Semiconductor Physics Division
Fachverband Halbleiterphysik (HL)

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Overview of Invited Talks and Sessions

(lecture rooms HSZ 01, BEY 81 BEY 118, BEY 154, POT 51 and POT 151; Poster P2)

Invited Talks

HL 6.1	Mon	11:00–11:45	HSZ 01	**Three dimensional SiGe quantum dot crystals** — •Thomas Fromherz
HL 8.1	Mon	14:00–14:45	HSZ 01	**Phonon-mediated non-equilibrium interactions between mesoscopic devices** — Georg Schinner, •Stefan Ludwig
HL 10.1	Mon	14:45–15:30	HSZ 01	**The Bose-Einstein condensation of excitons in quantum-Hall bilayers** — •Werner Dietsche, Lars Tiemann
HL 20.1	Tue	14:00–14:45	HSZ 01	**Electron spin coherence in singly charged quantum dots** — •Dmitri R. Yakovlev
HL 24.1	Tue	14:45–15:30	HSZ 01	**Phase coherent transport in (Ga,Mn)As** — •D. Neumaier, K. Wagner, U. Wurstbauer, M. Reinwald, W. Wegscheider, D. Weiss
HL 45.1	Thu	11:45–12:30	HSZ 01	**Strain Induced Growth Instability and Island Nucleation on Patterned Substrate** — •feng Liu
HL 47.1	Thu	14:00–14:45	HSZ 01	**Homoepitaxy and optical properties of ZnO epilayers grown on Zn- and O-polar substrates** — Bruno Meyer, Stefan Lautenschlaeger, Markus Wagner, •Axel Hoffmann
HL 54.1	Fri	11:00–11:45	HSZ 01	**Spin Noise Spectroscopy in Semiconductor Nanostructures** — •Jens Hübner, Michael Römer, Georg Müller, Hannes Bernien, Tammo Böntgen, Hauke Horn, Michael Oestreich

Focused Sessions within HL

Focused Session: Semi- and nonpolar group III nitrides I

Organization: Ferdinand Scholz (Universität Ulm), Ulrich T. Schwarz (Universität Regensburg)

HL 11.1	Tue	9:30–10:00	HSZ 01	**Characterization and Control of Recombination Dynamics in Low-dimensional InGaN-based Semiconductors** — •Yoichi Kawakami, Akio Kaneta, Masaya Ueda, Mitsuru Funato
HL 11.2	Tue	10:00–10:30	HSZ 01	**Optical polarization properties of nonpolar-oriented GaN films for polarization-sensitive and narrow-band photo-detectors** — •Holger T. Grahn
HL 11.3	Tue	10:45–11:15	HSZ 01	**Growth and characterisation of planar (11-20) and (11-22) GaN-based multiple quantum well structures** — •Menno Kappers
HL 11.4	Tue	11:15–11:45	HSZ 01	**Materials issues towards green laser diodes** — •Andreas Hangleiter
HL 11.5	Tue	12:00–12:15	HSZ 01	**Thermal trap emissions associated with stacking faults in undoped non c-plane GaN** — •Kay-Michael Günther, Hartmut Witte, Matthias Wieneke, Jürgen Bläsing, Armin Dadgar, Alois Krost
HL 11.6	Tue	12:15–12:30	HSZ 01	**Facet formation and ohmic contacts for laser diodes on non- and semipolar GaN** — •Jens Rass, Simon Ploch, Tim Wernicke, Luca Redaelli, Patrick Vogt, Sven Einfeldt, Michael Kneissl
HL 11.7	Tue	12:30–12:45	HSZ 01	**Growth of nonpolar a-plane GaN on r-plane Sapphire via HVPE** — •Stephan Schwaiger, Thomas Wunderer, Frank Lipski, Ferdinand Scholz

Focused Session: Semi- and nonpolar group III nitrides II

Organization: Ferdinand Scholz (Universität Ulm), Ulrich T. Schwarz (Universität Regensburg)

HL 22.1	Tue	14:00–14:30	BEY 118	**Optical anisotropy of nitride semiconductors** — •Rüdiger Goldhahn
HL 22.2	Tue	14:30–15:00	BEY 118	**Growth on nonpolar and semipolar GaN: The substrate dilemma** — •T. Wernicke, M. Weyers, M. Kneissl
HL 22.3	Tue	15:00–15:30	BEY 118	**Microscopic Correlation of Structural, Electronical and Optical Properties of semi- and non-polar grown Group-III-Nitrides** — •Frank Bertram
HL 22.4	Tue	15:45–16:00	BEY 118	**Fabrication of high quality semipolar GaN on full 2 inch for green light emitters** — •Thomas Wunderer, Frank Lipski, Stephan Schwaiger, Ferdinand Scholz, Michael Wiedenmann, Martin Feneberg, Klaus Thonke
HL 22.5	Tue	16:00–16:15	BEY 118	**Characterization of photoluminescence (PL) emission from semipolar {1-101} InGaN quantum wells** — •Hans-Jürgen Möstl, Clemens Vierheilig, Ulrich T. Schwarz, Thomas Wunderer, Stephan Schwaiger, Frank Lipski, Ferdinand Scholz
HL 22.6	Tue	16:15–16:30	BEY 118	**GaInN quantum wells with high indium concentrations on polar and nonpolar surfaces** — •Holger Jönen, Torsten Langer, Daniel Dräger, Lars Hoffmann, Heiko Bremers, Uwe Rossow, Sebastian Metzner, Frank Bertram, Jürgen Christen, Andreas Hangleiter

Focused Session: Novel nanowires electronic device concepts

Organization: Raffaella Calarco (Forschungszentrum Jülich), Joachim Knoch (Technische Universität Dortmund)

HL 26.1	Wed	9:30–10:00	HSZ 01	**Nanoelectronics - Why 1D nanowires?** — •Joerg Appenzeller
HL 26.2	Wed	10:00–10:30	HSZ 01	**Doping limits in silicon nanowires** — •Mikael Björk, Heinz Schmid, Joachim Knoch, Heike Riel, Walter Riess
HL 26.3	Wed	10:45–11:15	HSZ 01	**Polarity control of silicon nanowire transistors by electrostatic coupling to the Schottky contacts** — Walter Michael Weber, Lutz Geelhaar, Franz Kreupl, Henning Riechert, •Paolo Lugli
HL 26.4	Wed	11:15–11:45	HSZ 01	**Antimonide-based nanowire devices** — •Lars-Erik Wernersson
HL 26.5	Wed	12:00–12:30	HSZ 01	**Rf-characterization of III-V-Nanowire FET: Problems and Results** — •Franz Tegude, Werner Prost
HL 26.6	Wed	12:30–13:00	HSZ 01	**Semiconductor nanowires as building blocks for quantum devices** — •Thomas Schäpers, Sergio Estevez Hernandez, Gunnar Petersen, Robert Frielinghaus, Shima Alagha, Christian Blömers, Thomas Richter, Raffaella Calarco, Hans Lüth, Michel Marso, Michael Indlekofer

Focused Session: Quantum optomechanics

Organization: Eva Weig, Khaled Karrai (Ludwig-Maximilians-Universität München)

HL 32.1	Wed	14:00–14:30	HSZ 01	**Cavity Optomechanics using Optical Microresonators** — •Tobias Kippenberg, Albert Schliesser, Remi Riviere, Olivier Arcizet
HL 32.2	Wed	14:30–15:00	HSZ 01	**Experimental quantum optical control of micromechanical resonators** — •Markus Aspelmeyer
HL 32.3	Wed	15:00–15:30	HSZ 01	**Optomechanical correlations between light and mirrors** — •Antoine Heidmann, Pierre-Francois Cohadon, Tristan Briant

Focused Session: Different realizations of quantum registers

Organization: Jonathan Finley, Gerhard Abstreiter (Walter-Schottky-Institut München)

HL 38.1	Thu	9:30–10:00	HSZ 01	**Quantum control of spins and photons in diamond** — •Mikhail Lukin
HL 38.2	Thu	10:00–10:30	HSZ 01	**Quantum Information processing in diamond** — •Fedor Jelezko, Jörg Wrachtrup
HL 38.3	Thu	10:45–11:15	HSZ 01	**Coherence of a single spin in a tunable environment** — •Ronald Hanson

HL 38.4	Thu	11:15–11:45	HSZ 01	**Spectroscopy and Coherent Control of Single Spins** — •Gregory Fuchs

Symposia with partcipation of HL

Invited talks of the joint symposium Ab-Initio approaches to excitations in condensed matter (SYAI)

See SYAI for the full program of the Symposium.
(arranged by the devisions O, DS, HL and MA)
Organization: Claudia Ambrosch-Draxl (Montanuniversität Leoben), Matthias Scheffler (Fritz-Haber-Institut Berlin)

SYAI 1.1	Thu	15:00–15:30	SCH 251	**Insights and Progress in Density Functional Theory** — Paula Paula Mori-Sanchez, Aron Cohen, •Weitao Yang
SYAI 1.2	Thu	15:30–16:00	SCH 251	**Quasiparticle energy calculations in a new light: from defects in semiconductors to the f-electron challenge** — •Patrick Rinke
SYAI 1.3	Thu	16:00–16:30	SCH 251	**LDA+DMFT approach to excitations spectrum in Half-Metallic Ferromagnets** — •Alexander Lichtenstein
SYAI 1.4	Thu	17:00–17:30	SCH 251	**Insight and prediction of material properties from ab initio calculations of electronic excitations** — •Lucia Reining, Matteo Gatti, Ralf Hambach, Christine Giorgetti
SYAI 1.5	Thu	17:30–18:00	SCH 251	**Local excitations in strongly interacting charge-transfer insulators: Frenkel excitons within TD-LDA+U and strong coupling theory** — •Wei Ku
SYAI 1.6	Thu	18:00–18:30	SCH 251	**Electron tunneling and transport at molecular junctions** — •Roberto Car

Invited talks of the joint symposium Anderson Localization in Nonlinear and Many-Body Systems (SYAL)

See SYAL for the full program of the Symposium.
(arranged by the devisions DY, HL, MM and TT)
Organization: Sergej Flach (Max-Planck-Institut für Physik komplexer Systeme Dresden), Arkady Pikovsky (Universität Potsdam)

SYAL 1.1	Mon	14:00–14:30	BAR SCHÖ	**Delocalization by nonlinearity and interactions in systems with disorder** — •Dima Shepelyansky
SYAL 1.2	Mon	14:30–15:00	BAR SCHÖ	**Absence of Diffusion in a Fröhlich-Spencer-Wayne model for nonlinear random systems** — •Serge Aubry
SYAL 1.3	Mon	15:00–15:30	BAR SCHÖ	**Anderson localization and nonlinearity in disordered photonic lattices** — •Yaron Silberberg
SYAL 1.4	Mon	15:30–16:00	BAR SCHÖ	**Many Body Localization** — •Boris Altshuler
SYAL 1.5	Mon	16:00–16:30	BAR SCHÖ	**Localized states and interaction induced delocalization in Bose gases with quenched disorder** — •Thomas Nattermann
SYAL 1.6	Mon	16:30–17:00	BAR SCHÖ	**Single-particle and many-body Anderson localizations with Bose-Einstein condensates** — •Laurent Sanchez-Palencia

Invited talks of the joint symposium Organic photovoltaics: from single molecules to devices (SYOP)

See SYOP for the full program of the Symposium.
(arranged by the devisions CPP, DS, HL and O)
Organization: Silke Rathgeber (Max-Planck-Institut für Polymerforschung Mainz), Karl Leo (Technische Universität Dresden), Thomas Thurn-Albrecht (Martin-Luther-Universität Halle-Wittenberg)

SYOP 2.1	Thu	9:30–10:00	BAR SCHÖ	**Material Design for Organic and Hybrid Solar Cells – structural to functional control on all length scales –** — •Mukundan Thelakkat, Michael Sommer, Ruth Lohwasser, Sebastien Maria
SYOP 2.2	Thu	10:00–10:30	BAR SCHÖ	**Triplet exciton formation in organic photovoltaics** — Xudong Yang, Sebastian Westenhoff, Ian Howard, Thomas Ford, Richard Friend, Justin Hodgkiss, •Neil Greenham

SYOP 2.3	Thu	10:30–11:00	BAR SCHÖ	**Charge Carrier Dissociation and Recombination in Polymer Solar Cells** — •Vladimir Dyakonov, Carsten Deibel
SYOP 2.4	Thu	11:00–11:30	BAR SCHÖ	**Modeling exciton diffusion and dissociation at organic-organic interfaces** — •David Beljonne
SYOP 2.5	Thu	11:30–12:00	BAR SCHÖ	**Correlation of Interfacial Composition and Bulk Morphology to Device Performance in Organic Bulk Heterojunction Solar Cells** — David Germack, •Joseph Kline, Daniel Fischer, Lee Richter, Calvin Chan, David Gundlach, Michael Toney, Dean DeLongchamp
SYOP 2.6	Thu	12:00–12:30	BAR SCHÖ	**Developments on the acceptor side in plastic PV** — •Jan C. Hummelen

Invited talks of the joint symposium Spincoherence in Solids (SYSC)

See SYSC for the full program of the Symposium.
(arranged by the devisions MA, HL and DS)
Organization: Christian Back (Universität Regensburg), Michael Oestreich (Universität Hannover)

SYSC 1.1	Wed	9:30–10:00	BAR SCHÖ	**Optical Pumping of Nuclear Spins in Semiconductor Quantum Dots** — •X. Marie, B. Urbaszek, T. Amand, O. Krebs, A. Lemaître, P. Voisin, B. Eble, C. Testelin, M. Chamarro
SYSC 1.2	Wed	10:00–10:30	BAR SCHÖ	**Dyakonov-Perel' Spin-Dynamics in GaAs Quantum Wells** — •Richard Harley
SYSC 1.3	Wed	10:30–11:00	BAR SCHÖ	**Quantum dot spins in optical microcavities** — •Rudolf Bratschitsch
SYSC 1.4	Wed	11:00–11:30	BAR SCHÖ	**Spin relaxation in quasi-one-dimensional electron systems: transition from 2D to 1D** — •Alexander Holleitner
SYSC 1.5	Wed	11:30–12:00	BAR SCHÖ	**Triggering phase-coherent spin packets by pulsed electrical spin injection across an Fe/GaAs Schottky barrier** — •Bernd Beschoten
SYSC 1.6	Wed	12:00–12:30	BAR SCHÖ	**Quantum Spin Hall Effect in HgTe Quantum Well Structures** — •Hartmut Buhmann

Invited talks of the joint symposium Transport in Graphene (SYTG)

See SYTG for the full program of the Symposium.
(arranged by the devisions HL and DY)
Organization: Klaus Ensslin (Eidgenössische Technische Hochschule Zürich)

SYTG 1.1	Tue	14:00–14:30	BAR SCHÖ	**The nature of localization in graphene under quantum Hall conditions** — •Jurgen Smet
SYTG 1.2	Tue	14:30–15:00	BAR SCHÖ	**Electronic Transport in Graphene Nanostructures** — •Thomas Ihn, Christoph Stampfer, Johannes Güttinger, Francoise Molitor, Stephan Schnez, Arnhild Jacobsen, Klaus Ensslin
SYTG 1.3	Tue	15:00–15:30	BAR SCHÖ	**Spins and valley-spins in graphene nanostructures** — •Inanc Adagideli
SYTG 1.4	Tue	15:30–16:00	BAR SCHÖ	**Theory of ballistic transport in graphene** — •Bjoern Trauzettel

Walter Schottky Prize

HL 31.1	Wed	13:00–13:45	HSZ 01	**Optomechanics** — •Florian Marquardt

Sessions

HL 1.1–1.9	Mon	10:15–12:45	BEY 81	**III-V semiconductors I**
HL 2.1–2.7	Mon	10:15–12:15	BEY 118	**GaN: devices**
HL 3.1–3.9	Mon	10:15–12:45	BEY 154	**Heterostructures**
HL 4.1–4.9	Mon	10:15–12:45	POT 51	**II-VI semiconductors**

HL 5.1–5.10	Mon	10:15–13:15	POT 151	**Photovoltaic**
HL 6.1–6.1	Mon	11:00–11:45	HSZ 01	**Invited Talk Fromherz**
HL 7.1–7.12	Mon	13:30–17:00	BEY 118	**Quantum dots: Optical properties I**
HL 8.1–8.1	Mon	14:00–14:45	HSZ 01	**Invited Talk Ludwig**
HL 9.1–9.120	Mon	14:30–17:00	P2	**Poster 1**
HL 10.1–10.1	Mon	14:45–15:30	HSZ 01	**Invited Talk Dietsche**
HL 11.1–11.7	Tue	9:30–12:45	HSZ 01	**Focused Session: Semi- and nonpolar group III nitrides I**
HL 12.1–12.10	Tue	9:30–12:30	BEY 81	**Spin controlled transport I**
HL 13.1–13.13	Tue	9:30–13:00	BEY 118	**Optical properties**
HL 14.1–14.2	Tue	9:30–10:00	BEY 154	**Preparation and characterization**
HL 15.1–15.13	Tue	9:30–13:00	POT 51	**C/diamond I**
HL 16.1–16.9	Tue	9:30–12:00	POT 151	**III-V semiconductors II**
HL 17.1–17.10	Tue	10:00–13:00	BEY 154	**Quantum wires: Optical and transport properties**
HL 18.1–18.4	Tue	12:00–13:00	POT 151	**Impurities/amorphous semiconductors**
HL 19.1–19.2	Tue	12:30–13:00	BEY 81	**Theory of electronic structure**
HL 20.1–20.1	Tue	14:00–14:45	HSZ 01	**Invited Talk Yakovlev**
HL 21.1–21.7	Tue	14:00–16:00	BEY 81	**Devices**
HL 22.1–22.6	Tue	14:00–16:30	BEY 118	**Focused Session: Semi- and nonpolar group III nitrides II**
HL 23.1–23.5	Tue	14:00–15:15	BEY 154	**Transport in high magnetic field/quantum-Hall-effect**
HL 24.1–24.1	Tue	14:45–15:30	HSZ 01	**Invited Talk Neumaier**
HL 25.1–25.2	Tue	16:00–16:30	POT 51	**C/diamond II**
HL 26.1–26.6	Wed	9:30–13:00	HSZ 01	**Focused Session: Novel nanowires electronic device concepts**
HL 27.1–27.12	Wed	9:30–13:00	BEY 81	**GaN: preparation and characterization I**
HL 28.1–28.12	Wed	9:30–13:00	BEY 118	**ZnO: preparation and characterization I**
HL 29.1–29.12	Wed	9:30–13:00	BEY 154	**Quantum dots: Optical properties II**
HL 30.1–30.13	Wed	9:30–13:00	POT 51	**Si/Ge**
HL 31.1–31.1	Wed	13:00–13:45	HSZ 01	**Walter Schottky Prize**
HL 32.1–32.3	Wed	14:00–15:30	HSZ 01	**Focused Session: Quantum optomechanics**
HL 33.1–33.11	Wed	14:00–17:15	BEY 81	**Quantum wires: preparation and characterization**
HL 34.1–34.10	Wed	14:00–17:00	BEY 118	**Spin controlled transport II**
HL 35.1–35.13	Wed	14:00–17:45	BEY 154	**Semiconductor Laser**
HL 36.1–36.8	Wed	14:00–16:15	POT 51	**ZnO: preparation and characterization II**
HL 37.1–37.6	Wed	16:15–18:00	POT 51	**ZnO: devices**
HL 38.1–38.4	Thu	9:30–11:45	HSZ 01	**Focused Session: Different realizations of quantum registers**
HL 39.1–39.12	Thu	9:30–13:00	BEY 81	**Quantum dots: Optical and transport properties**
HL 40.1–40.11	Thu	9:30–12:45	BEY 118	**ZnO: preparation and characterization III**
HL 41.1–41.12	Thu	9:30–13:00	BEY 154	**GaN: preparation and characterization II**
HL 42.1–42.5	Thu	9:30–10:45	POT 51	**Interfaces/surfaces**
HL 43.1–43.10	Thu	9:30–12:30	POT 151	**Photonic crystals I**
HL 44.1–44.8	Thu	10:45–13:00	POT 51	**Organic semiconductors I**
HL 45.1–45.1	Thu	11:45–12:30	HSZ 01	**Invited Talk Liu**
HL 46.1–46.2	Thu	12:30–13:00	POT 151	**Hybrid systems**
HL 47.1–47.1	Thu	14:00–14:45	HSZ 01	**Invited Talk Meyer**
HL 48.1–48.91	Thu	15:00–17:30	P2	**Poster 2**
HL 49.1–49.9	Fri	10:15–12:45	BEY 81	**Quantum dots: preparation and characterization**
HL 50.1–50.9	Fri	10:15–12:45	BEY 118	**Ultra fast phenomena**
HL 51.1–51.9	Fri	10:15–12:45	BEY 154	**Photonic crystals II**
HL 52.1–52.8	Fri	10:15–12:30	POT 51	**Organic semiconductors II**
HL 53.1–53.6	Fri	10:15–11:45	POT 151	**Transport properties**
HL 54.1–54.1	Fri	11:00–11:45	HSZ 01	**Invited Talk Hübner**

AIW: Quo vadis, Halbleiter?

AIW 1.1	Wed	10:00–10:15	POT 151	**Begrüßung und Einführung** — •Bernd Schineller
AIW 1.2	Wed	10:15–11:00	POT 151	**Anorganische Leuchtdioden – Gegenwart und Zukunft** — •Klaus Streubel
AIW 1.3	Wed	11:00–11:45	POT 151	**Anorganische Photovoltaik – Energie für die Zukunft?** — •Jörg Müller
AIW 1.4	Wed	11:45–12:30	POT 151	**Organische Optoelektronik** — •Jan Blochwitz-Nimoth

AIW 2.1	Wed	14:00–14:45	POT 151	**Produktionstechnologien für Halbleiterschichten** — •Michael Heuken
AIW 2.2	Wed	14:45–15:30	POT 151	**Dielektrische Materialien für die Halbleitertechnik** — •Susanne Hoffmann-Eifert
AIW 2.3	Wed	15:30–16:15	POT 151	**Semiconductor Markets and Business Outlook** — •Tom P. Pearsall

Annual General Meeting Semiconductor Physics Division

Thursday 18:00–20:00 HSZ 101

- Begrüßung und Bericht
- Stichwortkatalog
- Wahl des Fachverbandsvorsitzenden und dessen Stellvertreter
- Verschiedenes

HL 1: III-V semiconductors I

Time: Monday 10:15–12:45 Location: BEY 81

HL 1.1 Mon 10:15 BEY 81

Epitaxy of self-assembled quantum dots on AlGaInAs lattice matched to InP for long wavelength emission using molecular beam epitaxy — •Mario Bareiss, Roland Enzmann, Marion Kraus, Daniela Baierl, Gerhard Böhm, Ralf Meyer, Jonathan Finley, and Markus-Christian Amann — Walter Schottky Institut, Technische Universität München, D-85748 Garching, Germany

We present the formation of InAs quantum dots with a low surface density on AlGaInAs lattice matched to InP(001) substrates using molecular beam epitaxy. Usually the deposition of self assembled quantum structures on InP results in the form of elongated quantum dashes. Only within a narrow regime of growth parameters the formation of circular shaped quantum dots is favoured as our study shows. Aiming for a low quantum dot density requires a high migration length of the Indium atoms. Therefore we used low growth rates down to 0.003 monolayers per second. To tailor furthermore the emission wavelength of the quantum dots to 1.5 micrometers the Aluminium to Gallium ratio in the barrier material was adjusted. Achieving very low quantum dot densities of approximatly one per square micrometer makes these quantum dots promising candidates for single photon generation in the telecommunication regime.

HL 1.2 Mon 10:30 BEY 81

Minority carrier lifetime of MOCVD grown InGaAsP and InGaAs absorbers for low bandgap tandem solar cells — •Nadine Szabo, Erol Sagol, Marinus Kunst, Klaus Schwarzburg, and Thomas Hannappel — Helmholtz Zentrum Berlin Glienicker Str. 100 14109 Germany

MOVPE-grown III-V semiconductor compounds are implemented in today's state-of-the-art third generation multi-junction solar cells. Conventional triple-junction solar cells grown on germanium, having Ge, Ga(In)As and GaInP as subcells, reached a record efficiency of 40.7%. This could be improved further if the Ge subcell is replaced by a double junction solar cell. The best bandgap combination was found out to be 0.7 eV and 1 eV. These bandgaps could easily be realized with materials such as InGaAs and InGaAsP which are lattice-matched to InP. The lifetime of minority charge carriers in these absorber materials is essential for the performance of solar cells. Time resolved photoluminescence (TRPL) and transient microwave conductivity (TRMC) measurements were used to evaluate the lifetime of the absorber materials grown in a double hetero-structure. To get meaningful results, a precise knowledge of the excess carrier density created by the pump pulse is necessary. With our single photon counting TRPL setup a carrier density regime between 10E9 cm-3 and 10E16 cm-3 in the VIS (λ<1000 nm) and 10E13 cm-3 and 10E16 cm-3 in the NIR (λ<1700 nm) can be assessed. We will present the lifetime of minority carriers in p-InGaAs and p-InGaAsP layers for different thicknesses as a function of excitation density.

