of about 35 nm. Thereby the growth model [1] can be confirmed.

This work was supported by the EU in the SANDiE Network of Excellence and by SFB 296 of the DFG.

[1] A. Rastelli, S. Stufler, A. Schliwa, R. Songmuang, C. Manzano, G. Costantini, K. Kern, A. Zrenner, D. Bimberg, and O. G. Schmidt, Phys. Rev. Lett. **92**, 166104 (2004)

HL 57 Theory of electronic structure

Time: Friday 11:00–12:45 Room: BEY 118

HL 57.1 Fri 11:00 BEY 118

Magnetic band structure of GaAs and InSb in ultrahigh magnetic fields — •Christian Ammann, Christian Strahberger, and Peter Vogl — Walter Schottky Institut, Technische Universität München, D-85748 Garching, Germany

The availability of ultrahigh magnetic fields for solid state investigations calls for reliable theoretical predictions of the electronic band structure in ultrahigh fields. We have calculated the magnetic band structure and optical absorption spectra of bulk GaAs and bulk InSb by means of an empirical $sp^3d^5s^*$ tight binding model where the magnetic field is incorporated non-perturbatively to capture effects that can only arise by taking the entire Brillioun zone into account. In fields up to 1000 T, the band structure can be interpreted in terms of Landau ladders arising from all valleys throughout the BZ whereas the spectrum shows a fractal behavior for higher fields. There is a strong dependence of the magnetic band structure on the B-field direction because of zone folding effects. We find the lowest $L\downarrow$-band state to cross the lowest $\Gamma\uparrow$-band state in GaAs at 600 T. The effective Lande g factor in InSb shows a strongly sublinear behavior due to strong hybridization of Γ and L band states beyond 100 T. For GaAs as well as InSb, we find efficient optical absorption in the far infrared range for intra-valence band transitions for B-fields between 100 T and 500 T.

HL 57.2 Fri 11:15 BEY 118

Excitons in stackes of ZnSe/CdSe quantum dots — •Tchelidze Tamar — Tbilisi State University, Department of Exact and Natural Sciences, Chavchavadze Ave.3 0218 Tbilisi Georgia

We investigated electron hole interaction in the flat 2D-quantum dot heterostructures with arbitrary number of stacked quantum dot layers. The calculation were carried out on the basic of obtained recurrent formula, which derives single particle energies and wave functions of electrons and holes in quantum dot heterostructures with n stacked layers from the single particle energies and wave functions for heterostructure with n-1 stacked layers. Interaction of electrons and holes were considered by means of direct diagonalizing of Hamiltonian matrix. We studied the dependence of exciton binding energy, probabilities of optical transitions in dependence on quantum dot and barrier layer size, as well as on the number of stacked layers. We have investigated the influence of impurities on the electron-hole Coulomb interaction in single and double stacks of quantum dots. We studied how the presence of one-charged donor and acceptor impurities affects on the exciton binding energy and probability of radiation decay in the flat 2D-quantum dots and quantum dot molecules.

HL 57.3 Fri 11:30 BEY 118

Orbital Functionals in Current Spin Density Functional Theory — •Stefano Pittalis, Stefan Kurth, Nicole Helbig, and E.K.U. Gross — Freie Universität Berlin, Theoretische Physik, Arnimallee 14 D-14195 Berlin

The proper description of non-relativistic many-electron systems in the presence of magnetic fields within a density-functional framework requires the paramagnetic current density and the spin magnetization to be used as basic variable besides the electron density. However electron-gas-based (LDA-type) functionals of Current-Spin-Density Functional Theory (CSDFT) exhibit derivative discontinuities as a function of the magnetic field whenever a new Landau level is occupied, which makes them difficult to use in practice. Since the appearance of Landau levels intrinsically is an orbital effect, it is appealing to use orbital-dependent functionals. Therefore, here CSDFT is presented in the framework of exchange-correlation energy functionals which are explicit functionals of two-component Kohn-Sham spinors. The integral equations for the exchange-correlation components of the scalar and vector potential and the magnetic field are derived in the formalism of the optimized effective potential method and a simplifying approximation to these equations is suggested. The formalism is then applied within the exchange-only limit to study two-dimensional quantum dots and atomic ground states.