HL 1.3 Mon 10:45 BEY 81

Investigation of the Bir-Aronov-Pikus spin relaxation mechanism in (110) GaAs quantum wells — •Stefan Oertel[1], Jens Hübner[1], Dieter Schuh[2], Werner Wegscheider[2], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover — [2]Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D-93040 Regensburg

We determine the spin relaxation time τ_s in (110)-oriented GaAs quantum wells by time- and polarization resolved photoluminescence spectroscopy. The major spin relaxation channel in III-V compounds, the D'yakonov-Perel' mechansim, is suppressed in growth direction of (110)-oriented heterostructures and the most prominent remaining spin relaxation mechanism in these quantum wells is the Bir-Aronov-Pikus (BAP) mechanism via interaction with unpolarized holes. By variation of the excitation density, we are able to directly control the electron hole density and thus determine the efficiency of the BAP spin relaxation mechanism. The electron hole interaction also depends strongly on temperature and hence the temperature dependence of τ_s^{BAP} directly yields a measure for the electron hole interaction strength.

HL 1.4 Mon 11:00 BEY 81

Intrinsic Spin Lifetimes in GaAs (110) Quantum Wells — •Georg Müller[1], Michael Römer[1], Dieter Schuh[2], Werner Wegscheider[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Gottfried Wilhelm Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

GaAs (110) quantum wells attract great attention due to the long spin lifetime for electron spins along the growth axis and are, therefore, of interest for future spin based optoelectronic devices.

At low temperatures, optical injection of a finite spin polarization yields strongly enhanced spin dephasing due to the Bir Aronov Pikus mechanism that arises from the exchange interaction between electrons and holes. Thus, the intrinsic spin lifetime in GaAs (110) quantum wells has been unknown. In this work, the non-demolition technique of spin noise spectroscopy, which only relies on statistical spin flucutations, is applied to GaAs (110) quantum wells in order to measure the intrinsic spin lifetimes. Furthermore, the Brownian motion of the electrons modifies the linewidth of the measured spin noise spectra due to time of flight broadening. This effect uniquely allows to study electronic motion at thermal equilibrium.

[1] G. Müller, M. Römer, D. Schuh, W. Wegscheider, J. Hübner, and M. Oestreich, Phys. Rev. Lett. **101**, 206601 (2008).

HL 1.5 Mon 11:15 BEY 81

Temperature and Concentration Dependent Spin Noise Measurements in GaAs — •Michael Römer, Georg Müller, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany

Spin noise spectroscopy is an elegant method to access electron properties of direct gap semiconductors in thermal equilibrium while avoiding carrier heating and excitation of electron hole pairs [1]. This technique is used to examine the electron spin lifetime and noise power in GaAs in dependence of electron doping concentration, sample temperature, and the probe laser wavelength. The measured power of the spin noise signal is used to extract information about the electron statistics and the position of the electrons in the conduction band. The measured data can be well explained using a model based on the change of the index of refraction due to the ever present thermal fluctuations of the electron spin.

[1] M. Römer, J. Hübner and M. Oestreich "Spin Noise Spectroscopy in Semiconductors", Rev. Sci. Instrum. **78**, 103903 (2007).

15 min. break

HL 1.6 Mon 11:45 BEY 81

Analysis of segregation profiles in InGaAs quantum wells via TEM and STEM — •Thorsten Mehrtens[1], Marco Schowalter[1], Knut Müller[1], Andreas Rosenauer[1], Dongzhi Hu[2], and Daniel M. Schaadt[2] — [1]Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen — [2]Institut für Angewandte Physik/DFG-Center für funktionelle Nanostrukturen, Universität Karlsruhe (TH), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe

Knowledge of the composition distribution in epitaxially grown semiconductor nanostructures is essential to understand the growth process, where segregation plays an important role. We report on InGaAs heterostructures grown by molecular beam epitaxy (MBE). Before the growth of the InGaAs layer the specimen was heated up briefly to remove Ga from a possible Ga floating layer. The temperature has been varied for different wells to study the influence on segregation. Composition profiles were measured by scanning transmission electron microscopy (STEM) with a high-angle annular dark field (HAADF) detector. This setup exploits the Z-dependence of the thermal diffuse high angle scattering. Simulations were performed with the frozen lattice approach in dependence on sample thickness and concentration. Comparing the measurement with the simulations leads to the concentration profile. Segregation coefficients have been calculated and compared to coefficients obtained with the composition evaluation by lattice fringe analysis (CELFA), which uses the chemical sensitive (002) and the undiffracted (000) beam. Both methods do not reveal a significant influence of the specimen heating on the segregation coefficient.

HL 1.7 Mon 12:00 BEY 81

Properties of of GaAs/GaMnAs core-shell nanowires — •Elisabeth Reiger[1], Andreas Rudolph[1], Marcello Soda[1], Matthias Kiessling[1], Benedikt Bauer[1], Dieter Schuh[1], Tomasz Wojtowicz[2], and Werner Wegscheider[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Institute of Physics, PAS, Al. Lotników 32/46, 02-668 Warszawa, Poland

Combining GaMnAs growth with nanowires would open a whole new field of spintronics application. For 2D GaMnAs/GaAs systems efficient spin injection into GaAs has been experimentally achieved. We investigate the possibilities to combine GaMnAs growth with the typical growth of nanowires. As GaMnAs has to be grown at low temperatures, it is not compatible to the typical axial growth conditions for nanowires. However, this does not apply for core-shell nanowires. Here, in a first step, GaAs core nanowires are grown using the gold catalyst technique on GaAs(111)B substrates. In a second growth step the GaMnAs shell is deposited on the side facets of the core nanowire using typical GaMnAs growth conditions as used for 2D film growth. We characterize the core-shell nanowires with scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The core nanowires show a zinc blend crystal structure with very few stacking faults. The GaMnAs shell - depending on the growth conditions - is uniformly deposited around the core or shows a very rough, 3D surface. Employing SQUID measurements we determine the Curie-Temperature and study the magnetic anisotropy of the nanowires.

HL 1.8 Mon 12:15 BEY 81

III/V surface channel devices: substrate preparation, interface passivation and growth — •Mirja Richter[1], Chiara Marchiori[1], David J. Webb[1], Christian Gerl[1], Marilyne Sousa[1], Christophe Rossel[1], Caroline Andersson[1], Roland Germann[1], Heinz Siegwart[1], Edward Kiewra[2], Yanning Sun[2], Joel De Souza[2], Devendra Sadana[2], Thanasis Dimoulas[3], and Jean Fompeyrine[1] — [1]IBM Zurich Research Laboratory, Rueschlikon, Switzerland — [2]IBM Watson Research Center, Yorktown Heights, NY, USA — [3]National Center for Scientific Research Demokritos, Athens, Greece

III/V-based metal-oxide-semiconductor field effect transistors (MOSFET) are considered as promising candidates for replacing Si-based devices at and beyond the 22 nm CMOS technology node. For their fabrication, it is essential to develop an effective surface passivation. Indeed, the presence of defects at the III/V-oxide interface introduces energy states in the gap which can pin the Fermi level. In addition, to profit from their intrinsic higher charge carrier mobility, high quality III/V channel deposition as well as surface preparation procedures are indispensable.

We will discuss MBE grown gate stacks with HfO2 dielectric and Si passivation layers. Structural characterization is accomplished by RHEED and in-situ X-ray photoelectron spectroscopy. Electrical properties of the stacks are studied by measurements performed on capacitors. By this means a minimum Si passivation layer thickness is determined. Data on long channel GaAs nFETs will also be presented.

HL 1.9 Mon 12:30 BEY 81

Electrostatic force microscopy measurement of carbon nanotube field-effect transistors — •Imad Ibrahim, Nitesh Ranjan, Juliane Posseckardt, Michael Mertig, and Gianaurelio Cuniberti — Institute for Materials Science and Max Bergmann Center of Biomaterials, Technische Universität Dresden, 01062 Dresden, Germany

Multi-tube field-effect transistors (FETs) are assembled between two metallic electrodes using dielectrophoresis, in which a solution of dispersed single-walled carbon nanotubes (SWCNTs) is put between the electrodes, and an AC voltage with an amplitude of 5-8 V and a frequency of 300 kHz is applied [1,2]. After depositing the SWCNTs between the electrodes, the solution is blotted with a filter paper and the sample is dried with air. Room temperature I-V measurements are performed for such multi-tube devices which are found to have transistor-like behaviour in most cases. Further on, the devices are characterized with Atomic force microscopy (AFM) and electrostatic force microscopy (EFM). By applying a voltage to the AFM tip in lift mode [3], we are able to detect changes of the potential along the deposited SWCNT interconnects, and thus, to identify local defects in the transistor channels.

[1] S. Taeger, M. Mertig, Int. J. Mat. Res. 98, 742 (2007). [2] N. Ranjan, M. Mertig, phys. stat. sol. (b) 245, 2311 (2008). [3] T. P. Gotszalk, P. Grabiec, I. W. Rangelow, Materials Science 21, 333 (2003).

HL 2: GaN: devices

Time: Monday 10:15–12:15 Location: BEY 118

HL 2.1 Mon 10:15 BEY 118

Development of InGaN-based thin disk lasers — •R. Debusmann[1], V. Hoffmann[2], W. John[2], O. Krüger[2], P. Vogt[1], M. Kneissl[1], and M. Weyers[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, EW 6-1, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Thin disk lasers consisting of an optically pumped vertical cavity surface emitting laser with an external cavity have gained much interest in recent years. The main reason for that is that they combine high power output of edge emitting lasers with high beam quality of surface emitting devices.

In particular for the group III-nitride material system thin disk lasers seem a promising solution for high power applications, because of the inherent problems in this material system to realize epitaxial structures with low electrical losses. Here we report on the development of InGaN thin disk lasers for emission wavelengths near 405 nm.

Besides the epitaxial heterostructure a number of fabrication steps have to be developed in order to realize such devices. We will discuss some of the developed key processes for device integration. In particular deposition of SiO_2/Ta_2O_5-DBR mirror stacks with reflectivity greater than 99.5% and substrate removal by excimer-laser liftoff in order to form the laser resonator will be discussed.

HL 2.2 Mon 10:30 BEY 118

Wavelength Dependence of Optical Gain and Laser Threshold in InGaN MQW Lasers — •Jessica Schlegel[1], Jan-Robert van Look[1], Veit Hoffmann[2], Arne Knauer[2], Patrick Vogt[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

For InGaN quantum well (QW) laser diodes emitting in the blue and green spectral range indium contents of more than 20 % are required. To optimize the growth of InGaN QWs we have investigated the influence of the indium content on the gain characteristics and laser threshold. Optically pumped laser structures with emission wavelengths ranging between 395 nm and 450 nm were characterized. The laser heterostructures were grown by metalorganic vapor phase epitaxy (MOVPE) on (0001) sapphire substrates. The optical gain spectra were measured based on the variable stripe length method (VSLM). Laser structures with emission below 420 nm showed wavelength independent laser thresholds. A strong increase of the laser threshold and the width of the optical gain spectra was observed for longer wavelength and higher indium contents. This behaviour can be attributed to material inhomogeneities, defects and the quantum confined Stark effect (QCSE).

HL 2.3 Mon 10:45 BEY 118

Optimization of InGaN multiple quantum wells for blue lasers — •J.R. van Look[1], J. Schlegel[1], V. Hoffmann[2], A. Knauer[2], S. Einfeldt[2], M. Weyers[2], P. Vogt[1], and M. Kneissl[1,2] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Group III-nitride based lasers with emission targeted at the blue and green spectral region have attracted great interest in recent years. For the optimization of these indium-rich active regions, optically

pumped as well as current-injection InGaN quantum well lasers with varying indium content and well width have been investigated. The laser heterostructures were grown by metalorganic vapor phase epitaxy (MOVPE) on (0001) sapphire substrates. The resulting structures with emission wavelengths ranging from 390 nm to 480 nm have been examined. In this talk we will present theoretical as well as experimental results on the characteristics of these indium rich InGaN multi quantum well (MQWs) lasers. The effect of well width in correlation with indium content on gain characteristics and laser threshold will be discussed. For optically pumped lasers with wells containing between 15% and 20% indium we observed a significant increase of the threshold excitation density to as much as 500 kW/cm2. In device structures for blue emitters with 480 nm luminescence observed under low excitation conditions, the laser emission strongly blue-shifted to 450 nm, which can be attributed to the compensation of the quantum confined stark effect (QCSE) under high excitation conditions.

HL 2.4 Mon 11:00 BEY 118

Towards InGaN-based light emitters with superior high-current performance — •Ansgar Laubsch[1], Matthias Sabathil[1], Werner Bergbauer[1], Martin Strassburg[1], Matthias Peter[1], Hans Lugauer[1], Tobias Meyer[1], Joachim Wagner[2], Norbert Linder[1], Klaus Streubel[1], and Berthold Hahn[1] — [1]OSRAM Opto Semiconductors GmbH, Leibnizstrasse 4, 93055 Regensburg, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, 79108 Freiburg, Germany

The last decade has seen tremendous progress in the epitaxial growth and in advanced chip designs of light emitting diodes (LEDs) with InGaN/GaN quantum-well (QW) heterostructures. This recently enabled an efficiency for conversion of electrical to optical power of almost 60 % for a blue ThinGaN® LED at operation current. Still, the internal quantum efficiency of such devices peaks far below the operation current density and then decreases monotonously. Understanding of this mechanism is crucial to reach the ultimate limits in efficiency. We identify a QW internal high density Auger-like loss process as the culprit and model our data with a coefficient of $C = 3.5 \cdot 10^{-31}\mathrm{cm}^{-6}\mathrm{s}^{-1}$. Thick InGaN QWs and an optimized multi quantum well structure are ways to reduce the carrier density. We study the physics of recombination and carrier distribution in such structures. Consistent with simulations, both concepts exhibit reduced high current saturation. We thus conclude that regardless of the employed concept, a decrease in carrier density is central to improve the high current efficiency of InGaN based light emitters.

15 min. break

HL 2.5 Mon 11:30 BEY 118

Heterostructure design optimisation of deep (In)AlGaN ultraviolet light emitting diodes — •T. Sembdner[1], T. Kolbe[1], A. Knauer[2], V. Küller[2], S. Einfeldt[2], P. Vogt[1], M. Weyers[2], and M. Kneissl[1,2] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Ultraviolet light emitting diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. However, due to week carrier confinement, strong piezoelectric fields and high defect densities the external quantum efficiencie of ultraviolet LEDs is still in the lower percent range. Here we present a comparison of heterostructure design simulations and experimental results for deep ultaviolet (In)AlGaN-multiple quantum well (MQW) LEDs grown by metalorganic vapour phase epitaxy on (0001) sapphire substrates. The emission wavelength was found near 320nm for an active region comprised of (In)AlGaN quantum wells and (In)AlGaN barrier layers. For these structures the effects of the p-contact layer design, the electron blocking layer and the MQW active region on the external quantum efficiency is investigated. The latter influence is particularly important as our simulations have shown that a single quantum well LED has a higher radiative rekombination rate in comparison with a MQW LED.

HL 2.6 Mon 11:45 BEY 118

Barrier alloy composition and polarization control in nitride light emitters — •Christoph Hums, Aniko Gadanecz, Armin Dadgar, Jürgen Bläsing, Alexander Franke, Thomas Hempel, Jürgen Christen, and Alois krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Although InGaN based light emitting diodes (LEDs) have been commercialized for general lighting applications and displays, they suffer from reduction in efficiency and a pronounced luminescence blue shift at high injection current levels. This behavior can be attributed to the strong polarization fields in c-direction of the active region and the associated quantum confined stark effect (QSCE). To reach higher external quantum efficiencies (EQE) the reduction of the polarization fields is inevitable. Most attempts in reducing the internal fields target on switching the direction of the quantum wells (QWs) from c-plane in a direction with reduced fields (e.g. a-plane). A new approach is polarization control by new barrier- and QW-materials as the ternary AlInN and the quaternary AlInGaN. We will present calculations of the internal polarization fields in the proposed structures, which allow an estimate of the needed alloy compositions. Then the growth of AlInN with high indium content will be discussed. The limits of indium incorporation, the critical layer thickness on GaN and its impact on the novel structures will be displayed.

HL 2.7 Mon 12:00 BEY 118

Phonon-assisted contributions to the Auger losses in InGaN quantum wells — •Bernhard Pasenow[1], Stephan W. Koch[1], Jörg Hader[2], and Jerome V. Moloney[2] — [1]Department of Physics and Materials Sciences Center, Philipps Universität Marburg, Renthof 5, 35032 Marburg, Germany — [2]Nonlinear Control Strategies Inc., 3542 N. Geronimo Ave., Tucson, AZ 85705 and Optical Sciences Center, University of Arizona, Tucson, Arizona 85721

The external quantum efficiency (EQE) of typical GaN-based light emitting diodes shows a maximum at very low pump currents and then decreases, often to only half that value for pump currents desired for applications. The reason for this effect is the loss of a significant fraction of the carriers pumped into the structure. One possible origin of this EQE-droop – beside some others like carrier leakage – is the carrier recombination through non-radiative Auger processes.
In our talk, we present a microscopic theory which is capable of describing non-radiative Auger losses in InGaN quantum wells. Since the calculated direct band-to-band Auger contributions are too small [1] in comparison to measurements, we focus on the phonon-assisted losses presenting details on our theoretical model, the structure of the Auger loss equations and numerical results.

[1] J. Hader, J.V. Moloney, B. Pasenow, S.W. Koch, M. Sabathil, N. Linder, and S. Lutgen, Appl. Phys. Lett. 92, 261103 (2008)

HL 3: Heterostructures

Time: Monday 10:15–12:45 Location: BEY 154

HL 3.1 Mon 10:15 BEY 154

Optical Modes in ZnO Nano-Pillar Resonators — •Annekatrin Hinkel, Rüdiger Schmidt-Grund, Helena Hilmer, Jesús Zúñiga Pérez, Chris Sturm, Christian Czekalla, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig, Germany

We report on cylindrical resonators, whose cavities are made of ZnO nano-wires with diameters of (50 ... 700) nm and length in the range of 10 μm . The cavities, simultaneously acting as active medium, are coated with concentric cylindrical shell Bragg reflectors (BR) consisting of 10.5 pairs of YSZ and Al_2O_3. The ZnO nano-wires and the BRs have been fabricated by using two-step pulsed laser deposition in the high- and low-pressure regime, respectively. Both, photoluminescence and reflectivity measurements were performed on the lateral surface of the wires in dependence on the wire diameter, the temperature and the exit angle and polarization of the light. The spectroscopic features can be assigned to exciton-polariton branches in photonic wires.

Exciton-polaritons are a subject of current research. Because of its large exciton oscillator strength and binding energy, polaritons in ZnO

are stable at room temperature and above. In photonic wires the photonic modes are 2D quantized, leading to modification of spontaneous emission and radiative recombination rates with respect to the 1D quantized case. Especially, lateral leakage of energy can be strongly restricted. Furthermore, the amount of polariton branches is increased. As interbranch scattering is possible, condensation of polaritons in the ground state would be enhanced.

HL 3.2 Mon 10:30 BEY 154

Successful fabrication of h-BN/ZnO heterojunction diodes — •Marc Brötzmann, Hayo Zutz, Anne-Katrin Nix, and Hans Hofsäss — II. Institute of Physics, University of Göttingen

In this work we investigated the electrical properties of h-BN/ZnO-heterostuctures. For this purpose several h-BN-films with thicknesses between 60nm and 80nm were grown on ZnO-substrates using Mass Separated Ion Beam Deposition (MSIBD). The deposition was performed with a substrate-bias of 100eV at room temperature.

The electrical properties were investigated using a two point measurement to record current-voltage (I-U) characteristics in the temperature range of 20-300K. The devices show a distinctive diode characteristic with threshold voltages of 6-8V and breakdown voltages of about 60-80V. We can not verify any satisfying agreement with common conduction mechanisms; therefore an extended conduction model based on the Shockley theory has been developed. In addition we observe huge ideality factors in the range of 75-160 due to high defect density (verified using Transmission Electron Microscopy measurements) and a resulting strong recombination current.

In this presentation we will discuss the development of the conduction model on the basis of temperature dependent I-U characteristics and TEM-measurements. In Addition, first results on photoconductivity behavior are also presented.

HL 3.3 Mon 10:45 BEY 154

Formation of Exciton-Polaritons up to 410 K in ZnO based planar resonators — •Chris Sturm, Helena Hilmer, Rüdiger Schmidt-Grund, Christian Czekalla, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Exciton-polaritons are quasi particles formed by the coupling of excitons with photonic modes. They can undergo a Bose-Einstein-Condensation (BEC) even at elevated temperatures; for ZnO based resonators the critical temperature at which BEC can occur was predicted up to 560 K. In this work we will present the observation of exciton-polaritons in a ZnO based resonator up to 410 K. This represents the first observation of exciton-polaritons above room temperature. The resonator consists of a half wavelength ZnO microcavity [1] embedded between two Bragg reflectors made of 10.5 layer pairs of YSZ and Al_2O_3. The exciton-polaritons were observed by means of photoluminescence (PL) and reflectivity (R) measurements at temperatures $(10 - 410)$ K. Taking into account the coupling between only one exciton mode and one cavity-photon mode we were able to describe the observed polariton dispersion as well as its broadening behaviour. Thereby, we obtain a Rabi splitting of about 95 meV (R) and about 90 meV (PL) at 10 K. Furthermore, non-resonant excitation dependent PL measurements of the resonator yield a saturation of the occupation of the ground state, i.e. there is a saturation of the relaxation from an excited state to the ground state.

[1] R. Schmidt-Grund *et al.*, Appl. Phys. B **93**, 331 (2008).

HL 3.4 Mon 11:00 BEY 154

Influence of strain on Mn codoped 2DHGs — •Ursula Wurstbauer[1,2], Stefan Knott[1], Werner Wegscheider[2], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, 220355 Hamburg — [2]Institut für Experimentelle und Angewandt Physik, Universität Regensburg, 93040 Regensburg

The properties of two-dimensional hole gases (2DHG) in a strained InAs quantum well structure strongly depend on the interaction of magnetic moments with itinerant holes. For low-temperature magnetotransport experiments weakly Mn codoped InAs QWs with InGaAs/InAlAs barriers and modulation-doped with Mn and/or C are grown on (001) GaAs substrates by means of molecular beam epitaxy. Metamorphic step graded buffer layers are used for strain engineering. The strain in the doping layer and QW can be precisely tailored by changing the In concentration in the buffer and the distance between buffer and active region. In the magnetic 2DHGs the strain plays an important role because band structure, incorporation of the Mn ions as well as orientation of their magnetic moments are strongly affected by the strain situation in the active QW region. We report on a detailed study of the impact of strain on morphology, doping efficiency and low-temperature magnetoresistance behaviour of such Mn co-doped 2DHGs.

HL 3.5 Mon 11:15 BEY 154

Dynamics of Dipolar Excitons in Coupled GaAs Quantum Wells — •Xaver Vögele[1], Dieter Schuh[2,3], Werner Wegscheider[2], Alexander Holleitner[1,3] und Jörg Kotthaus[1] — [1]Center for NanoScience, Ludwig-Maximilians-Universität, D-80539 München — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg — [3]Technische Universität München, Walter Schottky Institut, 85748 Garching

Photo-generated electron-hole pairs in double quantum well devices can be manipulated both in lifetime and position via a mesoscopic voltage-controlled electrostatic landscape. The quantum-confined Stark effect allows us to create long-living indirect excitons[1].

Recently, we demonstrated a novel electrostatic trap for indirect excitons in coupled GaAs quantum wells embedded in a field-effect device. There, the indirect excitons are trapped in the quantum wells just below the perimeter of SiO2-layers, which are sandwiched between the surface of the GaAs heterostructure and a semitransparent metallic top gate[2].

Here, we present time resolved measurements on the dynamics of the excitons inside the trap. We find that the expansion of the trapped excitons occurs on a much shorter time-scale than in the untrapped case. We attribute this to effective screening of quantum well disorder.

Financial support: Center for NanoScience (CeNS), the Nanosystems Initiative Munich (NIM), and the DFG Project KO 416/17.

[1] A. Gärtner et al. Appl. Phys. Lett 89, 052108 (2006). [2] A. Gärtner et al. Phys. Rev. B 76, 085304 (2007).

15 min. break

HL 3.6 Mon 11:45 BEY 154

High-Quality AlGaAs/GaAs Quantum Well-Microcavities for Exciton-Polariton Studies — •Arash Rahimi-Iman[1], Georgius Roumpus[2], Christian Schneider[1], Sven Höfling[1], Stephan Reitzenstein[1], Alfred Forchel[1], and Yoshihisa Yamamoto[2] — [1]Technische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [2]E. L. Ginzton Laboratory, Stanford University, Stanford, CA 94305-4088, USA

In a semiconductor microcavity with embedded quantum wells (QWs) new eigenmodes are formed called the polaritons when the confined cavity photon modes strongly couple to the QW excitons. Cavity polaritons and their ability to undergo Bose-Einstein condensation have been intensively studied in the last decade. As quasiparticles in semiconductors, polaritons have typically relatively short lifetimes, thus it is generally difficult to cool hot polaritons to the lattice temperature before they decay. Significantly higher polariton lifetimes would allow further progress in this field, e.g., the generation of a condensate in thermal equilibrium featuring macroscopic coherence.

We report on the observation of polaritons in an optically pumped planar high-quality (high-Q) AlGaAs/GaAs microcavity containing 12 GaAs QWs in a 3/2 λ AlAs cavity sandwiched between a lower and an upper distributed Bragg reflector with 32 and 36 mirror pairs, respectively. Moreover, time resolved photoluminescence from the lower polariton branch was measured with a streak camera in order to estimate the photon lifetime τ_{ph} and the Q-factor of the cavity, respectively. Thereby, a Q-factor of $> 10,000$ was determined for cavity photons.

HL 3.7 Mon 12:00 BEY 154

Internal quantum confined Stark effect in embedded IV-VI semiconductor nanodots — •Roman Leitsmann[1], Frank Ortmann[1], Friedhelm Bechstedt[1], Wolfgang Heiss[2], and Friedrich Schäffler[2] — [1]European Theoretical Spectroscopy Facility (ETSF) and Institut für Festkörpertheorie und -optik, Friedrich-Schiller Universität Jena, Germany — [2]Institut für Halbleiter- und Festkörperphysik, Johannes-Kepler-Universität Linz, Austria

The characterization of nanostructure properties versus dimension is of increasing importance for the nanotechnology. Especially the stoichiometry, geometry, and the electronic states of IV-VI semiconductor nanodots are of special interest [1,2]. We use ab initio methods to calculate structural and electronic properties of PbTe nanodots embedded in a CdTe semiconductor matrix as a function of the dot diameter.

The arrangement of polar dot-matrix interfaces induces an electrostatic field, which strongly influences the geometric and electronic properties and reduces the symmetry of the system. In particular, the localization of HOMO (highest occupied molecular orbital) and LUMO (lowest unoccupied molecular orbital) states at opposite nanodot corners can be explained by an internal quantum confined Stark effect (IQCSE) [3]. Using a parabolic model potential for the electron and hole confinement it can be shown that the IQCSE lead to a strong reduction of the integrated photoluminescence yield at low temperatures.

[1] New J. Phys. 8, 317 (2006) [2] JACS 128, 3516 (2006); JACS 129, 11354 (2007) [3] Phys. Rev. B 78, 205324 (2008)

HL 3.8 Mon 12:15 BEY 154

Tight-binding CPA Theory of Semiconductor Alloys — •Daniel Mourad und Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen

Alloys of the type A_xB_{1-x} can be realized for a wide class of semiconductor materials, e.g. for $Al_xGa_{1-x}As$, $In_xGa_{1-x}As$, $Cd_xZn_{1-x}Se$, Si_xGe_{1-x} ,$Al_xGa_{1-x}N$, $Ga_xIn_{1-x}N$, and many others. These substitutional semiconductor alloys find widespread applications in particular in nanoelectronic devices as quantum wells, quantum wires and quantum dots (QDs), as the band gap varies continuously with x, and therefore a band structure tayloring is possible by varying x. To calculate the electronic properties of such semiconductor alloys we start from multiband (sp^3) tight-binding (TB) models for the pure bulk semiconductor material A and B and apply the coherent potential approximation (CPA) to calculate the (configurationally averaged) electronic density of states and effective band structure. This treatment allows, in particular, for a reproduction of band bowing effects as a function of the concentration x and leads automatically to finite lifetime effects due to the loss of translational invariance. We compare the CPA results with results obtained in the much simpler virtual crystal approximation (VCA) and with ensemble averaged finite supercell calculations. Additionally, the application to QDs by combining this CPA-TB treatment with the recently developed TB models of nanostructures is hinted.

HL 3.9 Mon 12:30 BEY 154

Inhomogeneous and homogeneous broadening of excitonic spectra due to disorder — •Noemi Gögh[1], Peter Thomas[1], Irina Kuznetsova[1], and Torsten Meier[2] — [1]Department of Physics and Material Sciences Center, Philipps University Marburg — [2]Department of Physics, University Paderborn

In a disordered semiconductor heterostructure the excitonic line is both homogeneously and inhomogeneously broadened. While it is evident that disorder is responsible for inhomogeneous broadening, it is less obvious that disorder also contributes to homogeneous broadening (disorder-induced dephasing). We apply a one-dimensional tight-binding model of a disordered semiconductor. The optical polarization is calculated for a large number of configurations of the disorder potential and an ensemble average is performed at the end. We focus on homogeneous broadening due to disorder. Excitonic states in a disordered semiconductor are mutually coupled in the sense of Fano-resonances. At a certain spatial position the dominant energetic low-lying transition (corresponding to the 1s-exciton in an ordered three-dimensional situation) may be degenerate with the center-of-mass continuum of neighbouring excitonic transitions. Coupling of these states due to disorder, leading to homogeneous broadening, can be identified by Two-Dimensional-Fourier-Transfom-Spectroscopy (2DFTS), a variant of Four-Wave-Mixing. In order to illustrate the spectral features originating from such Fano situations, 2DFT-spectra are calculated first for conventional Fano situations. Then spectra of the disordered semiconductor model are interpreted in terms of Fano-coupling.

HL 4: II-VI semiconductors

Time: Monday 10:15–12:45 Location: POT 51

HL 4.1 Mon 10:15 POT 51

Monolithic distributed Bragg reflectors and microcavities lattice matched to ZnTe — •Wojciech Pacuski[1,2], Carsten Kruse[1], Stephan Figge[1], Tomasz Jakubczyk[2], Andrzej Golnik[2], Jan Gaj[2], and Detlef Hommel[1] — [1]Institute of Solid State Physics, University of Bremen, Postfach 330 440, D-28334 Bremen, Germany — [2]Institute of Experimental Physics, University of Warsaw, Hoza 69, PL-00-681 Warszawa, Poland

A distributed Bragg reflector (DBR) is a high quality mirror based on alternating layers with high and low refractive index. In a monolithic DBR made of semiconductors both layers should have the same lattice parameter, what makes the design and fabrication of such structures quite challenging. For the first time we present a monolithic distributed Bragg reflector with lattice parameter matched to ZnTe. It can be deposited on a ZnTe substrate with high crystalline quality.

Our DBRs were grown using molecular beam epitaxy (MBE) on a 1μm thick fully relaxed ZnTe buffer layer deposited on GaAs substrate. New materials presented in our work allow us to reach a high refractive index step $\Delta n = 0.5$. It results in a broad spectral stopband exceeding 60 nm width and in reflectivity coefficient as high as 99% (for only 15 DBR pairs). We are motivated by applications (e.g. lasers, detectors) for the orange and red spectral range; therefore our structures are designed for wavelengths close to 650 nm. In order to confirm the suitability of the structures for device applications, we realized a microcavity, which consists of a λ cavity sandwiched between two DBRs. It has a Q value exceeding 500.

HL 4.2 Mon 10:30 POT 51

Temperature dependent Raman scattering experiments of CdSe nanorods — •Patryk Kusch[1], Holger Lange[1], Mikhail Artemyev[2], and Christian Thomsen[1] — [1]TU-Berlin, Institut für Festkörperphysik, Berlin, Germany — [2]Institute for Physico-Chemical Problems, Belarusian State University, Minsk, Belarus

We present temperature dependent Raman scattering experiments of different sized colloidal CdSe nanorods. We monitor the dependence of the temperature on the longitudinal optical phonon (LO) related Raman band. The LO frequency shows a red shift with increasing temperature. This is consistent with a theoretical model from Balkanski et al.[1]. The exact influence of the sample temperature on the Raman spectra also depends on the nanorod geometry. The results are used to examine the interaction of phonon confinement and temperature effects. Furthermore the heat stability of the colloidal nanorods is investigated in order to examine their suitability for high temperature environments.

[1] M. Balkanski, R.F. Wallis and E. Haro, Phys. Rev. B28 (1983) 1928.

HL 4.3 Mon 10:45 POT 51

High temperature magnetic polaron formation in Mn-doped CdSe nanoparticles — Lars Schneider[1], •Gerd Bacher[1], Rémi Beaulac[2], Paul Archer[2], and Daniel R. Gamelin[2] — [1]Werkstoffe der Elektrotechnik und CeNIDE, Universität Duisburg-Essen, 47057 Duisburg — [2]Department of Chemistry, University of Washington Seattle, WA 98195-1700 (USA)

Transition metal doped semiconductor nanoparticles have attracted great interest because of their high application potential in spintronics and optoelectronics. E.g., doping with Manganese (Mn) can create interesting magnetooptical effects in CdSe nanoparticles [1]. Here we present time resolved photoluminescence (PL) measurements on size selected Mn-doped CdSe nanoparticles from the liquid phase. Nanoparticles with a mean particle diameter of 5nm and a Mn-content of 4.2% show at T = 5K a huge transient red shift of about 140 meV in contrast to less than 30 meV observed in CdSe reference nanoparticles of similar size. We attribute this to the formation of an exciton magnetic polaron (EMP)with a large internal exchange field. From the transient energy shift we are able to extract a characteristic time constant of 150 ps, which fits quite well to the magnetic polaron formation in self organized CdSe/ZnMnSe quantum dots [2]. Although the transient energy shift gets weaker with increasing temperature, a clear indication of magnetic polaron formation even above 200K is observed demonstrating the highest temperature ever obtained for EMP formation. [1]Beaulac et al., Nanoletters, 8 (2008), 1197. [2]Seufert et al., Phys. Ref. Lett., 88 (2002) 027402

HL 4.4 Mon 11:00 POT 51

Lifting of the fundamental cavity mode polarization degeneracy in CdSe/ZnSSe-quantum dot monolithic microcavities — •Moritz Seyfried, Joachim Kalden, Kathrin Sebald, Jürgen Gutowski, Arne Gust, Carsten Kruse, and Detlef Hommel — Institue of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

Lifting polarization degeneracy of the fundamental cavity mode in a quantum dot (QD)-based microcavity (MC) would allow to control the polarization state of the emitted photon in single-photon emitters. To realize devices in the blue to green spectral region, CdSe QDs were embedded in a monolithic ZnSSe based VCSEL structure grown by molecular beam epitaxy. Circular pillar MCs with diameters in the range from 500 nm up to 4000 nm were prepared by focused-ion-beam etching. Polarization dependent investigations of the fundamental cavity mode reveal a lifting of its degeneracy concerning the polarization. By an appropriate adjustment of the polarizer the two orthogonally polarized components of the fundamental mode can be observed individually with an energy splitting of up to 0.42 meV and quality factors of up to 7800. In any polarization orientation in between a superposition of both modes is detectable. Furthermore, an increase of the energy splitting with increasing pillar diameter is observed. As the MCs are nearly perfectly circular, a lifting of the mode degeneracy due to an elliptical cross-section of the pillars is very unlikely. Therefore, the existence of strain within the MCs as origin of the mode degeneracy is considered and tested by studying the influence of annealing.

HL 4.5 Mon 11:15 POT 51

High quality junctions by interpenetration of vapor liquid solid grown nanostructures for microchip integration. — Seid Jebril[1], Hanna Kuhlmann[1], Sven Müller[2], Carsten Ronning[3], Lorenz Kienle[4], Viola Duppel[5], and •Rainer Adelung[1] — [1]Funktionale Nanomaterialien, CAU Kiel, Kaiserstr. 2, D-24143 Kiel — [2]Nanowires and thin films, II. Physikalisches Institut, Friedrich-Hund-Platz 1, D-37077 Göttingen — [3]Institute for Solid State Physics, Universität Jena, Max-Wien-Platz 1, D-07743 Jena — [4]Synthese und Realstruktur, CAU Kiel, Kaiserstr. 2, D-24143 Kiel — [5]MPI für Festkörperforschung, Heisenbergstr. 2, D-70569 Stuttgart

The usability of nanostructures in electrical devices like gas sensors depends critically on the ability to form high quality contacts and junctions. For the fabrication of various nanostructures, vapor-liquid-solid (VLS) growth is a wide spread and very efficient technique. However, forming contacts with the VLS grown structures to utilize them in a device is still tedious, because either the substrate has to be epitaxial to the VLS material or a manual alignment is necessary. Here we demonstrate the contact formation by simply using the ability of individual crystals to interpenetrate each other during the straight forward VLS growth. This allows growing VLS structures directly on two neighboring gold circuit paths of a microchip; bridges over predefined gaps will be formed. Moreover, TEM investigations confirm the high quality of the crystalline junctions that allow demonstrations as UV and hydrogen-sensor. The VLS devices are compared with conventional produced [1] ZnO nanowires. [1] S. Jebril et al. Small,(2008)in press

15 min. break

HL 4.6 Mon 11:45 POT 51

Zeitaufgelöste Spektroskopie von magnetischen Polaronen in CdMnSe/CdMgSe Quantengräben — •Tillmann Godde[1], Irina I. Reshina[2], Sergey V. Ivanov[2], Ilya A. Akimov[1,2], Dmitri R. Yakovlev[1,2] und Manfred Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute RAS, 194021 St. Petersburg, Russia

Ein magnetisches Polaron beschreibt eine lokale ferromagnetische Ausrichtung, die aus der starken Wechselwirkung des magnetischen Moments eines elektrischen Ladungsträgers mit den Spins lokalisierter magnetischer Ionen resultiert. Die Dynamik eines magnetischen Exziton-Polarons wurde erstmals in semimagnetischen CdMnSe/CdMgSe Quantengräben untersucht. Mittels zeitaufgelöster Photolumineszens-Spektroskopie auf einer Pikosekundenskala wurden die Abhängigkeiten der Bildungs- und Lebensdauer sowie die Energie des magnetischen Polarons in Magnetfeldern bis zu 7 T und bei Temperaturen von 1,9 bis 25 K bestimmt. Die Bildungsdauer der magnetischen Polaronen liegen in dem Bereich von 100-400 ps. Die Energie von 15 meV des Polarons wurde direkt durch eine selektive Anregungstechnik gemessen und durch weitere Methoden bestätigt.

HL 4.7 Mon 12:00 POT 51

Accelerated, two-staged spin-lattice relaxation in (Zn,Mn)Se quantum wells — •Jörg Debus[1], Vitalii Yu. Ivanov[2], Andrei A. Maksimov[3], Dmitri R. Yakovlev[1], and Manfred Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland — [3]Institute of Solid State Physics, Russian Academy of Sciences, 142432 Chernogolovka, Russia

The dynamics of spin-lattice relaxation of the Mn ions in (Zn,Mn)Se-based diluted magnetic semiconductor quantum wells with low Mn concentration ($\leq 2\%$) is studied by time-resolved photoluminescence.

The quantum well magnetization is determined by single Mn ions as well as spin clusters with antiferromagnetically coupled Mn ions. Pair and triple clusters with next nearest neighbour ions acting as fast relaxing centers contribute to the energy transfer from the Mn system to the lattice via two-phonon Orbach transitions, resulting in a two-staged spin-lattice relaxation process. The efficiency of both processes is influenced by the Mn concentration, strength of applied magnetic field and optical excitation density.

A further impact of next nearest neighbour spin clusters on the spin-phonon interactions is revealed in cusps in the static and dynamic quantum well magnetization at specific magnetic fields below 10 T. The cusps correspond to an additional cooling of the Mn spin temperature due to a crossing of Zeeman-splitted cluster spin levels. Consequently, the emission of resonant phonons causes an acceleration of the spin-lattice relaxation.

HL 4.8 Mon 12:15 POT 51

Einfluss eines stöchiometriebedingten *p*-*n*-Übergangs auf die Diffusion in CdZnTe — •J. Kronenberg[1], F. Wagner[1], H. Wolf[1], Th. Wichert[1] und ISOLDE Collaboration[2] — [1]Technische Physik, Universität des Saarlandes, 66123 Saarbrücken — [2]CERN, PH Department, 1211 Genf

In früheren Studien wurde gezeigt, dass die Diffusion von Ag und Cu in CdTe ungewöhnliche Konzentrationsprofile aufweist [1]. Nach einseitiger Implantation und anschließender Diffusion unter Cd-Dampfdruck entsteht ein bzgl. der Probenmitte (Dicke ca. 800 μm) symmetrisches, peakförmiges Profil. Notwendig dazu ist Te-reiches, *p*-leitendes Material, das durch die thermische Behandlung unter Cd-Druck in Cd-reiches, *n*-leitendes Material umgewandelt wird. Liegen bei der Diffusionstemperatur die Dotieratome hauptsächlich als positiv geladene, hoch mobile Zwischengitteratome vor, so spiegelt das Konzentrationsprofil das Profil der Fermienergie wider. Dabei zeigen dessen Flanken die aktuelle Position des *p*-*n*-Übergangs zwischen Te reichem und Cd reichem Material an. Mittlerweile wurden auch für Au und Na in CdTe nahezu dieselben Eigenschaften beobachtet. Auch Co und Ni zeigen ungewöhnliche Diffusionsprofile, unterscheiden sich jedoch deutlich von denen für Ag, Cu, Na und Au. Die beobachteten kastenförmigen Profile reichen von der implantierten Oberfläche bis hin zum jeweiligen *p*-*n*-Übergang. Ursachen für die Entstehung der kastenförmigen Profile werden diskutiert.

Gefördert durch das BMBF, Projekt 05 KK7TS1

[1] H. Wolf *et al.*, Phys. Rev. Lett. **94** (2005) 125901

HL 4.9 Mon 12:30 POT 51

Homo- and heteroepitaxial growth of ZnS — •Udo Roemer, Stefan Lautenschlaeger, Sebastian Eisermann, Oliver Graw, Joachim Sann, Melanie Pinnisch, Andreas Laufer, and Bruno K. Meyer — Ist phisics institute, Justus Liebig University Gießen

ZnS in its zincblende structure has a direct bandgap of 3.6 eV at room temperature. As material for optoelectronic applications it possesses some advantages, for example the absence of crystal fields or piezoelectricity, compared to GaN or ZnO. So far there are only a handful of publications dealing the ZnS thin film growth, up to this work no homoepitaxial growth approach has been studied. We used both, ZnS single crystal substrates and GaP single crystal substrates to investigate the CVD growth of ZnS thin films. The grown epilayers have been studied using low temperature photoluminescence (PL), X-ray diffraction (XRD), Atomic Force Microscopy (AFM) and Secondary Ion Mass Spectroscopy (SIMS).

HL 5: Photovoltaic

Time: Monday 10:15–13:15 Location: POT 151

HL 5.1 Mon 10:15 POT 151

Spatially resolved photoluminescence measurements for a comparative analysis of $CuInS_2$ and $Cu(In,Ga)S_2$ thin films — •Florian Heidemann[1], Levent Gütay[1], Rudolf Brüggemann[1], Saoussen Merdes[3], Alexander Meeder[2], and Gottfried H. Bauer[1] — [1]Institute of Physics, CvO University Oldenburg, Germany — [2]SULFURCELL Solartechnik GmbH, Berlin, Germany — [3]Helmholtz-Zentrum Berlin, Germany

At present chalcopyrite semiconductors like $Cu(In,Ga)Se_2$ and $Cu(In,Ga)S_2$ are most promising absorbers for thin film solar cells. Due to their grainy structure and inhomogeneous growth they show considerable degrees of spatial inhomogeneities in structural, optical and optoelectronic properties in the length scale of grain sizes. To analyze these locally fluctuating magnitudes we have performed spectrally resolved luminescence measurements with a high lateral resolution ($\leq 1\mu$m) in a confocal microscope setup. This makes the determination of the spatial variation in the splitting of the quasi-Fermi levels ($\mu = E_{Fn} - E_{Fp}$) as well as the local absorbance of the material possible. A comparison of these properties, which are crucial for the solar light conversion efficiency, is made for $CuInS_2$ and $Cu(In,Ga)S_2$ absorber layers for data obtained from statistically representative scan areas. The results show that an increase in bandgap and the mean μ due to an incorporation of gallium does not come along with a decrease in the variation of μ over the absorber layer. A quantification of the lateral patterns of constant μ by Minkowski-operations indicates similar pattern sizes in the range of a few μm for the analyzed samples.

HL 5.2 Mon 10:30 POT 151

Diffusion processes and chemical changes at the (Zn,Mg)O/ $CuIn(S,Se)_2$ interface caused by RF magnetron sputtering deposition — •Felix Erfurth[1], Benjamin Hussmann[1], Lothar Weinhardt[1], Achim Schöll[1], Friedrich Reinert[1], Eberhard Umbach[1,2], Thomas Niesen[3], Jörg Palm[3], Sven Visbeck[3], Alexander Grimm[4], Iver Lauermann[4], and Reiner Klenk[4] — [1]Universität Würzburg, Experimentelle Physik II, 97074 Würzburg — [2]Forschungszentrum Karlsruhe GmbH, 76133 Karlsruhe — [3]Avancis GmbH & Co. KG, 81739 München — [4]Helmholtz Zentrum Berlin für Materialien und Energie, 14109 Berlin

(Zn,Mg)O buffer layers on $Cu(In,Ga)(S,Se)_2$ thin film solar cells are a promising alternative to CdS buffer layers. Although in the past the radio frequency magnetron sputtering deposition on (Zn,Mg)O has been empirically optimized to reach high efficiencies, only little is known about the influence of the sputter parameters on the electronic and chemical structure of the absorber/buffer interface. We have used in-situ X-ray Photoelectron Spectroscopy (XPS) and X-ray induced Auger Electron Spectroscopy (XAES) to analyze the influence of different sputter parameters and to compare samples prepared by different groups.

All samples show the formation of indium oxide and zinc - sulfur/selenide bonds at the buffer/absorber interface. Moreover, the hydroxide/oxide ratio at the interface is strongly increased as compared to the respective ratio in the bulk. Further studies showed a diffusion of sodium to the surface for thin (Zn,Mg)O layers.

HL 5.3 Mon 10:45 POT 151

Mikroskopische Lumineszenzeigenschaften von polykristallinen $CuInS_2$-Dünnschichten — •Anja Dempewolf[1], Frank Bertram[1], Alexander Franke[1], Thomas Hempel[1], Jürgen Christen[1], Joachim Klaer[2], Frank Wünsch[2] und Thomas Schedel-Niedrig[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie

Die Lumineszenzeigenschaften von sowohl unpassivierten als auch Si_xN- und ZnO/CdS-passivierten polykristallinen $CuInS_2$-Dünnschichten (CIS) für die Anwendung als Absorbermaterial in Solarzellen wurden mittels orts-, zeit- und spektral aufgelöster Kathodolumineszenz (KL) und spektral aufgelöster Photolumineszenz (PL) untersucht. Die auf einem Glassubstrat mit gesputtertem Mo-Kontakt durch ein RTP-Verfahren *(rapid thermal processing)* hergestellten CIS-Schichten besitzen eine Dicke von etwa 2,1 μm und weisen eine körnige Oberflächenmorphologie auf. Das integrale Tieftemperatur-KL-Spektrum (5 K) des CIS wird durch eine exzitonische Lumineszenz um 1,5 eV dominiert. In lokal aufgelösten Spektren lässt sich in einem Energiebereich von 1,35 eV bis 1,56 eV eine Vielzahl von einzelnen Emissionslinien identifizieren, die vor allem gebundenen Exzitonen und Donator-Akzeptor-Übergängen zugeschrieben werden. Allgemein zeigen die untersuchten Schichten in der Intensität und Emissionsenergie eine inhomogene Lumineszenzverteilung. So weichen die Lumineszenzeigenschaften individueller Körner als auch verschiedener Facetten eines einzelnen Korns signifikant voneinander ab.