HL 57.4 Fri 11:45 BEY 118

All-electron *GW* approximation in the augmented-plane-wave basis-set limit — •Christoph Friedrich[1], Arno Schindlmayr[1], Stefan Blügel[1], and Takao Kotani[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Department of Chemical and Materials Engineering, Arizona State University, Tempe, AZ 85287-6006, USA

The GW approximation for the electronic self-energy yields quasiparticle band structures in very good agreement with experiment, but almost all calculations so far are based on the pseudopotential approach. We have developed an implementation within the all-electron linearised augmented plane-wave (LAPW) method, which treats the core electrons explicitly. As errors resulting from the linearisation of the basis set are frequently overlooked, we here aim to investigate its influence on the GW self-energy correction. A systematic improvement is achieved by including additional local orbitals defined as second and higher energy derivatives of solutions to the radial scalar-relativistic Dirac equation, which constitute a natural extension of the LAPW basis set. Within this approach the linearisation error can be systematically reduced, and the exact augmented-plane-wave basis-set limit can be reached. While the electronic self-energy and the quasiparticle energies benefit from the better description of the unoccupied states, the resulting band gaps remain relatively unaffected.

HL 57.5 Fri 12:00 BEY 118

Calculation of non-resonant x-ray Raman spectra by real-space multiple-scattering — •Henning Sternemann[1], Christian Sternemann[1], Juha Aleksi Soininen[2], and Metin Tolan[1] — [1]Exp. Physik I / DELTA, Universität Dortmund, 44221 Dortmund — [2]Div. X-ray Physics, Dept. Physical Sciences, University of Helsinki, Finland

Non-resonant x-ray Raman scattering is a valuable tool to reveal detailed information on the structural and electronic properties of matter. Low energy absorption edges can be studied with a high incident x-ray energy. In order to extract information out of the measurements it is often necessary to use computer simulations. Whereas most bandstructure methods require periodic boundary conditions and small unit cells, an

extension of the ab initio real-space multiple-scattering approach [1] to non-resonant x-ray Raman scattering [2] is not confined by this limitation. We present calculations of K- and L-edges for simple elements such as Na and Si as well as for more complex materials like doped silicon clathrates.

[1] A. L. Ankudinov *et al.* Phys. Rev. B**65**, 104107, (2002), http://leonardo.phys.washington.edu/feff/
[2] J. A. Soininen *et al.* Phys. Rev. B**72**, 045136, (2005)

HL 57.6 Fri 12:15 BEY 118

GW Calculations Starting from Generalized Kohn-Sham Schemes: Application to InN — •Frank Fuchs[1], Jürgen Furthmüller[1], Friedhelm Bechstedt[1], and Georg Kresse[2] — [1]Institut für Festkörpertheorie und -optik, FSU-Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institut für Materialphysik and Center for Computational Materials Science, Universität Wien, Austria

The GW approximation of Hedin is arguably the most successful approach for the calculation of quasi-particle (QP) energies. Its accuracy has been proven for a variety of systems. Usually, GW corrections are calculated in a 'one shot' fashion, calculating G_0 and W_0 from solutions of the Kohn-Sham equations with an exchange-correlation potential in local density or generalized gradient approximation (LDA/GGA). However, this standard approach fails for a number of systems such as InN which share shallow 'semi-core' electrons and a 'negative gap' in LDA/GGA. Here we present GW calculations which start from solutions of generalized Kohn-Sham (gKS) equations [1]. Such a procedure yields a positive gap for all the investigated gKS functionals. However, a crucial dependence on the wave-function details is found for the semi-core states. The calculations were performed using a model dielectric function for the GW self-energy. The electron-ion interaction was modeled via the PAW method which provides direct access to the all-electron wave functions.

[1] A. Seidl et al., PRB **53**, 3764 (1996)

HL 57.7 Fri 12:30 BEY 118

Path-integral treatment of a translation invariant many-polaron system — •F. Brosens[1], S. N. Klimin[1,2], and J. T. Devreese[1,3] — [1]TFVS, Department of Physics, Universiteit Antwerpen, B-2610 Antwerpen, Belgium — [2]State University of Moldova, Kishinev, Moldova — [3]Department of Semiconductor Physics, TU Eindhoven, NL-5600 MB Eindhoven, The Netherlands

Using an extension of the Jensen-Feynman inequality for systems of identical particles, we derived an upper bound for the ground state energy of a translation invariant system of N interacting polarons, taking into account the Fermi-Dirac statistics of the electrons. The developed approach is valid for arbitrary coupling strength.

For sufficiently large values of the electron-phonon coupling constant and of the Coulomb coupling strength, a stable multipolaron ground state can be formed. The total spin of the system then takes its minimal value. The stability region of the multipolaron state becomes narrower if the number of electrons increases. For a stable multipolaron state, the addition energy exhibits peaks corresponding to closed shells. These features of the addition energy, as well as the total spin as a function of the number of electrons, might be observable experimentally, e.g., by capacitance and magnetization measurements in high-Tc superconductors.

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