HL 5.4 Mon 11:00 POT 151

Spectral Response of $CuIn_{1-x}Ga_xSe_2$ Heterodiodes Operated at Constant V_{OC} and Constant I_{SC} Compared with Traditionally Recorded Spectral Quantum Yield — •Sven Burdorf, Rudolf Brüggemann, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg D-26111 Oldenburg, F.R. Germany

Traditional spectral response experiments in solar cells, such as quantum yields show the dependence of the excess carrier contribution and respective recombination on the depth of the device in terms of the profile of the optical generation. However, this depth information is masked by the condition of current continuity that is met by contributions of minority as well as majority carriers across the entire depth of the device and commonly the information on local properties is not reflected straightforwardly. In our approach - analogously to the concept of the constant photocurrent method (CPM) - we have adjusted either constant V_{OC} (c-Voc) or I_{SC} (c-Isc) by recording the spectral photon fluxes necessary for these conditions. In particular in Voc operation excess carriers recombine exclusively within the device and thus the signal is more sensitive against recombination. Our results of the c-Voc and c-Isc experiments for CIGSe-heterodiodes show significant differences particularly in the short-wavelength regimes. The comparison of experimental results with numerical modeling shows that this difference is growing larger with increasing interface recombination.

15 min. break

HL 5.5 Mon 11:30 POT 151

Performance of InGaAsP/InGaAs tandem solar cells with an InGaAs/GaAsSb tunnel junction — •Erol Sagol, Nadine Szabo, Ulf Seidel, Christian Höhn, Klaus Schwarzburg, and Thomas Hannappel — Helmholtz-Zentrum Berlin, Glienicker Str. 100, 14109 Berlin-Germany

Three types of state-of-the-art III-V triple-junction solar cells have already surpassed the 40% efficiency mark, despite having non-optimized band gaps. But still considerably higher efficiencies can be achieved with a four-junction configuration, which has optimized band gaps around 1.9, 1.4, 1.0 and 0.7 eV. This can be realized with a mechanically stacked GaAs-based GaInP/GaAs tandem and an InP-based InGaAsP/InGaAs tandem cell. For this purpose, we grew InGaAsP/InGaAs tandem solar cells lattice-matched to InP by MOVPE. The InGaAs bottom cell (0.73 eV) and the InGaAsP top cell (1.03 eV) were connected with a tunnel junction, which was composed of highly doped n-InGaAs and p-GaAsSb layers. In order to evaluate the performance of the tunnel junction, separate devices were grown without the photoactive layers. High current densities of several thousand A/cm2 were achieved already in the bias regime of several 100 mV. Hence, voltage losses in the tunnel diode should not be of concern for the solar cell even under extreme concentration ratios (> 1000 suns). Our results show that the contribution of such a low band gap InGaAsP/InGaAs tandem bottom cell, reaching efficiencies above 10% under GaAs, is considerably higher than a conventional germanium subcell.

HL 5.6 Mon 11:45 POT 151

3D photonic crystal interlayers for mircomorph thin film silicon tandem cell — Andreas Bielawny[1], •Johannes Üpping[1], Paul T. Miclea[1], Ralf B. Wehrspohn[1], Carsten Rockstuhl[2], Falk Lederer[2], Marius Peters[3], Lorenz Steidl[4], Rudolf Zentel[4], Seung-Mo Lee[5], Mato Knez[5], Andreas Lambertz[6], and Reinhard Carius[6] — [1]Institute of Physics, mikroMD, University of Halle Wittenberg — [2]Institue of Physics, Solid States Optics, University of Jena — [3]Freiburg Centre for Material Research, University of Freiburg — [4]Dept. of Chemistry, Pharmacy and Earth Sci-

ence, University of Mainz — [5]Max Planck Institute of Microstructure Physics Halle — [6]Institute of Energy Research, IEF-5 Photovoltaics, Forschungszentrum Jülich GmbH

The concept of 3D photonic intermediate reflectors for micromorph silicon tandem cells has been investigated toward first prototype cells. The reflector enhances the absorption of spectrally selected light in the top cell and decreases the current mismatch between both junctions. Our device is an inverted opal structure made of ZnO and built using self organized nanoparticles and atomic layer deposition coating methods. This 3D photonic crystal intermediate layer is less dependent of the angle of incidence than other state of the art thickness dependent massive interlayers. We present design rules, preparation and characterization of a 3D photonic thin film device. A first prototype is compared to a state of the art reference silicon tandem cell.

HL 5.7 Mon 12:00 POT 151

Silicon nitride passivation of phosphorus highly doped emitters for p-type silicon solar cells — •Kamal Katkhouda[1,2], Karsten Meyer[1], Kevin Lauer[3,2], Roman Petres[4], Sviatoslav Shokhovets[2], and Gerhard Gobsch[2] — [1]ersol Solar Energy AG, Wilhelm-Wolff-Str. 23, 99099 Erfurt, Germany — [2]TU Ilmenau, Institut für Physik, Weimarer Str. 32, 98693 Ilmenau, Germany — [3]CiS Forschungsinstitut für Mikrosensorik und Photovoltaik GmbH, SolarZentrum Erfurt, Konrad-Zuse-Str. 14, 99099 Erfurt, Germany — [4]ISC International Solar Energy Research Centre Konstanz, Rudolf-Diesel-Str. 15, 78467 Konstanz, Germany

Solar cell passivation has always been an attractive topic for photovoltaic researches as this can enhance the performance of the solar cell remarkably. For a solar cell fabricated on p-type silicon it is necessary to achieve a good passivation on a phosphorus highly doped emitter. Silicon dangling bonds saturation and the field effect induced by built-in charge in the passivation-layer are the two well-known passivation effects on silicon surfaces. Some commonly used passivation layers, like SiO2 and SiNx, result in a positive built-in charge while others, e.g. Al2O3, produce a negative charge. Our main focus in this work are SiNx passivation films which were deposited by plasma enhanced chemical vapor deposition (PECVD) technique on different phosphorus highly doped emitter under varying gas flux ratio of silane and ammonia in the PECVD chamber. Optical properties of the films were characterized by spectroscopic ellipsometry while their passivation quality was studied by means of emitter saturation current measurement.

15 min. break

HL 5.8 Mon 12:30 POT 151

Influence of the excess carrier density depth profile on the photoluminescence yield — •Sebastian Knabe and Gottfried H. Bauer — Institute of Physics, University of Oldenburg, Germany

The photoluminescence (PL) emitted from excited semiconductors provides access via Planck's generalizes law to parameters like splitting of quasi-Fermi-levels, optical absorption, temperature and is originated by radiative recombination. The photon flux monitored in the detector is composed of the individual fluxes emitted from each volume element of the sample isotropically into the solid angle 4 π and particularly propagating across the sample to the surface.

We numerically reproduce the spectral PL by a one-dimensional diffusion excess carrier profile for depth dependent emission, including surface recombination velocities, excess carrier lifetimes and diffusion lengths, considering as well optical absorption, reflection at surfaces and according phase accumulation by a matrix transfer approach.

As the splitting of quasi-Fermi-levels usually is deduced experimentally from the high energy wing of the spectral PL-yield we show the limits and quantify the accuracy of this methods versus different excess depth profiles resulting from various surface recombination velocities and from depth dependent carrier lifetimes as well. We furthermore discuss the difference in spectral PL-behavior between a plane wave approach applicable for layer thicknesses being small compared with the laser excitation area and small spot excitation e.g. for SNOM experiments.

HL 5.9 Mon 12:45 POT 151

Diffusion of substrate impurities into solar-grade CIGS layer structures — •Shahmahmood Obeidi[1], Roland Würz[2], Axel Eicke[2], and Nicolaas Stolwijk[1] — [1]Institute of Materials Physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Industriestr. 6, 70565 Stuttgart, Germany

The deposition of CIGS involves the diffusion of impurities out of the substrate through the Mo back contact into the absorber layer of the solar cell. In some cases, e.g., Fe the performance of the cell is found to suffer. Therefore it is important to study the diffusion behaviour of such impurities both qualitatively and quantitatively. We investigated the diffusion of iron in polycrystalline CIGS after growth. In order to start with Fe-free CIGS layers before the diffusion experiment we chose CIGS/Mo/float-glass structures as samples and provided them with front-side Fe sources. Two methods were applied: the radiotracer method using Fe-59 as suitable isotope and secondary ion mass spectrometry (SIMS) with natural Fe as diffusion source. Diffusion anneals in the temperature range from 200°C to 500°C were performed in a lamp furnace or an oil bath. The values for the diffusion coefficient range from $7.5 \cdot 10^{-15}$ to $8.8 \cdot 10^{-12}$ $cm^2 s^{-1}$ in the temperature interval investigated. An activation enthalpy of 1.0 eV was determined from an Arrhenius fit and the extrapolation of the Arrhenius line to the CIGS deposition temperature (550°C) yields a diffusion coefficient of $2.0 \cdot 10^{-10}$ $cm^2 s^{-1}$. We will discuss to what extent the present results may be interpreted in terms of grain boundary diffusion.

HL 5.10 Mon 13:00 POT 151

Carrier collection efficiency in chalcopyrite solar cells with varied absorber layer thickness — •Heiner Lendzian[1], Janet Neerken[1], Martin Knipper[1], Jürgen Parisi[1], Ingo Riedel[1], Stefan Jost[2], Thomas Dalibor[2], and Jörg Palm[2] — [1]Energy- and Semiconductor Research Laboratory, Department of Physics, Carl von Ossietzky University of Oldenburg, D-26111 Oldenburg, Germany — [2]AVANCIS GmbH & Co. KG, Otto-Hahn-Ring 6, Gebäude 31, D-81739 Munich, Germany

In this contribution we examine the effect of thickness-reduced absorber thin films employed in efficient chalcopyrite solar cells on the presence of defect states and photon conversion efficiency as well as the inherent limitation of carrier collection lengths. The investigated solar cells were produced in a well controlled and reliable pilot line and were characterized by means of current-voltage and capacitance-voltage profiling. Furthermore, the spectral absorption coefficient was measured and the resulting absorption depth is compared to the results obtained from spectral response measurements. The analysis yields an accurate determination of effective carrier collection lengths and thereby a good estimate of optimal absorption layer thicknesses.

HL 6: Invited Talk Fromherz

Time: Monday 11:00–11:45 Location: HSZ 01

Invited Talk HL 6.1 Mon 11:00 HSZ 01

Three dimensional SiGe quantum dot crystals — •Thomas Fromherz — Institute of Semiconductor and Solid State Physics, Johannes Kepler University, A-4040 Linz, Austria

The formation of SiGe quantum dots (QDs) on a regular, two dimensional lattice has been demonstrated to result in an extremely narrow QD size distribution and correspondingly narrow QD photoluminescence spectra. Overgrowing this first QD layer with a thin Si cap followed by a few monolayers Ge results in the formation of vertically aligned QDs. In our samples, 10 QD layers vertically perfectly aligned to the first layer without deterioration of the narrow size distribution were grown. Crystallographically, the resulting three dimensionally ordered QDs represent an artificial crystal as evidenced by x-ray diffraction. Using interference lithography based on UV radiation at 13.5 nm wavelenghth, lattices with periods small enough to couple neighboring QDs also electronically can be defined. Three dimensional envelope function approach band structure calculations based on the nextnano[3] simulation tool show that by a proper choice of the distances between neighboring QDs, delocalized electron ground states built up by a superposition of QD states can be realized. Thus, also from an electronic

point of view, these three dimensionally ordered QDs represent an artificial crystal with electronic and optic properties adjustable by the period and the structure of the QDs.

The work was performed in collaboration with C. Dais, J. Stangl, E. Müller, Y. Ekinci, D. Grützmacher, H. H. Solak, R. T. Lechner, E. Wintersberger, S. Birner, and Václav Holý.

HL 7: Quantum dots: Optical properties I

Time: Monday 13:30–17:00 Location: BEY 118

HL 7.1 Mon 13:30 BEY 118

(111)-Grown InGaAs/GaAs Quantum Dots as Ideal Source for Entangled Photon Pairs — •Andrei Schliwa, Momme Winkelnkemper, and Dieter Bimberg — Inst. für Festkörperphysik, TU-Berlin

For a number of protocols of future secure communication systems the generation of entangled photon pairs are essential. Thier creation, based on the XX => X => 0 recombination cascade in QDs, requires necessarily a vanishing excitonic fine-structure splitting (fss). The latter is hard to achieve for QDs grown on (001)-substrate, because piezoelectricity and QD elongation induce a lateral anisotropy leading to sizable values of the fss. The structural anisotropy and the piezoelectricity are intrinsic characteristics of the (001) substrate orientation featuring different surface mobilities along [110] and [1-10] and polar axes with non-vanishing projections on the growth plane. Therefore, we propose the use of QDs grown on (111)-GaAs substrates. Using eight-band k.p theory in conjunction with an enhanced configuration interaction (CI) method we calculate the fss for (111)-grown QDs in conjunction with their exciton-biexciton separation as function of size, aspect ratio and chemical composition. Assuming an, at least, threefold rotational structural symmetry of the Qds, we show that the corresponding piezoelectric field does not lower this symmetry any further. Thus, the excitonic bright states remain degenerate; an intrinsically perfect source of entangled photon pairs is available. This result is of general character and applies to all self-organized QDs in the zinc-blende system.

HL 7.2 Mon 13:45 BEY 118

InGaAs QDs on GaAs(111) substrate for entangled photon pairs — •Irina Ostapenko[1], Andrei Schliwa[1], Erik Stock[1], Sven Rodt[1], Vladimir Haisler[2], and Dieter Bimberg[1] — [1]IFP, TU Berlin — [2]Institute of Semiconductor Physics, Novosibirsk, Russia

Quantum dots (QDs) are ideally suited for the generation of polarization-entangled photon pairs [1] that enable certain quantum cryptography protocols [2] and quantum teleportation [3]. However, even a small fine-structure splitting of the bright-exciton state may hinder the formation of such pairs based on the biexciton to exciton to vacuum recombination cascade. Our recent calculations [4] have revealed that growth of InGaAs QDs on GaAs(111) substrates leads to a vanishing fine-structure splitting. Here we expect a three-fold rotational symmetry in the growth plane and piezoelectric effects will not reduce the symmetry of the confining potential in contrast to QDs grown on GaAs(001) substrates [5]. We report on a successful approach to grow such QDs via droplet-mode MBE. Optical characterization is performed by cathodoluminescence and electroluminescence in combination with metal shadow masks. The results are compared to droplet-exiptaxy QDs on "standard" GaAs(001) substrates.

[1] O. Benson et al., Phys. Rev. Lett. 84, 2513 (2000)
[2] A. K. Ekert, Phys. Rev. Lett. 67, 661 (1991)
[3] T. Jennewein et al.,Phys. Rev. Lett. 88, 017903 (2002)
[4] A.Schliwa et al., Deutsche Patentanmeldung (2008)
[5] O.Stier et al., Phys. Rev. B 59, 8 (1999)

HL 7.3 Mon 14:00 BEY 118

Time-resolved studies of pulsed electrical spin initialization in single InGaAs quantum dots — •P. Asshoff, W. Löffler, J. Zimmer, H. Flügge, H. Füser, M. Hetterich, and H. Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

For spin-injection light-emitting diodes with a diluted magnetic semiconductor as spin aligner, we have recently demonstrated that the achievable spin-injection fidelity in quantum dots ranges from nearunity to even negative values depending on the individual dot. To study the origin of this phenomenon, we investigated the temporal behavior of the spin-injection fidelity using ns-pulses for the electrical injection into the dots. In quantum dot ensemble measurements, we clearly see that the polarization degree drops within the first nanoseconds of the electrical pulse. Measurements concerning the temporal evolution of the polarization degree for single quantum dots as well as approaches to theoretically model the observed dynamics will be presented. The latter should open up the possibility to relate the spin-injection fidelity of individual quantum dots to scattering mechanisms, which may allow for improved designs to enhance spin injection significantly. Furthermore, our time-resolved studies of the pulsed spin initialization process are a first step towards future spin manipulation experiments.

HL 7.4 Mon 14:15 BEY 118

Microphotoluminescence on in situ stressed single InAs quantum dots — •Sven Wildfang, Matthias Klingbeil, Matthias Grave, Andrea Stemmann, Christian Heyn, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

We have set up an experiment that enables us to vary and control the strain state of self-assembled InAs quantum dots (QDs) utilizing a micro mechanical device. We monitor the energy spectrum of a single QD by means of microphotoluminescence. When applying stress to a QD we find a reversible change in the spectrum. The distributions of stress in our structure during the experiments were simulated with COMSOL Multiphysics. The simulations were based on the works of van de Walle [1]. We simulated the behavior of the global band gap of InAs embedded in GaAs under stress induction. The results of our simulations could in principle be verified. Additionally in high resolution measurements we observe a change in the relative energy spacing both in the s- and the p-shell transitions. This arises from a change of the shape of the confining potential of a QD. [2, 3, 4]

We acknowledge financial support by the Deutsche Forschungsgemeinschaft via GrK 1286 and SFB 508.

[1] C. G. Van de Walle, Phys. Rev. B 39, 1871 (1989).
[2] A. Schliwa et al., Phys. Rev. B 76, 205324 (2007).
[3] M. Grundmann et al., Phys. Rev. B 52, 11969 (1995).
[4] S. Mendach et al., Phys. Rev. B 78, 035317 (2008).

15 min. break

HL 7.5 Mon 14:45 BEY 118

Cavity-enhanced emission of single photons by electrically driven InGaAs/GaAs-Quantum dot based RC-LEDs — •Jan Amaru Töfflinger[1], Erik Stock[1], Anatol Lochmann[1], Dieter Bimberg[1], Askhat K. Bakarov[2], Aleksandr I. Toropov[2], Aleksandr K. Kalagin[2], and Vladimir A. Haisler[2] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, Lavrenteva avenue 13, 630090 Novosibirsk, Russia

In order to optimize single photon emitting devices we developed Resonant-Cavity LEDs (RC-LED). MBE was employed to grow quantum dot densities of about $10^8 cm^{-2}$. Such devices are a key for the realization of quantum cryptography systems. A main feature of our RC-LEDs is a built-in AlGaO current aperture allowing us to electrically excite a single quantum dot at very low currents below 15 nA. A specially designed resonant cavity leads to increased external quantum efficiency due to an increase of the spontaneous emission rate by the Purcell effect and a controlled direction of emission. We were able to focus on our APD-detectors a photon rate of almost 10^9 photons/sec which is a factor 10 times higher compared to devices without a resonant cavity [1]. Photon-correlation measurements prove that indeed single photons are emitted by a single quantum dot at a wavelength of about 940nm. This work is partly funded by the SfB 787 and the NATO SfP 982735.

[1] A. Lochmann et al., Electron. Lett. 42, 774 (2006)

HL 7.6 Mon 15:00 BEY 118

Electronic and optical properties of laterally coupled InGaAs quantum dots — •Jie Peng and Gabriel Bester — Max Planck Institute for Solid State Research, Stuttgart, Germany

We calculate the electronic and optical properties of laterally coupled InGaAs/GaAs quantum dot molecules under lateral electric field using empirical pseudopotentials and configuration interaction. Our model structure is directly taken from recent experiments where an In-poor basin develops below the dots. The coupling of the electron states is significantly enhanced by the presence of the basin, while the holes remain mainly uncoupled. At the proper electric field —between 0 V/cm and 300 V/cm, depending on the dot molecule— the electron states can be tuned to be evenly distributed between both dots, forming bonding and antibonding states. The optical absorption is shown to exhibit two bright transitions, mostly independent of the applied field. In emission, we argue that a fast electron-dynamics must be introduced, since the electrons are not subject to a true potential barrier between the dots and consequently only the lowest of the electron states is occupied. Following this approach, we obtain only one bright peak at high electric fields and two peaks (at higher temperature, four peaks) at the tuning point of the electron states. The results are shown to compare very well with recent experiments. A simple 4x4 Hamiltonian is derived to explain the results in the intuitive dot-localized basis.

HL 7.7 Mon 15:15 BEY 118

Piezoelectric versus shape-induced optical anisotropy of InAs/GaAs quantum dots — •Thomas Eissfeller, Stefan Birner, Till Andlauer, and Peter Vogl — Walter Schottky Institut, TU München, 85748 Garching

We predict anisotropic optical properties of self-assembled overgrown InAs/GaAs quantum dots invoking a detailed 3D electronic structure theory such as implemented in nextnano. For InAs quantum dots grown on [001] n-GaAs substrate, a strong optical anisotropy between $[1\bar{1}0]$ and [110] linearly polarized light has been observed experimentally for the two lowest intrasubband s-p^- and s-p^+ transitions within the conduction band. Here, p^- and p^+ are the first two excited quantum dot states and are oriented along $[1\bar{1}0]$ and [110]. We show that the experimentally observed energy splitting of a few meV between the p^- and p^+ state with $E(p^-) < E(p^+)$ can be explained satisfactorily by an elaborate 3D 8-band k.p model that includes the linear piezoelectric effect but does not include higher order piezoelectric couplings. Previous work [1] suggested a different result since the piezoelectric potential was incorrectly rotated by 90°. We find that dot shape elongation along $[1\bar{1}0]$ combined with the correct linear piezoelectric effect is incompatible with the experimental findings. However, we predict that for dot elongations along [100] or [010], the optical spectrum for linearly polarized light becomes nearly isotropic and both s-p^- and s-p^+ transitions become allowed transitions. [1] A. Schliwa, M. Winkelnkemper, D. Bimberg, PRB **76** (2007)

HL 7.8 Mon 15:30 BEY 118

Effect of uniaxial stress on single particle states and fine structure splitting of excitons in InGaAs self-assembled quantum dots — •Ranber Singh and Gabriel Bester — Max Planck Institute for Solid State Research, Stuttgart, Germany

We investigate the effect of uniaxial stress on single particle states and fine structure splitting (FSS) of excitons in InGaAs self-assembled quantum dots by applying uniaxial stress along the [110] and [100] crystallographic directions using the empirical pseudopotential approach and configuration interaction. It is shown that the tuning of FSS in quantum dots is sensitive to the atomistic symmetry of the structures and the direction of applied stress. Related to the structure's symmetry, is the appearance of crossings as well as anti-crossings of the bright exciton lines. For stresses along [100], the minimum FFS is at 0 MPa (40 MPa) in InAs/GaAs ($In_{0.6}Ga_{0.4}As$/GaAs) dots. For the stress along [110] direction, the minimum FFS is at -19 MPa (-40 MPa) in InAs/GaAs ($In_{0.6}Ga_{0.4}As$/GaAs) dots. The single particle energies of S, P electron and hole states increases linearly with the increase in stress. The P hole states tend to spilt under [110] stress, while P electron states show no significant splittings.

15 min. break

HL 7.9 Mon 16:00 BEY 118

(111)-Grown InGaAs/GaAs Quantum Dots as Ideal Source for Entangled Photon Pairs — •Andrei Schliwa, Momme Winkelnkemper, and Dieter Bimberg — IFP, Fak. II, TU-Berlin

For a number of protocols of future secure communication systems the generation of entangled photon pairs are essential. Their creation, based on the $XX \rightarrow X \rightarrow 0$ recombination cascade in QDs, requires necessarily a vanishing excitonic fine-structure splitting (fss). The latter is hard to achieve in a controlled way for QDs grown on (001)-substrate. Dot to dot variations of piezoelectricity and QD elongation, which induce a lateral electronic anisotropy, lead to variations of the fss. The structural anisotropy and the piezoelectricity are intrinsic characteristics of the (001) substrate orientation featuring different surface mobilities along [110] and [1-10] and polar axes with non-vanishing projections on the growth plane. Therefore, we propose the use of QDs grown on (111)-GaAs substrates. Using eight-band $\mathbf{k}\cdot\mathbf{p}$ theory in conjunction with an improved configuration interaction method we calculate the fss for (111)-grown QDs together with the biexciton binding energy as function of size, aspect ratio and chemical composition. Assuming a threefold rotational structural symmetry of the QDs, we show that the corresponding piezoelectric field does not lower this symmetry any further. Thus, the excitonic bright states remain degenerate and the $XX \rightarrow X \rightarrow 0$ cascade presents an intrinsically perfect source of entangled photon pairs. This result is of general character and applies to all self-organized QDs in a zinc-blende system [1].

[1] Deutsche Patentanmeldung Nr.: 10 2008 036 400.2

HL 7.10 Mon 16:15 BEY 118

Independent Tuning of Different Few Particle States in Single InGaAs Quantum Dots Using Lateral Electric Fields — •Malte Frederik Huck, Michael Kaniber, Max Bichler, and Jonathan James Finley — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present studies of the optical emission from single quantum dots (QDs) subject to electric field perturbations applied in the plane of the QDs. The samples consist of low density ($\sim 5\mu m^{-2}$) self-assembled InGaAs QDs grown by molecular beam epitaxy embedded in a GaAs slab. Metal split gate contacts with a 2μm separation were established on top of the sample allowing the optical properties of the QDs to be probed with static electric fields up to 50 kV/cm. Photoluminescence and photocurrent measurements were performed to identify the different charge configurations of the QD and to study the influence of the external electric fields on the corresponding few particle states. We observe pronounced energy shifts of individual emission lines up to $|\Delta E|$=4meV, due to the quantum confined Stark effect. Surprisingly, different states from the same QD are found to exhibit characteristic red- and blue-shifts. This behaviour is attributed to the interplay between the field induced polarization of the state, producing the Stark shift, and the change of the Coulomb interaction and correlation effects. The observed shift rates are in good agreement with theoretical predictions. Our results show that single charge neutral exciton and biexciton transitions can be tuned into resonance, providing strong potential to realize a source of energy-time entangled photon pairs.

HL 7.11 Mon 16:30 BEY 118

Phonon replica of a single electrically pumped InAs/GaAs quantum dot from large diodes without current constriction — •Erik Stock[1], Andreas Baumgartner[2], Till Warming[1], Amalia Patane[2], Laurence Eaves[2], Mohamed Henini[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, D — [2]School of Physics and Astronomy, University of Nottingham NG7 2RD, UK

Electrical pumping of a single self organized quantum dots (QD) is essential for the fabrication of semiconductor based single photon and entangled photon pair sources. By controlling the applied bias we are able to pump a single quantum dot in a pin diode with a diameter of 200 μm containing a large number ($\approx 10^7$) of InAs/GaAs QDs. No current constriction or shadow mask were necessary to observe single well resolved (< 0.2 meV) lines in the electroluminescence. This demonstrates the high carrier capture efficiency of a single QD.

We measure high resolution EL spectra, taken with large dynamic range. The observed emission line exhibits a broadening consistent with theoretically modelled acoustic phonon scattering. 36 and 39 meV below the emission line we observe a triangular shaped emission as it has been predicted theoretically for the optical phonon scattering [2]. These results show, how low-dimensional lattice vibrations couple to a single QD, which will be important for future applications. We acknowledge the SfB 787, NATO SfP 982735 and EPSRC, UK.

[1]L. Turyanska et al., Appl. Phys. Lett **89**, 092106 (2006) [2]E. A. Muljarov, and R. Zimmermann, Phys. Rev. Lett. **98**, 187401 (2007).

HL 7.12 Mon 16:45 BEY 118

Spectroscopic studies of stacked InGaAs QDs structures with and without strain coupling — •Lewis Lingys, Aleksandar Gushterov, and Johann-Peter Reithmaier — Universität Kassel, Technische Physik, Institut für Nanostrukturtechnologie und Analytik

InGaAs/GaAs quantum dots are of great interest for studying light-matter interactions on a basic level also leading to new device applications like quantum dot (QD) lasers or single-photon sources. Here we present spectroscopic studies of stacked QDs structures which consist of a number of alternating layers of InGaAs QDs and barriers of GaAs. The samples were grown with solid source molecular beam epitaxy (MBE). We investigated e.g. stacks with 30 layers of QDs with high dots density with absorption spectroscopy and photoluminescence (PL) spectroscopy in the regime where no strain coupling can be expected, i.e. with GaAs barrier thicknesses of 50 nm. Then we reduced the thicknesses of the barrier layers for different stacks down to regions where the formation of islands is influenced by the localized strain fields caused by the underlying dots layer. Absorption spectroscopy and PL spectroscopy provide here together a complementary analysis as for example absorption spectroscopy gives direct information about the wetting layer states whereas with PL spectroscopy in most cases the wetting layer cannot be analysed. Morphology data was gained by atomic force microscopy (AFM).

HL 8: Invited Talk Ludwig

Time: Monday 14:00–14:45 Location: HSZ 01

Invited Talk HL 8.1 Mon 14:00 HSZ 01

Phonon-mediated non-equilibrium interactions between mesoscopic devices — Georg Schinner and •Stefan Ludwig — Center for NanoScience and Fakultät für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München

With shrinking device dimensions quantum interactions in nanoscale devices become increasingly important for possible applications such as quantum information processing. Here we investigate non-equilibrium interactions between adjacent mesoscopic circuits defined in the plane of a two-dimensional electron system (2DES) of a GaAs/AlGaAs heterostructure.

Charge detection utilizing a biased quantum point contact (QPC) has become an essential probe for studying the electronic properties of nanoscale devices such as coupled few electron quantum dots. We explore the non-equilibrium back-action of a biased QPC onto nearby nanostructures, tackling the question of possible interaction mechanisms. In a recent experiment ballistic non-equilibrium electrons with a well defined excess energy above the Fermi level are injected into the 2DES. While the injected hot electrons are confined to the emitter circuit, part of their energy is transferred to an unbiased detector. Here, we measure an interaction mediated current across a tunable barrier. Surprisingly, the excess energy of electrons excited in the detector is bounded by about 1.3 meV, corresponding to the maximum energy of interface phonons that can be absorbed by equilibrium electrons. Our results illustrate the importance of interactions mediated by interface acoustic phonons generated by ballistic non-equilibrium electrons.

HL 9: Poster 1

Time: Monday 14:30–17:00 Location: P2

HL 9.1 Mon 14:30 P2

Noncovalent Functionalization of Single Walled Carbon Nanotubes — •Pascal Bluemmel, Vitaliy Datsyuk, Antonio Setaro, and Stephanie Reich — Fachbereich Physik, Freie Universitaet, Berlin

Functionalization provides a tool to alter the electronic and dynamic properties of carbon nanotubes [1-2]. The degree of alteration depends on the type of bonding and the properties of the attached molecule. For some applications it is important to minimize the influence of the bond. Noncovalent functionalization is indicated to be a suitable way of attaching molecules to nanotubes while avoiding drastic modifications due to the bond itself [3].

We investigate pyrene and other organic molecules that are exohedrally adsorbed onto the nanotube surface via pi-pi stacking. The functionalized nanotubes are probed optically by absorption-, photoluminescence- and Raman spectroscopies.

[1] C.S. Lin et al. J. Phys. Chem. C 2007, 111(11), 4069-4073
[2] M. Müller et al. Phys. Stat. Sol. (b) 2007, 244 No. 11, 4056-4059
[3] X. Guo et al. J. Am. Chem. Soc. 2005, 127, 15045-15047

HL 9.2 Mon 14:30 P2

Temperature dependence of the conductivity of ballistic graphene — •Matthias Bräuninger[1], Markus Müller[2], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany — [2]Department of Theoretical Physics, University of Geneva, CH-1211 Geneva, Switzerland

We investigate the temperature dependence of the conductivity in ballistic graphene using Landauer transport theory. The finite temperature only enters in the Fermi distribution functions of the reservoirs, but not in any inelastic scattering strength. Remarkably, we obtain results that are qualitatively in agreement with many features that were recently observed in transport measurements on (high mobility) suspended graphene. The conductivity at high temperature T and low density n grows linearly with T, while at low T and high n it follows $\sigma \sim \sqrt{|n|}$. In the intermediate regime the conductivity is a non-monotonic function of either T or n, exhibiting a minimum at $T = 0.693\hbar v\sqrt{|n|}$ where v is the Fermi velocity.

HL 9.3 Mon 14:30 P2

Ab initio investigations of defects in bilayer graphene — •Michael Bachmann and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

Recent experimental observations of bilayer graphene using scanning tunnelling microscopy show scattering patterns with a 6-fold symmetry [1,2]. These cannot be explained by substitutional defects which cause scattering patterns with 3-fold symmetry. We report ab initio calculations of defects in bilayer graphene that can explain the 6-fold symmetry of the measured scattering patterns. They do not occur in single layer graphene. They occur if a defect in one layer induces changes in the electronic structure of the other layer. This work has been supported in part by the NIST-CNST/UMD-NanoCenter Cooperative Agreement.

[1] G.M. Rutter, J.N. Crain, N.P. Guisinger, T. Li, N.P. First, J.A. Stroscio, Science **317**, 219 (2007)
[2] N.P. Guisinger, G.M. Rutter, J.N. Crain, C. Heiliger, N.P. First, J.A. Stroscio, J. Vac. Sci. Technol. **26**, 932 (2008)

HL 9.4 Mon 14:30 P2

Temperature-dependent Measurements of Phonon Dynamics in Highly Oriented Pyrolytic Graphite — •Martin Scheuch[1], Konrad von Volkmann[1], Luca Perfetti[2], Tobias Kampfrath[1], Christian Frischkorn[1], and Martin Wolf[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Laboratoire des Solides Irradiés, Ecole polytechnique, 91128 Palaiseau cedex, France

We have employed THz time-domain spectroscopy in the range from 10 to 30 THz to obtain the complex dielectric function of Highly Oriented Pyrolytic Graphite (HOPG) for temperatures from 10 to 300 K. In addition to static measurements, we apply a pump pulse at 790 nm to investigate the dynamics of the energy dissipation of the photo-excited

charge carriers. Our data allow us to evaluate the lifetimes of various strongly coupled high-energy phonon modes [1]. Agreement with theoretical predictions [2] is good and yields the coupling strength between these high-energy and other low-energy phonon modes. Our results are relevant to graphene and carbon nanotubes, which are closely related to graphite.

[1] T. Kampfrath et al., PRL 95, 187403 (2005) [2] N. Bonini et al., PRL 99, 176802 (2007)

HL 9.5 Mon 14:30 P2

Electron diffraction on carbon nanotubes (CNTs) — •Christian Huber, Dominik Preusche, David Kalok, Christoph Strunk, and Josef Zweck — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31, 93040 Regensburg, Germany

Depending on their specific structure, which can be described by the chiral indices, single walled carbon nanotubes (SWNT) may be either metallic or semiconducting materials. For the interpretation of measurements on spin polarized electron transport in SWNTs, contacted between magnetic leads, it is of importance to know the structure and hence the conductive properties as exactly as possible. Therefore, electron nano diffraction in a transmission electron microscope is performed on SWNTs. From these diffraction patterns, supported by high resolution images and simulations, it is possible to derive the chiral indices needed.

HL 9.6 Mon 14:30 P2

Combined optical and AFM analysis of combustion produced nano organic particles — •Antonio Setaro[1], Annalisa Bruno[2], Patrizia Minutolo[3], Andrea D'Anna[2], and Stephanie Reich[1] — [1]Fachbereich Physik, Freie Universität, Berlin — [2]Università degli studi di Napoli Federico II — [3]Istituto Ricerche Combustione-CNR Napoli

Combustion processes result in a wide range of products. Recently much attention is being devoted to the nanosized products of combustion, as their presence within the atmosphere has very profound impact not only from the climatologic point of view but also from a medical one, as many epidemiological studies outline the direct correlation between high concentration of carbonaceous nanoparticulate and deseases.
Samples from premixed laminar ethylene- air flame operating in different conditions from no-sooting to slightly sooting have been collected. Different optical techniques coupled with AFM-microscopy are here employed for getting a better insight on the chemical and morphological nature of these nanoparticulates.

HL 9.7 Mon 14:30 P2

CVD Growth of Carbon Nanotubes Using Molecular Nanoclusters as Catalyst — •Karin Goss, Akashdeep Kamra, Christian Spudat, Carola Meyer, Paul Kögerler, and Claus M. Schneider — Research Centre Jülich, Institute for Solid State Research, Electronic Properties, JARA-Jülich-Aachen Research Alliance, 52425 Jülich, Germany

Carbon nanotubes (CNTs) are known to possess superior mechanical and electronic properties that caused a lot of research in multiple fields of nanophysics. For transport measurements on CNTs and functionalized derivatives such as peapods isolated single-walled carbon nanotubes (SWNTs) are favourable. With the chemical vapour deposition (CVD) method such CNTs can be grown directly on substrates and their quality is governed by the catalyst used in the CVD procedure. Our experiments are motivated by a possible constriction of the CNT diameter distribution, which could facilitate the synthesis of peapods. Hence we investigated CNTs grown with molecular $Mo_{72}Fe_{30}$ nanoclusters as a catalyst by AFM, SEM and Raman spectroscopy. In comparison to our standard catalyst, which is composed of Fe clusters agglomerated at alumina nanoparticles, the molecular nanoclusters could enable the growth from highly defined catalyst particles. Additionally the role of the oxidation state of Mo for the growth mechanism is discussed.

HL 9.8 Mon 14:30 P2

Carbon aerogel electrodes for electrochemical double-layer capacitors based on resorcinol-formaldehyde sediments — •Mario Zeller[1], Volker Lorrmann[1], Dirk Hauschild[2], Jens Pflaum[1,2], Gudrun Reichenauer[1], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg — [2]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg

Carbon aerogels are promising candidates for electrochemical double-layer capacitors (EDLC) electrodes, because their microstructure is tuneable over a broad range. EDLC electrodes based on monolithic carbon aerogel offer an excellent electrical conductivity, however, they are very brittle.

We prepared binder electrodes based on carbon aerogel powder via pyrolysis of resorcinol-formaldehyde sediments. The influence of the respective preparation parameters, such as the concentration of the catalyst on the pore size distribution, surface and micropore properties, was evaluated by means of nitrogen sorption. Scanning electron microscopy was used to determine the size of the carbon particles.

For electrochemical investigation of the binder electrodes in different electrolytes, cyclic voltammetry (CV), and impedance spectroscopy in a three-electrode cell was performed. In addition, galvanostatic charging and discharging were investigated in a two-electrode cell, where both, the anode and cathode constituted by carbon aerogel electrodes.

The relationship between the structure and the electrochemical performance of the carbon aerogel binder systems is discussed.

HL 9.9 Mon 14:30 P2

Composite electrode of carbon aerogel and MnO_2 for electrochemical capacitors — •Christian Weber[1], Volker Lorrmann[1], Carsten Deibel[2], Jens Pflaum[1,2], Gudrun Reichenauer[1], and Vladimir Dyakonov[1,2] — [1]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg — [2]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg

Electrochemical capacitors (EC) bridge the gap between conventional capacitors with high power but low energy density and batteries with high specific energy density but rather low power density. There are two types of EC: Double-layer supercapacitors, that store charges electrostatically in the electrochemical double-layer between electrolyte and high surface area electrodes of activated hard carbon. In pseudocapacitance supercapacitors the charge storage is of faradaic nature, e.g. redox processes in MnO_2. We have blended the organic precursor of a synthetic activated hard carbon (carbon aerogel) with MnO_2 particles to be used as electrode for EC. The aim is to combine the faradaic- and the double-layer capacitance of MnO_2 and carbon, to increase the achievable capacity of the electrode. The electrochemical properties of these composites were investigated with cycling voltammetry, charge/discharge cycling and impedance spectroscopy. Structural analysis was performed via nitrogen sorption, scanning electron microscopy and X-ray diffraction.

HL 9.10 Mon 14:30 P2

Transport measurements in width modulated graphene nanoribbons — •Silvia Schmidmeier, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

We investigate electronic transport both in graphene and graphene nanoribbons (GNRs). The lateral confinement of the charge carriers in the quasi one-dimensional ribbons creates an energy gap near the charge neutrality point, where the gap depends on the width of the GNR. Here we are using this width dependence to create a potential modulation along the nanoribbon. To this end, the ribbon width is varied periodically, which we expect to affect the electronic transport in an interesting way. GNRs with different width, flat as well as modulated ribbons, were fabricated by electron beam lithography and plasma etching techniques. The devices are fully tunable by two graphene sidegates and a backgate. Here we present the first measurements on those GNRs. In order to verify the single-layer character we performed quantum Hall measurements and found the characteristic half-integer quantization. By examining the differential I-V characteristics of the GNRs a transport gap is clearly observed at the Dirac point. We also measured the magnetoconductance in a perpendicular magnetic field for different temperatures. At low magnetic fields weak localization is clearly visible, therefore the phase coherence length can be determined by 1D weak localization theory. Additionally it was extracted in an independent way from the amplitude of the universal conductance fluctuations.

HL 9.11 Mon 14:30 P2

Indirect exchange interaction in graphene — •Józef Barnaś[1,2], Vitalii Dugaev[3,4], Paweł Małyszek[1], and Volodya Litvinov[5] — [1]Department of Physics, Adam Mickiewicz University, 61-614 Poznań, Poland — [2]Institute of Molecular Physics, PAN, 60-179

Poznań, Poland — [3]Department of Physics, Rzeszów University of Technology, 35-959 Rzeszów, Poland — [4]Department of Physics and CFIF, Instituto Superior Técnico, 1049-001 Lisbon, Portugal — [5]Waveband/Sierra Nevada Corporation, Irvine, CA 92618, USA

We have analyzed the problem of magnetic correlations, indirect exchange interaction of magnetic impurities, and magnetic Friedel oscillations in graphene, mostly concentrating on the possible effects of spin-orbit interactions. The spin-orbit interaction produces a gap, which makes the correlation functions less long-ranged. Two kinds of spin-orbit interaction are taken into account: intrinsic spin-orbit coupling which inherently exists in graphene plane, and Rashba spin-orbit interaction due to asymmetry between bottom and top surfaces. Using the relativistic model of Dirac, we have calculated the magnetic polarization profile with Friedel oscillations effectively damped by the spin-orbit interaction. The interaction between magnetic impurities may lead to ferromagnetic ordering. The effective coupling constant is shown to depend on the location of magnetic impurities in the graphene sublattices.

HL 9.12 Mon 14:30 P2

Magnetic properties of transition metal doped Si nanocrystals and their size dependence. — •Christian Panse[1], Frank Küwen[2], Roman Leitsmann[1], and Friedhelm Bechstedt[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universtität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Energieforschungszentrum Niedersachsen, Technische Universität Clausthal, Am Stollen 19, 38640 Goslar, Germany

For investigation of the magnetic and spin-related properties of nanoparticles we examine transition metal doped semiconductors. In particular Si nanocrystals (NCs) doped with Mn and Fe atoms are under investigation. We consider two different impurity positions: substitutional and interstitial sites. The optimized geometries show bond-length deviations from the ideal geometry of less than 1.5% for nearest neighbor atoms. Interestingly in the Si-rich limit interstitial impurity sites lead to the most stable bonding configurations. In addition, the existence of a so-called self-purification effect is shown for very small Si NCs.

To verify Hund's rule for the NC systems we have analysed the spin and charge distribution in these systems in detail. A strong dependence of the total magnetic moment on the energetic position of the metal d-states with respect to the Fermi level could be observed.

HL 9.13 Mon 14:30 P2

Effects of doping on the elastic properties of silicon — •Nicole Santen and Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik, Universität Bonn, Germany

The application of strained silicon in transistor design has led to significant progress in increasing the performance of devices. However, although the method is state of the art, many aspects in conjunction with the mechanical behaviour of strained Si layers have not yet been fully understood or even studied.

The influence of doping on the elastic properties of silicon is studied by means of the perturbed angular correlation method (PAC) using the acceptor ^{111}In as probe. This nuclear technique is well suited for studying strain on an atomic scale. After doping via ion implantation and subsequent annealing the Si samples are bent along the ⟨110⟩ crystal axis which leads to a uniaxial tensile strain.

It was found that the response of the silicon lattice to mechanical stress showed strong differences depending on the dopant species. Doping with acceptors does not change the elastic properties of silicon, whereas in n-doped silicon a significant strain relaxation is observed.

HL 9.14 Mon 14:30 P2

An x-ray Raman scattering study of the temperature–induced disproportionation in a-SiO — •Omid M. Feroughi[1], Christian Sternemann[1], Achim Hohl[2], Christoph J. Sahle[1], Heiko Conrad[1], Joe Bradley[3], Mali Balasubramanian[4], Jerry Seidler[3], and Metin Tolan[1] — [1]Fakultät Physik / DELTA, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Institute for Materials Science, Darmstadt University of Technology, D-64287 Darmstadt, Germany — [3]University of Washington, Department of Physics, Seattle, WA 98195 USA — [4]Argonne National Lab, 9700 Cass Avenue, Argonne, IL 60439 USA

The study of bulk amorphous silicon monoxide (a–SiO_x with $x \approx 1$) attracted great interest over the past years due to its relevance for opto– and micro–electronic applications. Native a–SiO shows a temperature–induced disproportionation in which regions of Si and SiO_2 grow by coalescence at the cost of the sub–oxides contained in the bulk material resulting in a formation of Si nanocrystals. This disproportionation is studied by means of nonresonant x–ray Raman scattering (XRS) at the Si $L_{2,3}$–edges in the temperature range between 600°C to 1200°C. XRS probes soft x–ray absorption edges using incident x–ray energies between 7 and 12 keV which yields a high bulk sensitivity. Such measurements allow a quantitative assessment of the sub–oxide contributions in native and annealed a–SiO to characterize the disproportionation process. Differently annealed a–SiO samples were also examined with x–ray diffraction which shows that bulk a–SiO is amorphous at least up to 850°C and Si nanocrystals have formed at about 950°C.

HL 9.15 Mon 14:30 P2

Phase separation and nanocrystal formation in bulk amorphous GeO — •Christoph J. Sahle[1], Christian Sternemann[1], Achim Hohl[2], Ralph Wagner[3], Dirk Lützenkirchen-Hecht[3], Alexej Herdt[3], Omid M. Feroughi[1], Heiko Conrad[1], and Metin Tolan[1] — [1]Fakultät Physik / DELTA, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Institute for Materials Science, Darmstadt University of Technology, D-64287 Darmstadt, Germany — [3]Abteilung Physik, Bergische Universität Wuppertal, D-42097 Wuppertal, Germany

Bulk amorphous germanium monoxide (a–GeO_x with $x \approx 1$) is studied regarding the temperature–induced disproportionation, i.e phase separation of GeO_x into Ge and GeO_2, and formation of Ge nanocrystals by measurements of the Ge K–edge XANES employing fluorescence yield detection and x–ray diffraction. Germanium/oxygen systems are an interesting class of materials due to their potential as precursors for the synthesis of Ge nanocrystals in an oxide–matrix. The disproportionation of a–GeO_x was characterized in the temperature range between 160°C and 640°C. Phase separation sets in at 250°C and is almost completed at 440°C. X–ray diffraction proves the occurrence of Ge nanocrystals of several nm diameter embedded in a GeO_2 matrix for temperatures above 500°C. The findings are discussed by a structural model of a–GeO_x in which the native amorphous Ge monoxide is proposed to consist of nanoscaled regions of Ge and GeO_2 which are separated by ultra–thin sub–oxide interfaces.

HL 9.16 Mon 14:30 P2

Spin Noise Spectroscopy in ^{28}Si — •Tammo Böntgen[1], Helge Riemann[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover — [2]Institut für Kristallzüchtung, Max-Born-Str. 2, 12489 Berlin

We employ spin noise spectroscopy [1] to examine the intrinsic spin lifetime of electrons bound to phosphorus donors in isotopically pure ^{28}Si at low temperatures. The up to now reported spin lifetime of these electrons are already extremely long but no measurement of the intrinsic lifetime has been undertaken yet. In addition we will measure the ultra narrow exciton transition lines in ^{28}Si. These transition lines scale with the isotopical purity of the sample and should be according to calculations as small as 100 neV in the studied Silicon.

[1] M. Römer, J. Hübner, and M. Oestreich, Rev. Sci. Instrum. **78**, 103903 (2007)

HL 9.17 Mon 14:30 P2

Optical Selection Rules in Silicon — •Hauke Horn, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany

We use selective optical excitation around the direct band gap of silicon at room temperature and polarization resolved detection of the photoluminescence from the indirect band gap transition to probe the optical spin selection rules in this important semiconductor material. The degree of circular polarization from the indirect transition is monitored, while the excitation from the top most valence band Γ_8^+ to the lowest conduction band Γ_6^- at the center of the Brillouin zone is tuned to the excitation from the split-off band Γ_7^+. To shorten the carrier lifetime to less than the spin relaxation time a biased silicon photodiode is used as sample.

HL 9.18 Mon 14:30 P2

Process conditions for doping with Spin On dopants — •Sebastian Stoll, Peter Iskra, Helmut Lochner, Dorota Kulaga-Egger, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The use of spin on dopants (SOD) as a way of doping in place of ion implantation has become more important over the past years. The advantages of SOD are reduced costs and the avoidance of crystal lattice damages compared to ion implantation. SOD can be applied on the wafer by using standard photo resist equipment. The dopant produces a doped silicate film, acting as an unlimited diffusion source. By the use of a suitable diffusion process and film thickness, the sheet resistance can easily be adjusted.

First we investigated the standard procedure to apply the SOD on the wafer, known from publications. We optimized the procedure achieving a defect free and homogenous film of the SOD. Furthermore we analysed the dopant concentration and the sheet resistance after diffusion process at different temperatures. Investigations were carried out by SIMS, SEM and four-point measurements.

Finally, n- und p- MOSFETs were fabricated and characterised.

HL 9.19 Mon 14:30 P2

Investigation of defect and phosphorus related states in very thin films of μc-Si — •Konrad Klein[1], Martin Eberl[1], Benedikt Stoib[1], Andre R. Stegner[1], Oleksandr Ashtakov[2], Friedhelm Finger[2], Martin Stutzmann[1], and Martin S. Brandt[1] — [1]Walter Schottky Institut, Am Coulombwall 3, 85748 Garching — [2]Forschungszentrum Jülich, 52425 Jülich

Although very thin μc-Si films with a thickness of a few ten nanometers are used as p- and n-type layers in μc-Si thin film solar cells, only the defect and doping induced states of thick films with a thickness of several hundred nanometers have been studied systematically with Electron Spin Resonance (ESR) and Electrically Detected Magnetic Resonance (EDMR) [1,2]. Since it is known that film properties change with the thickness [3], we have investigated the paramagnetic states of 20 nm thin films of phosphorus-doped μc-Si with various doping concentrations using EDMR. The results show defect and donor related states, which are already known from thicker films, as well as two new broad paramagnetic resonances at g $\approx$ 2.034 and g $\approx$ 1.984. We discuss possible origins of these lines comparing the results with those obtained for phosphorus-doped crystalline silicon, silicon nanocrystals and recent results obtained with pulsed EDMR for μc-Si thin film solar cells [4]. [1] J. Mueller et al., Physical Review B, 60, 11666 (1999) [2] K. Lips et al., Solar Energy Materials and Solar Cells, 78, 513 (2003) [3] M. Tzolov et al., Journal of Applied Physics, 81, 7376 (1997) [4] J. Behrends et al., Journal of Non-Crystalline Solids, 354, 2411 (2008)

HL 9.20 Mon 14:30 P2

Morphological properties of three dimensional Ge nanoclusters grown on SiO_x (x<2) films — •Zakir Seyidov[1], Maria Rubezhanska[2], Christian Hofer[1], Yuri Kozyrev[2], Christian Teichert[1], and Anton Naumovets[3] — [1]Institute of Physics, Montanuniversitaet Leoben, Franz Josef Str. 18, A-8700 Leoben, Austria — [2]Institute of Surface Chemistry, Generala Naumova Str. 17, UA-03164 Kiev, Ukraine — [3]Institute of Physics, Prospect Nauki 46, UA-03028 Kiev, Ukraine

Novel optoelectronic and nanoelectronic devices require smaller and smaller size of their components. This explains the interest in Ge nanostructure formation in an SiO_2 matrix. A possibility of epitaxial formation of such Ge nanostructures on initial amorphous SiO_x (x<2) films is considered. Their surface was investigated using atomic-force microscopy. The height, size and distribution density of germanium nanoislands of the resultant film were determined. Ge nanoclusters were about 1-3 nm in height and 10-25 nm in the basis for the initial and intermediate stages of their formation with very low distribution density about 5 10^8 cm^{-2}. For other samples [1], Ge nanoclusters grew larger: about 20 nm in height and 30 nm in the basis. Their distribution density over the substrate surface exceeded 10^{11} cm^{-2}. Characteristics of the formed nanostructure at the different formation stages were shown both doped (Sb, B) and undoped films. This research was supported by ÖAD Project UA No 2007/05.

[1]Yu.N.Kozyrev et al., Proceedings of ICTF14&RSD2008 p.76

HL 9.21 Mon 14:30 P2

Optical and electrical characterization of silicon nanowires etched from highly doped silicon wafers — •Pratyush Das Kanungo, Nadine Geyer, Vadim Talalaev, Oussama Moutanabbir, Nikolai Zakharov, Ren Bin Yang, Peter Werner, and Ulrich Gösele — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Metal assisted catalytic etching of silicon nanowires (Si NWs) from silicon wafers is one of the most popular *top-down* approaches in nanotechnology. In order to use these NWs as future nano-devices, extensive investigations of the optical and electrical properties of them are required. We report on the optical and electrical characterization of Si NWs etched from highly doped (0.001 to 0.006 Ω-cm) n-type (111) Si wafers by an aqueous solution of HF and silver nitrate. Room temperature, as well as low temperature photoluminescence of the Si NWs, separated from the original silicon substrate and dispersed on a GaAs substrate, showed significant blue-shift and broadening of the silicon peak at silicon band gap as compared to the silicon substrate. Room temperature Raman spectra of the same sample showed a red shift and broadening of the principal Si-Si peak compared to the silicon substrate. Electrical measurement of individual NWs with Pt-Si contacts fabricated by electron beam lithography showed the expected electrical conductivity.

HL 9.22 Mon 14:30 P2

MOVPE of semipolar GaN on m-plane sapphire — •M. Frentrup[1], S. Ploch[1], M. Pristovsek[1] und M. Kneissl[1,2] — [1]TU Berlin, EW 6-1,Institut für Festkörperphysik, Hardenbergstr.36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str.4, 12489 Berlin, Germany

InGaN multiple quantum well (MQW) light emitting diodes on c-plane GaN suffer piezoelectric and spontaneous polarization effects. These effects lead to the well known quantum confined stark effect (QCSE), which causes a reduction of the radiative recombination efficiency. Theoretical calculations have predicted that for certain semipolar surfaces a strong reduction of the QCSE can be expected. Possible candidates for semi-polar surfaces are e.g. the $\{10\bar{1}\bar{1}\}$, $\{2\bar{1}\bar{1}2\}$ and $\{10\bar{1}\bar{3}\}$. We have investigated the growth of semi-polar GaN on $(10\bar{1}0)$ sapphire (m-plane) with metal organic vapor phase epitaxy (MOVPE). The epitaxy of nitrides on sapphire consists of three different steps - nitridation, nucleation, and buffer growth. The surface temperature for the different steps, especially for the nitridation was varied in the range between 530°C and 1100°C. We have also varied the nucleation temperature between 500°C and 700°C. The GaN growth was characterized by in-situ spectral reflectance and wafer curvature. The samples were characterized ex-situ by X-ray diffraction, AFM and photoluminescence.

HL 9.23 Mon 14:30 P2

MOVPE growth of AlGaN films — •Ö. Savaş[1], J. Stellmach[1], C. Meissner[1,2], M. Pristovsek[1], and M. Kneissl[1] — [1]TU Berlin, Institut für Festkörperphysik EW6-1, Hardenbergstr. 36, 10623 Berlin, Germany — [2]ISAS Berlin, Albert-Einstein-Str. 9, 12489 Berlin, Germany

For UV light emitting diodes (LEDs) the growth of AlGaN with high Al-content is essential. By varying the Al-content in $Al_xGa_{x-1}N$ emission energies between 3.4 and 6.2 eV can be achieved.

We have investigated the growth of AlGaN on GaN/sapphire templates by metal-organic vapour phase epitaxy (MOVPE) in a Thomas Swan vertical close coupled showerhead reactor. The influence and understanding of the strong gas phase prereactions between trimethylaluminium (TMAl) and ammonia (NH_3) are important for high quality AlGaN growth. To study these critical prereactions these effects of growth parameters like NH_3 and TMAl partial pressures, total reactor pressure and growth temperature on the Al-incorporation has been investigated. We found that the growth rate decreased with increasing temperature and the Al-content increased proportional to the square root of the TMAl partial pressure. Further investigation, in particular the effects of the gap between the showerhead (inlet for the vapours) and the substrate on the prereaction are under way.

HL 9.24 Mon 14:30 P2

Aufbau und Erprobung eines einfachen GIXRF-Messplatzes — •Stephanie Fritze, Jürgen Bläsing und Alois Krost — Institut Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Deutschland

Die Röntgenfluoreszenzanalyse unter streifendem Einfall ist eine Methode zur Strukturanalyse, die in den letzten Jahren immer mehr an Bedeutung gewonnen hat, um Konzentrationen von Elementen und Schichtdicken von Halbleiterstrukturen zu bestimmen. Aus der Kombination eines Röntgenfluoreszenz- und eines Röntgenreflektometrie-Messplatzes wurde ein GIXRF (Grazing Incidence X-Ray Fluorescence) Messplatz aufgebaut. Mittels kontinuierlicher, semimonochromatischer und monochromatischer Anregung wurden Schichtsysteme auf der Basis von (In,Ga,Al)N auf Silizium bzw. Saphir (MQW, DBR,

FET) und dünne Schichten verschiedener Metalle (Kontaktierungen) untersucht. Erste Ergebnisse der Fluoreszenzauswertung werden mit Simulationen verglichen und den Messungen der Reflektometrie und der Diffraktometrie gegenübergestellt und interpretiert.

HL 9.25 Mon 14:30 P2

Herstellung und Implantation von ^{172}Lu(^{172}Yb) in GaN und Messung bei tiefen Temperaturen — •Riccardo Valentini und Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik, Nußallee 14-16, 53115 Bonn

Für optoelektronische Bauteile werden Halbleiter mit großer Bandlücke verwendet, die mit Seltenen Erden dotiert sind. Um deren Verhalten nach der Implantation zu untersuchen, hat sich die Methode der γ-γ-Winkelkorrelation (PAC) bewährt. Ein geeignetes Isotop zur Untersuchung solcher Halbleiter ist ^{172}Yb.

Die Herstellung des Mutterisotops ^{172}Lu erfolgt durch Bestrahlung einer Thulium-Folie mit ^{4}He, ^{169}Tm(α,n)^{172}Lu am Bonner Isochron-Zyklotron und die Implantation in GaN am Bonner Isotopenseparator, d.h. Herstellung und Implantation finden vor Ort statt.

Es soll die Temperaturabhängigkeit der Hyperfeinfelder für ^{172}Lu(^{172}Yb) in GaN untersucht werden. Wir führen Messungen bei tiefen Temperaturen zwischen 25 K und 295 K in einem Kryostaten durch. Zu erwarten ist generell eine Zunahme der Wechselwirkungsfrequenz. Der Verlauf bei Temperaturen um 100 K konnte bisher noch nicht eindeutig geklärt werden. Die Messungen werden auf einer PAC-Anlage durchgeführt, die das Material LSO als Szintillator benutzt. Dadurch kann eine bessere Energieauflösung, eine höhere Anisotropie und eine kürzere Messzeit als mit gängigen Szintillatormaterialien erzielt werden.

HL 9.26 Mon 14:30 P2

Optical study of Rare earth ion implantation in GaN heterostructures — •JAYANTA KUMAR MISHRA, UWE ROSSOW, and ANDREAS HANGLEITER — INTITUTE OF APPLIED PHYSICS, UNIVERSITY OF BRAUNSCHWEIG,MENDELSSOHNSTRASSE 2,38106,BRAUNSCHWEIG.

Rare earth ion implanted GaN or AlGaN is a very promising material to be utilized for light emitting devices. When rare earth ions are used for that purpose, the implanted GaN shows photoluminescence in the visible range (480-650nm)[1]. We investigate the use of AlGaN/GaN/AlGaN heterostructures for the purpose of implantation. Based on the results of TRIM simulations, we choose a primary ion energy of 100 keV for Europium ion implantation.The dose and projected range are 1014cm-2 and 42 nm respectively. We have varied both the thickness of the GaN layer as well as the composition of the AlGaN cladding layers and studied the influence on Eu3+ luminescence properties.

1.J. H. Park and A.J.Steckl,APPLIED PHYSICS LETTERS 88,011111 ,2006.

HL 9.27 Mon 14:30 P2

Systematic study of *C*- and *M*-plane growth of GaN on $LiAlO_2$ by plasma assisted MBE — •Ralf Schuber[1], Yen-Liang Chen[2], Yu-Chi Hsu[2], and Daniel M. Schaadt[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH) and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe — [2]Department of Physics, National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC

Group III nitrides grown along the <0001> direction show a strong quantum confined Stark effect due to the electric fields resulting from the spontaneous and piezoelectric polarization. These fields cause a reduction of the oscillator strength due to a spatial separation of electrons and holes and a decrease in the energy of the radiative transition. Epitaxial layers with non-polar surfaces such as the *M*-plane $\{1\bar{1}00\}$ are attractive due to the absence of built-in electrical fields. $LiAlO_2$ constitutes a particularly suitable substrate as its lattice mismatch to both *C*- and *M*-plane oriented GaN lies below 2%. While molecular beam epitaxy growth of *M*-plane films on $LiAlO_2$ has been well established, the growth of *C*-plane nitrides on $LiAlO_2$ is poorly understood. To investigate the transition from *M*-plane to *C*-plane growth, we have studied the impact of various growth parameters, such as the Ga to N flux ratio, the nucleation and epi layer temperature and thickness. It was found that the crystal orientation of GaN can be adjusted by selecting appropriate growth conditions.

HL 9.28 Mon 14:30 P2

TEM Investigation of Ultrathin GaInN/GaNQuantum Well Structures with high Indium Content — •Lars Hoffmann, Heiko Bremers, Holger Jönen, Daniel Dräger, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institute of Applied Physics, Braunschweig, Germany

While GaN-based blue light emitting diodes exhibit exceptionally large internal quantum efficiencies (up to 80% at room temperature) their green counterparts quickly become less efficient at longer wavelength. Therefore, a green laser diode based on GaN still has to be demonstrated. Material quality and very high piezoelectric fields are the likely cause for that. While LED efficiency greatly benefits from V-shaped pits decorating threading dislocations, laser diodes require highly perfect interfaces and homogeneous quantum wells. Using Transmission Electron Microscopy (TEM) we have studied ultrathin (< 2nm) high indium content quantum well (QW) structures suitable for blue-green laser diodes. Some of the grown structures showed partial relaxation and thermal degradation. Moreover, we observed high defect densities in the low temperature grown upper waveguides. We investigate the mechanisms of relaxation and possible misfit dislocation generation in the QW structures.

HL 9.29 Mon 14:30 P2

Microscopic properties of spontaneously formed non-polar and semi-polar GaN growth domains on r-plane sapphire — •B. Bastek, J. Christen, T. Hempel, P. Veit, M. Wieneke, A. Dadgar, J. Bläsing, and A. Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

We present a study about the microscopic optical and structural properties of spontaneously developed growth domains of non-polar GaN and semi-polar GaN on the same sapphire wafer. For optimizing the lattice match between a-plane GaN and r-plane Sapphire the growth conditions for an AlInN nucleation layer were investigated. Most of the samples exhibit layers with pure a-plane GaN of good crystallographic quality. However, on some samples a circular region of semi-polar (nearly (11-26)) GaN emerged. The thickness of the frame strongly depends on the chosen growth conditions for the nucleation layer. At the boundary the optical properties of the two growth domains drastically change. In the non-polar a-plane GaN domains the basal plane stacking fault (BSF) luminescence exceeds the excitonic luminescence by a factor of three which is specific for hetero-epitaxial non-polar GaN. In contrast the excitonic luminescence dominates the BSF emission by a factor of seven in the semi-polar region accompanied by an absolute increase of the intensity. Besides structural properties we will show *-Cathodoluminescence and TEM images of the boundary region.

HL 9.30 Mon 14:30 P2

Novel Low Temperature Surface Reconstructions of GaN(0001) Surface — Danda Acharya, •Kendal Clark, Muhammad Haider, Erdung Lu, Arthur Smith, and Saw-Wai Hla — Ohio University, Physics and Astronomy Department, Athens, Ohio 45701, USA.

Low temperature electronic and structural properties of a nitrogen polar, gallium rich GaN (0001) surface have been investigated by using scanning tunneling microscopy and spectroscopy at 5 K and 80 K substrate temperatures. Deviating from the known room temperature surface reconstructions, we find novel low temperature surface structures having a rhombohedral lattice with a 12 * 12 gallium atomic periodicity. From the tunneling spectroscopy data, two of the surface states of GaN (0001) originated from the overlap of gallium adatom wavefunctions have been directly observed. By means of bias dependent scanning tunneling microscope imaging, we show that these novel surface structures are contributed from the predicted surface state bands, B1 and B2. This work is supported by the National Science Foundation NSF-PIRE grant, OISE 0730257, and the United States Department of Energy, DE-FG02-02ER46012 grant.

HL 9.31 Mon 14:30 P2

Lumineszenzuntersuchungen an „photonic band gap“ GaN-LED Strukturen auf SOI-Substrat — •A. Franke[1], J. Krimmling[1], T. Hempel[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2], K.X. Lin[3], S.L. Teo[3] und S. Tripathy[3] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]AZZURRO-Semiconductor AG, Magdeburg — [3]Institute of Material Research and Engineering, IMRE, Singapore

Zur Erhöhung der Auskoppeleffizienz von GaN-LEDs wurde unter Verwendung von trockenchemischen Ätzmethoden ein photonischer Kristall hergestellt. Die LEDs wurden mittels MOVPE auf einem 6” SOI-Substrat gewachsen. Als aktives Medium dient ein InGaN/GaN Muli-

quantumwell (MQW). Zur Oberflächenstrukturierung wurde die Probe unter Verwendung von plasmagestütztem Trockenätzen und ICP-Sputtern in zylindrische Mesas von etwa 230 μm Querschnitt unterteilt. Hierauf wurden entlang des Durchmessers auf einem ca. 50 μm breiten Streifen Nanokegel mit einem Querschnitt von etwa 300 nm strukturiert. Integrale Mikro-Photolumineszenzspektren (μ-PL), lateral über die Mesen gemittelt, zeigen eine dominante MQW-Emission bei 560,6 nm, moduliert durch starke Fabry-Perot-Interferenzen sowie bandkantennahe GaN-Lumineszenz bei 354,5 nm. μ-PL mappings zeigen am Ort der Nanostrukturierung eine starke Erhöhung der Intensität der GaN Lumineszenz sowie eine Rotverschiebung der Emissionswellenlänge um etwa 3 nm. Im Kontrast dazu ist die Intensität der MQW-Emission lateral konstant, jedoch wird hier eine starke Blauverschiebung um 6 nm im Bereich der Nanokegel beobachtet.

HL 9.32 Mon 14:30 P2

Towards Galliumnitride nanowire field-effect transistors — •Jörg Kinzel[1], Jens Ebbecke[2], Hubert Krenner[1], Raffaela Calarco[3], Toma Stoica[3], and Achim Wixforth[1,4] — [1]Lehrstuhl für Experimentalphysik 1, Universität Augsburg, Germany — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom — [3]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, Germany, and JARA- Fundamentals of Future Information Technology — [4]Center for NanoScience, Ludwig-Maximilians-Universität, München, Germany

Group III-nitride nanowires (NWs) have drawn particular interest over the past years owing their potential for wide-spread applications in nano-electronics and optoelectronics at ambient temperatures. We report on recent progress on the realization of field effect transistors using doped GaN nanowires grown by molecular beam epitaxy[1]. We define metal source-drain and top gate electrodes by electron-beam lithography and a lift-off technique. Samples are characterized by temperature- and bias-dependent conductivity measurements.

[1] R. Calarco, M. Marso, T. Richter, A. I. Aykanat, R. Meijers, A. v.d. Hart, T. Stoica, and H. Lüth, Nano Letters, 2005 Vol. 5, No. 5, 981-984

HL 9.33 Mon 14:30 P2

Carbon doped InGaAs/InAlAs heterostructures on relaxed buffer layers — •Marika Kubová, Katharina Schulze, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg, Germany

The InAlAs/InGaAs heterostructures with high In content are promising candidates for spintronic applications such as spin-valve mesoscopic devices due to their large Landé g-factor (around 15 in InAs), large Rashba effect and low Schottky barrier to evaporated metals. We grow InGaAs/InAlAs/InAs heterostructures using a step-graded metamorphic buffer layer on GaAs (001) substrates via molecular beam epitaxy. In order to obtain 2DEGs or 2DHGs, these structures have been grown either undoped [1] or remote doped with Si [2] and Mn [3]. Here we present results on carbon doped InGaAs/InAlAs heterostructures with embedded InAs channel. The magnetotransport measurements on these samples at low temperatures show a change of the conductivity from p-type to n-type via illumination and weak localisation at low magnetic fields.

[1] F. Capotondi, G. Biasiol, I. Vobornik, L. Sorba, F. Giazotto, A. Cavallini, B. Fraboni, J. Vac. Sci. Technol. B 22, 702 (2004)

[2] A. Richter, M. Koch, T. Matsuyama, Ch. Heyn, U. Merkt, Appl. Phys. Lett. 77 (20) 3227, (2000)

[3] U. Wurstbauer, I. Gronwald, U. Stöberl, A. Vogl, D. Schuh, D. Weiss, W. Wegscheider, Physica E 40, 1563 (2008)

HL 9.34 Mon 14:30 P2

Magnetic and magneto-transport properties of self-assembled MnAs-nanoclusters on undoped GaInAs-surfaces. — •Matthias T. Elm[1], Shinjiroh Hara[2], Hans-Albrecht Krug von Nidda[3], and Peter J. Klar[1] — [1]Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany — [2]Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo, Japan — [3]Experimentalphysik V, University of Augsburg, Germany

Self-assembled MnAs nanoclusters were grown on undoped GaInAs/InP (111)B-substrate by MOVPE. The MnAs nanoclusters were randomly distributed on the samples. The c-axis of all clusters is orientated perpendicular to the growth direction. The lateral size and height of typical nanoclusters are 100 and 47 nm, respectively. The density of the nanoclusters varies from 2.8×10^8 to 6.6×10^8 cm^{-2} due to different growth conditions. The growth of the MnAs nanoclusters leads to a p-type conductivity of the samples with carrier concentrations of about 2×10^{18}cm^{-3} at room temperature. The magnetic properties were probed by ESR measurements in order to determine the magnetic anisotropy of the clusters. The samples were also investigated by angle-dependent magneto-transport measurements in the temperature range from 20 to 280 K in external magnetic fields up to 10 T. The differences in the temperature-dependent behavior, in the magneto-resistance as well as the influence of the ferromagnetic clusters on the transport will be discussed.

HL 9.35 Mon 14:30 P2

Hole Density in (Ga,Mn)As layers grown on (001), (110) and (311) GaAs Substrates — •Michael Hirmer, Michael Mayr, Tobias Korn, Ursula Wurstbauer, Martin Utz, Stefanie Heydrich, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Universität Regensburg, Universitätsstraße 31, 93053 Regensburg, Germany

The dilute magnetic semiconductor (DMS) $Ga_{1-x}Mn_xAs$ is a very promising candidate for building spintronic devices, due to theoretically predicted room temperature ferromagnetism. Since the ferromagnetism of this Zener-like DMS is hole-mediated, the ferromagnetic transition temperature T_C corresponds to $T_C \alpha x_{eff} p^{1/3}$ (x_{eff}: effective Mn concentration, p: carrier density). We present a detailed study of carrier concentrations, determined by Hall measurements and Raman scattering on thin $Ga_{1-x}Mn_xAs$ films. The films were grown on (001), (311) and (110) semi-insulating GaAs substrates with layer thicknesses ranging from 5 to 300 nm and Mn contents of 6% using low temperature molecular beam epitaxy. Hole concentrations in the range of 10^{20} cm^{-3} were found with highest values for (001), in correspondence with the measured T_C values. Samples with higher T_C show a contribution of side jump to AHE, only. Measurements before and after annealing suggest that the AHE is not caused by scattering processes, only, consist with theoretically predicted intrinsic contributions. Therefore, we used Raman scattering intensity analysis of the uncoupled LO and the coupled plasmon LO phonon mode to determine p, independent of transport measurements, before and after annealing.

HL 9.36 Mon 14:30 P2

Annealing studies of Hf implanted $Al_xGa_{1-x}N$ — •Thomas Geruschke[1], Katharina Lorenz[2], and Reiner Vianden[1] — [1]Helmholtz - Institut für Strahlen- und Kernphysik, Universität Bonn, Germany — [2]Instituto Tecnologico e Nuclear, SACAVEM, Portugal

The annealing behaviour of 0.5 μm $Al_xGa_{1-x}N$ on sapphire substrate after implantation of ^{181}Hf was studied using the perturbed angular correlation (PAC) technique. Different $Al_xGa_{1-x}N$ samples from the commercial supplier TDI Inc. were implanted with the radioisotope ^{181}Hf at the Bonn Isotope Separator. Subsequently the samples were annealed in a rapid thermal annealing apparatus at 1273 K in nitrogen atmosphere. The strength of the electrical field gradient at the probe site varies almost linear with the concentration x of aluminum in the ternary compound, whereas the uniformity of this hyperfine interaction has its minimum at $x \approx 0.5$. To confirm the linear behaviour, additional measurements will be carried out. First results will be presented and discussed.

HL 9.37 Mon 14:30 P2

Control of Mn magnetic moments in GaAs quantum dots — •Peter Moraczewski and Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße9, 20355 Hamburg

In semiconductor quantum dots electrons and holes are confined in all three spatial directions. Their eigenstates can be tailored by the used materials, the size and the shape of the dot and also by applied electric and magnetic fields. When we dope the quantum dot with atoms carrying a large magnetic moment, like Mn, they will interact with the electrons or holes via the Coulomb and Exchange interaction. We can now expect to manipulate the alignment of the Mn-spins by changing the states of electrons or holes. In III-V semiconductors such as GaAs the Mn atom is an acceptor, so holes will be the main charge carriers. We calculate the eigenstates of several holes in a quantum dot by k*p-theory-, under the influence of a magnetic field and with many-body interaction. Then we examine the interplay between the hole states and the magnetic moments of one or two manganese impurities.

HL 9.38 Mon 14:30 P2

Fabrication and Characterization of Cu-Doped GaN —

•Philipp Ganz[1,2], Christoph Sürgers[2,3], and Daniel M. Schaadt[1,2] — [1]Universität Karlsruhe, Institut für Angewandte Physik, 76131 Karlsruhe, Germany — [2]Universität Karlsruhe, DFG-Center for Functional Nanostructures, 76131 Karlsruhe, Germany — [3]Universität Karlsruhe, Physikalisches Institut, 76131 Karlsruhe, Germany

Semiconductor based spintronics may be implemented using InN quantum dots, which show long and temperature in-dependent spin-life times. To inject spins electrically into these quantum dots, a spin alignment layer which yields high spin-polarizations at room temperature is essential for realistic applications. A possible material for a nitride based spin aligner is Cu-doped GaN. Theoretical predictions show the possibility of ferromagnetism and high spin-polarization for certain Cu arrangements. Initial experimental results have already indicated ferromagnetism. However, the origin of the ferromagnetism is still under debate. Additionally, the influence of defects on the ferromagnetism in Cu doped nitrides is still unclear. We have used density functional theory to verify previous theoretical predictions and to investigate the effects of various parameters on the ferromagnetic nature of the material. Additionally, we have investigated the growth of Cu-doped GaN by molecular beam epitaxy and the influence of growth parameters, such as the metal to nitrogen flux ratio, Cu to Ga flux ratio and growth temperature, on the magnetic properties.

HL 9.39 Mon 14:30 P2

Spin Noise Spectroscopy on Donors in GaAs — •Hannes Bernien, Georg Müller, Michael Römer, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany

In recent experiments spin noise spectroscopy (SNS) has proven to be a very sensitive technique to study electron spin dynamics in semiconductors at thermal equilibrium[1]. Here we present SNS-measurements on donor bound electrons in very low doped bulk GaAs. In this environment the donors do not interact with each other and form artificial atoms. We discuss the detection of single donor bound electron spins, which should have extremely long spin relaxation times compared to ensemble spin relaxation times. In further experiments the electron bound to the donor will be used to probe and study the local nuclear magnetic field at the donor site.

[1] M. Römer. J. Hübner, and M. Oestreich, Rev. Sci. Instrum. **78**, 103903 (2007)

HL 9.40 Mon 14:30 P2

Magnetooptics of Gd-doped GaN — •Jan Heye Buss, Jörg Rudolph, and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr Universität Bochum, Germany

SQUID measurements of Gd-doped GaN showed Curie-temperatures up to 700 K [1]. GaN:Gd is therefore discussed as a potential electron spin aligner for room temperature spintronics. We perform room temperature magneto-optical Kerr effect (MOKE) measurements at the band edge to directly probe the effect of Gd-doping (2.7×10^{19}cm^{-3}) on the valence and conduction band. While ferromagnetic GaMnAs shows huge Kerr signals (up to 5000 μrad) [2], no difference in Kerr rotation (within the 30 μrad sensitivity of our setup) is found in comparison with an undoped GaN reference sample. These findings are in agreement with recent XMCD data from Ney et. al. [3] and suggest that the ferromagnetism observed in SQUID measurements is not related to the GaN host matrix.

[1] S. Dhar et al., Phys. Rev. Lett. **94**, 037205 (2005).
[2] A. V. Kimel et al., Phys. Rev. Lett. **94**, 227203 (2005).
[3] A. Ney et al., Phys. Rev. B. **77**, 233308 (2008).

HL 9.41 Mon 14:30 P2

Growth of InAs quantum dots on hydrogen cleaned GaAs surfaces — •Ahish Kumar Rai, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik Ruhr-Universität Bochum Universitätsstraße 150, Gebäude NB,D-44780 Bochum,Germany

The goal of this work is to introduce site-selective growth of InAs quantum dots on ex-situ patterned GaAs layers. A key step in this process is the cleaning on the surface after patterning. We will report on cleaning by atomic hydrogen. The surface was as exposed to air and chemicals like photo resist. After striping and cleaning, InAs quantum dots have been grown followed by a GaAs cap layer. The quality of the cleaning process is evaluated by measuring the quantum dot photo luminescence, which is very sensitive to surface contaminations. We will discuss the influence of various parameters e.g. the substrate temperature during cleaning.

HL 9.42 Mon 14:30 P2

The role of surface kinetics in achieving high non-equilibrium N concentrations in bulk GaAs — •Hazem Abu-Farsakh[1,2] and Jörg Neugebauer[1,2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Str. 1, 40237 Düsseldorf, Germany — [2]Universität Paderborn, Warburger Str. 100, 33098 Paderborn, Germany

Ternary $GaAs_{1-x}N_x$ and quaternary $In_xGa_{1-x}As_{1-y}N_y$ alloys have attracted a considerable interest for applications including infrared laser diodes and photovoltaic solar cells. Despite the very low equilibrium solubility of N in bulk GaAs, N concentrations up to few percents can be achieved in MBE growth experiments. *Ab-initio* calculations indicate that N incorporation in the subsurface layer is thermodynamically most favorable, which can be utilized to achieve high concentrations by employing surface kinetics [1]. To explore possible roles for surface engineering we have calculated the kinetic barriers for various mechanisms and reaction paths of N at the GaAs(001) surface. Based on our results we propose a trapping mechanism that effectively prohibits N from getting incorporated in the subsurface layers. These results also allow (*i*) to identify the mechanism which controls the achievable enhancement in the bulk N concentration, (*ii*) to revise previous growth and incorporation models, and (*iii*) to provide a direct microscopic basis of the recently reported In-N compositional anti-correlation in $In_xGa_{1-x}As_{1-y}N_y$ quantum wells [2].

[1] H. Abu-Farsakh and J. Neugebauer, Phys. Rev. B (submitted).
[2] M. Albrecht, H. Abu-Farsakh *et al.*, Phys. Rev. Lett. **99**, 206103 (2007).

HL 9.43 Mon 14:30 P2

Anisotropy of electron Lande g-factor in (110) GaAs quantum wells — •Sergej Kunz[1], Stefan Oertel[1], Jens Hübner[1], Dieter Schuh[2], Werner Wegscheider[2], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover — [2]Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D-93040 Regensburg

We measure the electron Lande g-factor and electron spin lifetime in (110)-oriented GaAs quantum wells by time- and polarization resolved photoluminescence spectroscopy. The electron Lande g-factor shows an anisotropy on the in plane magnetic field direction and this anisotropy is investigated in detail for different quantum well widths. Furthermore, the electron spin dynamics is determined in dependence on quantum well widths and spin orientation.

HL 9.44 Mon 14:30 P2

Magnetism in manganese modulation-doped two-dimensional hole systems — •Wolfgang Krenner[1,4], Benedikt Rupprecht[1], Tjark Windisch[1], Ursula Wurstbauer[2,3], Marc Wilde[1], Werner Wegscheider[2], and Dirk Grundler[1] — [1]Physik Department E10, TU München, James-Franck Str. 1, 85748 Garching — [2]Institut für Angewandte und Experimentelle Physik II, Universität Regensburg, Universitätsstr. 31, 93040 Regensburg — [3]Current address: Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [4]Current address: Physik Department E20, TU München

Diluted magnetic semiconductors on the one hand and two-dimensional carrier systems with strong spin-orbit-coupling on the other hand have been of increasing interest over the past few years. Here we present magnetization measurements on a Mn-modulation doped InGaAs/InAs quantum well at 400 mK in external magnetic fields of up to 15 T. For the measurements a Micromechanical Cantilever Magnetometer (MCM) mounted on a rotational stage was employed. This allows the variation of the tilt angle between the sample magnetization and the external magnetic field.

The measurements show a fourfold anisotropy and a hysteretic behavior of the magnetization around B=0. This may be associated with the coupling of the free holes to the magnetic moments of the Mn dopants. An oscillatory behavior that was observed in high magnetic fields could be interpreted as the de Haas-van Alphen effect of the free holes.

We thank the DFG for funding via project GR1640/3 in SPP 1285.

HL 9.45 Mon 14:30 P2

MBE growth of GaAs/GaMnAs core-shell nanowires — •Andreas Rudolph[1], Marcello Soda[1], Matthias Kiessling[1], Benedikt Bauer[1], Dieter Schuh[1], Tomasz Wojtowicz[2], Werner Wegscheider[1], and Elisabeth Reiger[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Institute of Physics, PAS, Al. Lotników 32/46, 02-668 Warszawa, Poland

We investigate the growth conditions of core-shell nanowires consisting of a GaAs core and a magnetic GaMnAs shell. The diluted magnetic semiconductor GaMnAs is of great interest for spintronics applications as it allows a high degree of spin injection into GaAs. However, as the typical growth temperature of GaMnAs is very low it is not compatible with typical growth conditions for axial growth of nanowires. The GaAs core NW is grown on GaAs(111)B substrates using the gold catalyst technique. To gain control over the position and the diameter of the nanowire we recently started nanostructuring the Au film by electron beam lithography. In a second step the GaMnAs is grown on the <110> facets of the GaAs nanowire using typical growth parameters of the 2D growth on GaAs(110). We study the influence of various growth parameters, e.g. the substrate temperature, the flux ratio Ga/As4... on the GaMnAs shell growth. The nanowires are characterized by SEM, TEM and SQUID.

HL 9.46 Mon 14:30 P2

Magnetotransport and THz photoresponse of combined Hall-Corbino- devices patterned on HgCdTe based wafers. — •Fathi Gouider[1], Christof Brüne[3], Jens Könemann[2], Yuri Vasilyev[4], Marek Bugar[5], and Georg Nachtwei[1] — [1]Institut für Angewandte Physik, TU-Braunschweig, Mendelssohnstraße 2, D-38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany — [3]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [4]A.F. Ioffe Physical Technical Institute, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia — [5]Institute of Physics, Charles University in Prague, Ke Karlovn 5, 121 16 Prague2 , Czech Republic

Quantum- Hall- (QH) - systems are discussed as promising THz detectors. In this presentation we present photoconduction measurements of the HgTe/HgCdTe- (MCT) - Quantum well in Hall bar, Corbino as well as combined Corbino- Hall bar geometry in the quantum-Hall- (QH) - regime accomplished. FIR photoconduction measurements of the MCT samples are done to supply a contribution for the basic research of the photoconduction at QH-systems and in addition to contribute to the development of a sensitive as well as spectrally adjustable QH detectors. The materiel system MCT is due to the small effective mass (compared with GaAs) and the smaller magnetic fields for operation of interest. For the measurements a superconducting 10 T-magnet and an adjustable *p*-Ge cyclotron resonance laser are operated (the laser as FIR source, wave-length range of 120 - 180μ m).

HL 9.47 Mon 14:30 P2

Ortsaufgelöste Photostromuntersuchungen an Zinkoxid Schottky-Kontakten — •Zhipeng Zhang, Christian Czekalla, Matthias Schmidt, Alexander Lajn, Holger Hochmuth, Holger von Wenckstern und Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

Wir präsentieren ortsaufgelöste Light Beam Induced Current (LBIC)-Untersuchungen an gesputterten Schottky-Kontakten auf heteroepitaktischen Zinkoxid (ZnO)-Dünnschichten. Für die LBIC-Messungen wurde ein HeCd-Laser (325 nm) verwendet. Als Kontaktmaterialien wurden Silber (Ag), Gold (Au), Palladium (Pd) und Platin (Pt) verwendet, welche sowohl in Argon- (nicht reaktiv) als auch in Sauerstoffatomosphäre (reaktiv) auf die Probenoberfläche gesputtert wurden. Die LBIC-Scans der reaktiv gesputterten Kontakte zeigten eine deutlich höhere laterale Homogenität als die der nicht reaktiv gesputterten. Durch Aufbringen einer zusätzlichen nicht reaktiv gesputterten Deckschicht (capping) konnte die Homogenität weiter erhöht werden. Weiterhin wurden an Pd-Schottky-Kontakten verschiedene Kombinationen aus Kontaktmetall- und Capping-Schichtdicken, abgeschieden unter verschiedenen Sputterbedingungen, untersucht. Die Kontakte wurden mittels Strom-Spannungs- sowie Kapazitäts-Spannungsmessungen bezüglich ihrer elektrischen Eigenschaften charakterisiert.

HL 9.48 Mon 14:30 P2

Determination of Hall-mobilities using a maximum entropy approach — •Robert Heinhold, Matthias Brandt, Holger von Wenckstern, Gisela Biehne, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany

Hall measurements are one of the most commonly used techniques to characterize semiconductors. Such measurements are integral measurements and do, therefore, require homogeneous samples. Nevertheless, it is possible to differentiate layers with different mobilities by performing variable field Hall effect measurements. In this work we employ an iterative algorithm for a multi-carrier characterization using the maximum entropy principle (MEP) [1]. The main concept is to consider the mobility spectrum in the form of a probability distribution which we use to define the information entropy. Maximizing this entropy leads us to the most probable spectrum of carrier mobilities and their relative contribution to the total conductivity. We applied the MEP method to analyze the data measured on various semiconductor single-crystals and multi-heterostructures.

[1] S. Kiatgamolchai et al.: Phys. Rev. E **66**, 036705 (2002).

HL 9.49 Mon 14:30 P2

Energy dynamics in ZnSe/ZnMnSe double-quantum-well structures — •Stephanie Jankowski, Wolfram Heimbrodt, Swantje Horst, Alexej Chernikov, and Sangam Chatterjee — Department of Physics and Material Sciences Center, Phillipps-University Marburg, Renthof 5, 35032 Marburg

Asymmetric ZnSe/ZnMnSe double-quantum-well (DQW) structures with different barrier width have been grown between dilute magnetic ZnMnSe cladding layers on a (100) GaAs substrate with a ZnSe buffer. The DQWs have been studied by cw and time resolved spectroscopy in external magnetic fields up to 7 Tesla. The ZnSe quantum wells are under tensile strain in these DQW structures yielding the light-hole exciton states to be the energetically lowest lying states. This is the main difference to earlier papers, where tunnelling of carriers and excitons have been studied in DQW structures with heavy hole excitons being the lowest lying states. In the magnetic field we were able to change the barrier height, to split the states of the wells due to the Giant-Zeeman-effect of the ZnMnSe barriers and to manipulate the radiationless energy transfer processes between the 3d-internal transitions and the excitonic states. As a result of the sophisticated interaction of these mechanisms a unique excitation energy dynamics was found and will be discussed in detail.

HL 9.50 Mon 14:30 P2

Optical and magnetic properties of MnS in low dimensions — •Manuel Demper[1], Limei Chen[1], Christine Bradford[2], Hans-Albrecht Krug von Nidda[3], Kevin A. Prior[2], Alois Loidl[3], and Wolfram Heimbrodt[1] — [1]Departement of Physics and Material Science Center, Philipps University, Marburg — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh — [3]Center for Electronic Correlation and Magnetism, University Augsburg

The continuously decrease of magnetic structures sooner or later reaches fundamental boundaries. Hence, it is essential to understand the magnetic interactions in low dimensions. Therefore we investigated the transition from 3D-2D on a series of MBE grown zinc blende MnS-layers with various thicknesses between 1ML and 8.6nm by using photoluminescence and SQUID techniques. The PL spectra of these antiferromagnetic MBE-layers exhibit a strong yellow emission band, which belongs to the internal d-d transition of the manganese ions. This $^4T_1 \rightarrow ^6A_1$ transition offers an optical access to the magnetic properties of MnS. Thus, the temperature dependence of the yellow emission bands shows a significant red-shift at low temperatures caused by the energy relaxation of the Mn d-states at the para- to antiferromagnetic phase transition. Surprisingly, there is no clear indication for a reduced Néel-temperature down to one monolayer. These optical results are confirmed by SQUID measurements. Besides the antiferromagnetic phase transition, the thinnest MnS films additionally exhibit a clear ferromagnetic phase below 150K. The unique behaviour will discussed in detail.

HL 9.51 Mon 14:30 P2

Simulation of wavepropagation in nanocrystalline powders — •Daniel Schneider, Johannes Fallert, Janos Sartor, Roman J. B. Dietz, Viktor Zalamai, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany

In strongly scattering and optically amplifying materials, random lasing can be observed at sufficient high excitation powers. Apart from pure signal amplification in such a laser spectrally sharp and spatially localized modes can be observed due to backscattering and interference. In this contribution we show simulations of the localized random lasing modes which are based on a finite difference time domain method. This way the propagation of electromagnetic waves in randomly aligned nano particles can be calculated. The simulation parameters are fitted to actual experiments on ZnO nanoparticles in order to compare the results of the simulations with experimental data.

HL 9.52 Mon 14:30 P2

Temperature dependance of lasing modes in ZnO nanorods — •Janos Sartor, Johannes Fallert, Victor Zalamai, Florian Maier-Flaig, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe(TH), Germany

ZnO can be grown in the form of nanorods which form a natural cavity for nanoscaled lasers. In this work the temperature dependance of stimulated emission from nanorods under quasi-stationary excitation has been investigated. Collection by a microscope objective allows to analyze the photoluminescence from single nanorods. Stable multimode lasing can be observed after optical pumping of the ZnO nanorods. Though the lasing threshold increases with higher temperatures, the individual laser modes can be traced up to room temperature. A spectral red-shifting of the modes which is observed at higher temperatures is attributed to the narrowing of the bandgap with increasing temperature and an additional band gap renormalization due to high carrier concentrations.

HL 9.53 Mon 14:30 P2

Investigation of physical damage in artificially structured $Al_xZn_{1-x}O$ and ZnO thin layers, respectively — •Markus Piechotka[1], Torsten Henning[1], Martin Eickhoff[1], Peter J. Klar[1], Bernd Szyszka[2], and Thomas Wassner[3] — [1]JLU Giessen, Germany — [2]IST Braunschweig, Germany — [3]WSI Munich, Germany

The $Al_xZn_{1-x}O$ films were grown by magnetron RF-sputtering whereas the ZnO films were grown epitaxially using plasma assisted MBE. The layers were artificially structured into arrays of similar wires using photolithography followed by an etching step. The wire diameters were varied between 4 and 1000 μm. Chemical wet etching using a $H_3PO_4 - HAc - H_2O$-mixture and radio frequency ion thruster based ion beam etching, respectively, is used to transfer the pattern into the thin films. The structural properties of the wire edges were analyzed by atomic force microscopy. The influence of the etching induced damage as well as surface effects due to varying surface-to-bulk-ratio on the electronic properties were studied by resistance measurements in the temperature range from 2 to 300 K and in magnetic fields between 0 and 10 T.

HL 9.54 Mon 14:30 P2

Nitrogen doping of RF-sputtered Cu_xO samples investigated by Raman spectroscopy — •David Hartung, Swen Graubner, Bruno K. Meyer, and Peter J. Klar — Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany

A series of Cu_xO layers of about 300 nm thickness was grown by RF-sputtering on glass-substrates. Nitrogen gas was used for doping in the sputter process. For the different samples the nitrogen flow varied between 0.2 and 4 sccm. In order to determine the influence of nitrogen on the structural properties, the samples were investigated by Raman spectroscopy. For excitation of the samples three different laser-wavelengths were used, a HeNe- (633 nm), a frequency-doubled Nd:YAG- (532 nm) and a HeCd-laser (325 nm). The resulting Raman spectra shed light on the question whether and how the nitrogen is incorporated and its influence on the Cu_xO crystalline structure.

HL 9.55 Mon 14:30 P2

Thermoelectric measurements on artificially structured ZnO/ZnS bars — •Gert Homm, Torsten Henning, Bruno K. Meyer, and Peter J. Klar — Institute of Experimental Physics I, Justus-Liebig-University Gießen, Gemany

ZnO layers of about 700 nm thickness were grown by RF Sputtering on glass substrates. The layers are n-type with electron concentrations of about 10^{21} cm^{-3}. Arrays of the as grown samples were artificially structured by photolithography. The patterns consist of regular arrays of bars with different spacings and bar width. The bars can be arranged in different angles with respect to the temperature gradient applied in the measurement. The patterns were transferred by wet-chemical etching. In a second sputter process a thin layer (500 nm) of ZnS was grown on the structured array to achieve the ZnO/ZnS bar structure. The Seebeck coefficient is measured in the temperature range from 50 to 300 K. The influence of the artificial structuring and the orientation of the wires with respect to the temperature gradient on the Seebeck coefficient is discussed.

HL 9.56 Mon 14:30 P2

Artifical structuring of Cu_2O by wet chemical etching — •Julian Benz, Daniel Reppin, Swen Graubner, Torsten Henning, and Peter J. Klar — Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany

Cuprous oxide layers of about 350 nm were artificially structured by means of photolithography and wet chemical etching. We used patterns of different sizes and investigated different etchants. To determine the etch rates and the aspect ratio we used atomic force microscopy. Wet chemical etching was employed to artificial structurize Cu_2O/ZnO heterostructures to investigate the p-n-junction. The results of the different etchants and different etch concentrations are discussed respectively.

HL 9.57 Mon 14:30 P2

Anisotropy of the dielectric function of ZnO including exciton-polariton formation obtained from ellipsometry — •Munise Cobet[1], Ronny Kirste[1], Markus Wagner[1], Axel Hoffmann[1], Christoph Werner[2], Christoph Cobet[2], Norbert Esser[2], and Christian Thomsen[1] — [1]Institut für Festkörperphysik, TU Berlin, 10623 Berlin — [2]ISAS- Institute for Analytical Sciences, 12489 Berlin

The complex dielectric tensor of ZnO is obtained by analysis of ellipsometric data for photon energies of 2.5-32 eV. The comparison to ab-initio calculations performed including many-body effects shows a good agreement for both independent components. A strong anisotropy mainly above 10 eV could be verified by our results. At the band gap ZnO shows free exciton absorptions containing a significant formation of polaritons and the related exciton-phonon-complexes. The scattering near k=0 with the longitudinal optical phonon shows up in a replication of the three-peak structure every 72meV but might be mixed with higher excitations (n=2,3,.). A possible reversal in the two upper valence bands due to a negative spin-orbit-splitting is considered as a consequence of the near resonance between the Zn3d-level and the O2p-orbital (p-d-repulsion). Vice versa, strain as a structural treatment could affect the d-level or lead to changes in the crystal-field interaction. Raman and XRD revealed even in homoepitaxial grown samples the existence of strain. At energies 9.5-16 eV transitions including the 3d-level and at higher energies O2s-core-level occur. The loss function shows prominent peaks at the plasmon frequencies $\hbar\omega_p$.

HL 9.58 Mon 14:30 P2

Growth and characterization of ZnO nanostructures for hybrid solar cells — •Florian Maier-Flaig[1], Johannes Fallert[1], Janos Sartor[1], Jonas Conradt[1], Manuel Reinhard[2], Alexander Colsmann[2], Uli Lemmer[2], Daniel Weissenberger[3], Dagmar Gerthsen[3], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [2]Lichttechnisches Institut, Universität Karlsruhe (TH), Germany — [3]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe (TH), Germany

Among the multitude of prospects of ZnO-nanostructures, recently their integration in hybrid solar cells has attracted a large interest. In this contribution we show our results in growth of ZnO-nanostructures used for solar cells. The underling vapour-liquid-solid (VLS) growth has been optimized to achieve a high density of thin nanowires with a suitable length. First, we point out the influence of different conducting substrates on the manner of growth. For the realization of efficient solar cells a high conductivity through these nanowires and the connected substrate is of crucial importance. Therefore additional doping has successfully been introduced in the wires by the simple choice of the conducting substrate, shown via photoluminescence measurements. Finally we present first results of dye-sensitized hybrid solar cells based on ZnO-nanostructures.

HL 9.59 Mon 14:30 P2

Influence of Mn on the impurity-band transport in Cl-doped (Zn,Mn)Se — •Jörg Teubert[1], Peter J. Klar[1], and Michael Hetterich[2] — [1]I.Physikalisches Institut JLU-Giessen — [2]Institut für

Angewandte Physik, Universität Karlsruhe

The hopping mechanism of conduction in ordinary, non-magnetic semiconductors has been studied extensively, but little is known about the influence of magnetic interactions in this regime. In II_{1-x}-Mn_x-VI compounds, Mn^{2+}-ions are incorporated isovalently on group II lattice sites. The half filled d-shells of Mn ions give rise to local magnetic moments (total spin $S = 5/2$). At a concentration of $x \approx 6\%$, the hydrogen-like wavefunction of a shallow donor overlaps with several hundred localized spins giving rise to s-d exchange interaction. We present magnetotransport properties of n-doped $Zn_{0.94}Mn_{0.06}Se$:Cl crystals with Cl doping concentrations both below and above the metal-insulator transition. The modifications of the impurity band transport induced by magnetic interactions will be studied and the interpretations given by present theories will be discussed.

HL 9.60 Mon 14:30 P2

Temperature dependent incorporation and thermal stability of hydrogen in zinc oxide layers — •Marc K. Dietrich, Achim Kronenberger, Andreas Laufer, Sebastian Zöller, Angelika Polity, and Bruno K. Meyer — I. Physikalisches Institut Justus Liebig Universität Gießen, Germany

Hydrogen-doped zinc oxide films (ZnO:H) were deposited on c-axis sapphire by radio frequency magnetron sputtering. An argon-hydrogen gas mixture was used as sputtering gas. At first we investigated the influence of substrate temperature on the incorporation of hydrogen. Hydrogen-doped zinc oxide films deposited at room temperature had a carrier density of about 10^{20} cm^{-3}. Hydrogen diffusion has been observed by annealing those films at high temperatures in a nitrogen atmosphere. In the experiments the annealing temperature as well as the annealing time has been varied.

The hydrogen incorporation in the zinc oxide film was verified by secondary ion mass spectrometry. X-ray diffraction measurements showed that the lattice spacing of c-axis in zinc oxide increased at higher hydrogen concentrations.

HL 9.61 Mon 14:30 P2

Photoluminescence properties of ZnS single crystals and CVD thin films — •Melanie Pinnisch[1], Joachim Sann[1], Oliver Graw[1], Stefan Lautenschläger[1], Markus Wagner[2], Jan-Hindrik Schulze[2], Axel Hoffmann[2], and Bruno K. Meyer[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin,, Germany

ZnS with its large bandgap of 3.6 eV at room temperature is a promising candidate for optoelectronic applications in the blue and near UV. However, the fundamentals of the material have not been investigated properly. Neither acceptor nor donor bound exciton recombinations have been properly identified so far. In this work we report on low temperature and time resolved photoluminescence properties of ZnS single crystals grown by seeded vapour transport. By comparing the recombination energies of the PL-spectra with theoretical effective-mass-approximation-values we try to assign the luminescences to specific crystal defects. Finally we compare the results to photoluminescence data from ZnS CDV thin films grown on GaP- or Si-substrates.

HL 9.62 Mon 14:30 P2

Critical thickness of ZnMnSe spin aligner layers on GaAs — •B. Westenfelder, R. Dörlich, P. Asshoff, D. Z. Hu, D. M. Schaadt, H. Kalt, and M. Hetterich — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

The diluted magnetic semiconductor ZnMnSe proved to be an efficient spin aligner in quantum dot spin-injection light-emitting diodes, where polarization degrees close to 100% were demonstrated. Since the minimization of spin scattering is crucial for high-fidelity spin-injection, the spin aligner should have a high epitaxial quality. Within this context, the critical thickness of the ZnMnSe layer is of importance - beyond the critical thickness, misfit dislocations are produced and strain relaxation occurs. To determine the critical thickness of ZnMnSe with different Mn concentrations, we grew suitable epilayers on GaAs(001) and analyzed them by x-ray diffraction techniques. As expected, we observed that the critical thickness of ZnMnSe is reduced when Mn is incorporated. The results obtained will be presented and compared with different theoretical models.

HL 9.63 Mon 14:30 P2

Electronic and Optical Properties of Lithium doped ZnO Nanocrystals — •Markus R. Wagner[1], Ronny Kirste[1], Christian Rauch[1], Gordon Callsen[1], Munise Cobet[1], Wolfgang Gehlhoff[1], Enno Malguth[1,2], Michael Lehmann[3], Sebastian Polarz[4], Yilmaz Aksu[5], and Matthias Driess[5] — [1]Institut für Festkörperphysik, TU Berlin — [2]Georgia Institute of Technology, Atlanta — [3]Optisches Institut, TU Berlin — [4]Fachbereich Chemie, Universität Konstanz — [5]Institut für Chemie, TU Berlin

Lithium doped ZnO nanoparticles were grown using a novel organometallic precursor system, where the resulting material is preorganized on a molecular stage with Li concentration varied between 0.1% and 12%. XRD patterns and high resolution TEM images demonstrate that the ZnO crystals are of similar size (70-80nm) and solely crystallise in the wurtzite structure, with no other phases present. The successful incorporation of Li on the Zn lattice site is clearly proven by EPR measurements. It is shown that the Li doping leads to the introduction of lithium related acceptor states which consequently result in a strong lowering of the Fermi level. EPR and PL further show the additional introduction of Fe impurities. The lowering of the Fermi level is proven by the disappearance of the shallow donor EPR signal without optical excitation and by evident presence of Fe3+. The band-edge PL spectra are dominated by the bound exciton emission and a strong surface bound exciton line at 3.31eV. In addition, a DAP luminescence is observed and confirmed by time resolved PL. The binding energy of this acceptor state, introduced by Li doping, is calculated to 150meV.

HL 9.64 Mon 14:30 P2

Raman Spectroscopy on Lithium Doped ZnO Nanocrystals — •Ronny Kirste[1], Yilmaz Aksu[2], Markus R. Wagner[1], Surajit Jana[2], Gordon Callsen[1], Matthias Driess[2], and Axel Hoffmann[1] — [1]TU Berlin, Institute of Solid State Physics, Berlin — [2]TU Berlin, Institute of Chemistry: Metalorganics and Inorganic Materials, Berlin

ZnO still receives much attention due to its possible application for field emission displays, high frequency electronic devices, short wavelength lasers or light emitting diodes. But there is still a lack of knowledge in terms of p-doping of ZnO. Over the past years, Lithium revealed to be a good candidate for shallow acceptors. So far ZnO:Li has been investigated by many methods in different groups. However, there is only little knowledge about the influence of Li doping to the vibrational properties of ZnO. Recently Yadav et al. (JAP 104, 053507) reported about low energy Raman modes below 200 1/cm and a high energy mode around 1090 1/cm. They attributed them to zone boundary phonons and a resonant second order mode, respectively. In this contribution a detailed analysis of these Raman modes in ZnO:Li nanocrystals with different Li incorporation will be presented. We will show that these modes already appear at very low Li concentrations. According to the 1090 1/cm line, a dependence of the intensity on the Li incorporation can be seen. Furthermore excitation dependant Raman measurements will be presented. To complete our investigations photoluminescence measurements have been performed. Thereby no dependency between exciton energy and Li incorporation can be seen.

HL 9.65 Mon 14:30 P2

Dry Etching of ZnO using an Inductively Coupled Plasma: Role of plasma chemistry — •Minisha Mehta[1], Marcel Ruth[1], Karoline Piegdon[1], David Krix[2], Hermann Nienhaus[2], and Cedrik Meier[1] — [1]Experimental Physics, University of Paderborn, Warburger Str.100, 33098 Paderborn, Germany — [2]Experimental Phyics, University of Duisburg-Essen, Lotharstr.1, 47057 Duisburg,Germany

ZnO has gained much interest due to its potential applications in optoelectronic and electronic devices. In order to achieve the small dimensions required for such devices, the development of plasma etching instead of wet chemical etching is imperative. Dry etching processes for ZnO using an inductively coupled plasma (ICP) based on $SiCl_4$ and CH_4 plasma chemistry have been investigated. The influence of plasma chemistry, base pressure, radio frequency (rf) table power and ICP power on etch characteristics have been studied. The etch rate, etch profile and surface morphology of etched samples were characterized by surface profilometer, scanning electron microscopy and atomic force microscopy, respectively. It was found that CH_4-based chemistry showed a higher etch rate than the $SiCl_4$ based chemistry, presumably due to the formation of highly volatile metal organic zinc compound.

Moreover, Auger electron spectroscopy (AES) and X-ray photon spectroscopy (XPS) have been performed and analyzed to examine the surface stoichiometry of etched ZnO using both plasma chemistries. Furthermore, based on UV-photoluminescence study, the effect of dry etching on the optical properties of ZnO will also be outlined.

HL 9.66 Mon 14:30 P2

Catalytic growth of ZnO nanowires via chemical vapor deposition — •Sebastian Eisermann, Stefan Lautenschläger, Torsten Henning, and Bruno K. Meyer — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Zinc oxide nanowires were synthesized on silicon via a catalytically activated vapor-liquid-solid process governed by chemical vapor deposition. On the silicon substrates, square two dimensional arrays of equally spaced gold nanodots with diameters of approximately 100 nm were structured via electron beam lithography and acted as catalysts. The structural properties of the nanowires were investigated via X-ray diffraction (XRD) and scanning electron microscope (SEM) measurements. Raman measurements were performed to examine the lattice dynamics. The optical characteristics were checked with photoluminescence (PL) and cathodoluminescence (CL) analysis.

HL 9.67 Mon 14:30 P2

Structure and optical properties of ZnO nanocrystals embedded in amorphous SiO_2 — •Gillian Mayer[1], Mikail Fonin[1], Ulrich Rüdiger[1], Reinhard Schneider[2], Dagmar Gerthsen[2], Nils Janssen[3], and Rudolf Bratschitsch[3] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe, 76128 Karlsruhe, Germany — [3]Fachbereich Physik, Universität Konstanz and Center for Applied Photonics, 78457 Konstanz, Germany

Zinc oxide (ZnO) is a wide gap semiconductor with a broad range of optoelectronic applications due to its direct band gap and high exciton binding energy. ZnO quantum dots have attracted attention since their spins might be used as qubits in quantum information technology.

In this study, ZnO nanocrystals (NCs) were grown by radio-frequency magnetron sputtering as a $SiO_2/ZnO/SiO_2$ layer stack on Si(100) and $Al_2O_3(0001)$ substrates with an intermediate in situ annealing step. Structural properties were investigated by transmission electron microscopy (TEM), which reveals a uniform dispersion of ZnO NCs with sizes up to 16 nm in the amorphous SiO_2 matrix. High resolution TEM shows a well-defined hexagonal close packed wurtzite structure for individual NCs with lattice parameters close to those of bulk ZnO. Statistics of the NC sizes lead to a grain size of 5 ± 2 nm for more than 70 % of the NCs. The chemical separation of the ZnO NCs from the surrounding SiO_2 matrix is corroborated by energy-filtered TEM. Measurements of the optical transmittance confirm the results obtained by TEM.

HL 9.68 Mon 14:30 P2

Optical characterization of epitaxially grown $Zn_{1-x}Mg_xO/ZnO$ quantum wells — •Thomas Sander[1], Peter J. Klar[1], Martin Eickhoff[1], and Thomas Wassner[2] — [1]JLU Giessen, Germany — [2]WSI Munich, Germany

The $Zn_{1-x}Mg_xO/ZnO$ quantum wells and $Zn_{1-x}Mg_xO$ epitaxial layers were grown by molecular beam epitaxy on sapphire as well as on ZnO substrates. The photo-modulated reflectivity of the samples was measured at room temperature using a HeCd laser (325 nm) for modulation. The phonon spectra were investigated by Raman spectroscopy using different excitation wavelengths of 633 nm, 532 nm and 325 nm, respectively. The optical transitions in the photo-modulated spectra will be assigned and discussed in terms of the band structure. The changes of the Raman spectra of the epitaxial layers as a function of x will be analysed.

HL 9.69 Mon 14:30 P2

Acceptor centres in Ga_2O_3 — •Jan Stehr[1], Andreas Laufer[1], Detlev M. Hofmann[1], Bruno K. Meyer[1], Daniel Röhrens[2], and Manfred Martin[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D- 35392 Giessen — [2]Institut für Physikalische Chemie, RWTH Aachen, Landoltweg 2, D- 52074

Ga_2O_3 is a wide band gap semiconductor ($E_{gap} = 4.9$ eV) with potential applications as a TCO material (Transparent Conducting Oxide). The n-type conductivity of the undoped material is caused by the presence of oxygen vacancies which act as shallow donors. The oxygen vacancies can be introduced by heat treatments in reducing atmospheres such as ammonia. Information on the nature of the acceptors in this material is rare.

We investigated a set of Ga_2O_3 powder samples by electron paramagnetic resonance (EPR) which were annealed in ammonia at 780 °C for 5, 18, 30 and 120 minutes. We observe 3 centres. Signal A at g = 4.3 is prominent in all samples and is attributed to residual Fe impurities. Signal B, consists of a set of two groups with 4 lines of equal intensities. The spectrum is explained by a state with S = 1/2 and I = 3/2. Possible candidates are Ga^{4+}, Cu^{2+} or As^0. The g-values $g_\perp = 2.33$ and $g_{||} = 2.04$ are typical for an acceptor centre. Signal C is the oxygen vacancy shallow donor at g = 1.96, as expected the intensity of this signal is increasing with the nitridation time. The intensity of signal B is not correlated which can be taken as evidence that it is of an extrinsic origin.

HL 9.70 Mon 14:30 P2

High Resolution RBS on High-k Dielectrics — •Maik Vieluf[1,2], Rainer Grötzschel[1], Christian Neelmeijer[1], Frans Munnik[1], and Steffen Teichert[1,2] — [1]Institute of Ion Beam Physics and Materials Research, FZD, Bautzner Landstraße 128, 01314 Dresden, Germany — [2]Qimonda Dresden GmbH & Co. OHG, Koenigsbruecker Strasse 180, D-01099 Dresden, Germany

The further development of microelectronic circuits requires the usage of new materials and, consequently, the characterization of materials properties on the relevant length scale. In particular it is important to analyse the depth dependent element distribution or elemental composition on interfaces of new ultrathin layer stacks with subnanometer depth resolution. A well-established complementary method is High Resolution Rutherford Backscattering Spectrometry (HRRBS). This technique is based on binary elastic nuclear scattering with well known cross sections and the inelastic energy losses of incident ions. The high energy resolution, necessary for high depth resolution, is achieved using a Browne Buechner type magnetic spectrometer with a position sensitive detector (PSD) at the 3 MeV Tandetron accelerator of the FZD. We present recent results of the investigation of the initial stage of layer growth if ZrOx and HfOx on native SiOx or TiN. The shape of the high resolution energy spectra provides knowledge about interfaces between different layers. Furthermore, the elemental areal density is also an important parameter to obtain information about atomic layer growth. For this reason, the depth dependent charge state distribution of such ultrathin layers close to the surface is investigated and discussed.

HL 9.71 Mon 14:30 P2

Influence of magnetic dopants on the metal-insulator transition in semiconductors — •Jörg Teubert[1], Peter J. Klar[1], and Wolfram Heimbrodt[2] — [1]I.Physikalisches Institut JLU-Giessen — [2]Philipps-Universität Marburg

By incorporating magnetic impurities into semiconductors, one immediately enters interesting intermediate areas between the fields of magnetism and semiconductor physics. In III-Mn-V compounds the magnetic impurity Mn serves both as the source of a large localized magnetic moment and as the source of a loosely bound hole due to its acceptor character. We will compare the transport behavior of InSb:Mn (magnetic) with InSb:Ge (non-magnetic). Both Mn and Ge form shallow acceptor levels in InSb with identical acceptor activation energies. Thus, the MIT occurs at the same critical impurity concentration and the two systems are directly comparable. However, InSb:Mn and InSb:Ge samples reveal distinct differences in their electric resistivity near the MIT. InSb:Ge shows the commonly observed behavior whereas InSb:Mn exhibits a strong enhancement of the resistivity below 10 K and pronounced negative magnetoresistance effects at 1.6 K. Both effects increase by applying hydrostatic pressure. A qualitative model explaining the observed effects based on spin effects will be presented.

HL 9.72 Mon 14:30 P2

Multifractal Analysis for the Anderson Model and in Small World Networks — •Martin Emmrich, Philipp Cain, and Michael Schreiber — Institut für Physik, Technische Universität, D-09107 Chemnitz

We study the influence of long-range links on the critical behavior of the Anderson model of localization (AML) by means of multifractal analysis of the electronic wave functions. In three dimensions it is known that the wave functions of the AML exhibit a localization-delocalization transition which can be driven by disorder strength. For

the discrete AML on a three-dimensional cubic lattice the disorder is considered as an uncorrelated variation of the on-site potential and each site is connected to its six neighbor sites. We extend the AML by modifying the links between sites similar to a small-world network (SWN) where the six links of each site can connect to any other site in the system independent of the distance between the sites. This transformation between network topologies is implemented gradually by replacing links with a given probability, which allows us to trace the critical behavior starting from the AML to the new SWN case. We find that already a small number of SWN links leads to an increase of the critical disorder of the localization-delocalization transition.

HL 9.73 Mon 14:30 P2

Energy Level Statistics for the Anderson Model and in Small World Networks — •Oliver Böhm, Philipp Cain, and Michael Schreiber — Institut für Physik, Technische Universität, D-09107 Chemnitz

The Anderson model of localization (AML) describes the behavior of a single electron in a disordered solid. In three dimensions this model shows a localization-delocalization (LD) transition of the electronic wave function. For our investigation we evaluate the statistics of energy level spacings which allows us to characterize the LD transition and to distinguish between localized and delocalized behavior. First, we study the discrete AML on a three-dimensional cubic lattice where disorder is described by a variation of the on-site potential and each site is connected to its six neighbor sites. Then we extend the AML by modifying the links between sites similar to a small-world network (SWN) where the six links of each site can connect to any other site in the system independent of the distance between the sites. The particularity of these networks is, that the average path length is much shorter as in regular networks. It is not obvious whether an LD transition can be observed. Since we transform links to SWN links with a given probability we can trace the critical behavior starting from the known case of AML. We show that an increase of the critical disorder results already from a small percentage of SWN links.

HL 9.74 Mon 14:30 P2

Optimized cleaning procedures for silicon wafers — •Jochen Otzmann, Helmut Lochner, Peter Iskra, Dorota Kulaga-Egger, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The usage of improved cleaning methods is an increasingly important issue for the fabrication of nanoscale semiconductor devices. Even smallest impurities can lead to a total loss of the device, due to leakage currents or interface traps for example.

We investigate improved cleaning procedures to decrease or remove organic and inorganic contaminations on wafer surfaces, like carbon impurities and the native or chemical oxide on silicon substrates. Therefore several different process plans were defined. P-i-n diodes were fabricated in an Applied Materials Centura Cluster Tool with epitaxial growth. The substrate was an n+Silicon 100 wafer. After several cleaning processes, all wafers got the same intrinsic layer and a p+Si top coating. To get the results the wafers were structured and analyzed. With the help of I-V measurements the p-i-n diodes were evaluated and secondary ion mass spectrometries (SIMS) affirm the results.

New results led us to further optimized processing parameters. We will present suggestions on potential improvements and results from our successful experiments

HL 9.75 Mon 14:30 P2

Electric field-induced exciton localization in quantum wells — •Karsten Sperlich[1], Patrick Ludwig[2], Alexei Filinov[2], Michael Bonitz[2], Heinrich Stolz[1], Detlef Hommel[3], and Arne Gust[3] — [1]Department of Physics, University of Rostock, Germany — [2]Department of Physics, Christian-Albrechts University of Kiel, Germany — [3]Institute of Solid State Phyics, University of Bremen, Germany

We report on first spectrally and spatially high resolved measurements of a recently suggested flexible electrostatic confinement for excitons in a single quantum well [1], which is created by a fine tip electrode due to the quantum-con*ned Stark effect. For this strongly correlated system we present finite-temperature quantum Monte-Carlo results and discuss the specific trap parameters at which prominent many-particle effects, including the Wigner crystal phase of spatially indirect excitons, are expected to be accessable [2].

[1] Ludwig et al., phys. stat. sol. (b) 243, No. 10, 2363 (2006)
[2] Sperlich et al., phys. stat. sol. (c) 2008

HL 9.76 Mon 14:30 P2

Microwave Spectroscopy of Confined and Edge Magnetoplasmons in 2D Electron Stripes — •Tobias Krohn[1], Nikolai Mecking[1], Matthias Wiemann[2], Ulrich Kunze[2], Johannes Kunze[3], Christian Heyn[1], and Detlef Heitmann[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, 44780 Bochum — [3]Lehrstuhl für Integrierte Systeme, Ruhr-Universität Bochum, 44780 Bochum

We have investigated the photovoltage that was induced by irradiating microwaves on typically 30 x 60 μm^2 stripes containing a two-dimensional electron system (2DES) in a modulation-doped AlGaAs/GaAs heterostructure. The experiments were performed in sweeps of a magnetic field B that was applied perpendicularly with respect to the 2DES. The temperature was 4.2 K.

Our set up allows us to investigate a wide frequency range from 9 GHz to 325 GHz. We use special frequency modulation techniques to reduce impedance matching effects in the microwave setup. We observe a rich mode spectrum with modes exhibiting positive or negative B dispersions, which we can model, respectively, by confined magnetoplasmon and edge magnetoplasmon modes. Both types of modes are governed by characteristic lengths. We find that these lengths reflect the stripe's dimensions.

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

HL 9.77 Mon 14:30 P2

FIR and Microwaves Spectroscopy on Two-Dimensional Hole Systems in Mn doped InAs Quantum Wells — •C. G.v.Westarp, N. Mecking, W. Hansen, D. Heitmann, and U. Wurstbauer — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

We have investigated hole systems in InAs quantum wells sandwiched in between InGaAs and InAlAs layers. One serie of our samples was modulation doped in the AlGaAs by δ carbon doping and by manganese co-doping, another series was doped with manganese. We have performed microwave and FIR transmission spectroscopy, covering the range of 60 GHz to 9000 GHz (300 cm^{-1}) at low temperatures (1.6 K) and perpendicular magnetic fields up to 14 T.

We observe a well pronounced cyclotron resonance with a non-parabolic effective mass with typical values of 0.1 m$_e$ at high magnetic fields. On some samples additional resonances are found with exhibit an anticrossing with the cyclotron resonance.

We gratefully acknowledge support through SFB 508.

HL 9.78 Mon 14:30 P2

Transport properties of magnetic-codoped two-dimensional hole system — •Stefan Knott, Ursula Wurstbauer, and Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg

The interaction of localized magnetic moments with a two dimensional hole system (2DHS) is studied with low-temperature magnetotransport measurements on molecular beam epitaxially grown InAs or InAlGaAs quantum-well structures that are C-modulation and Mn co-doped. Measurements in magnetic fields applied perpendicular to the 2DHS reveal the typical transport behaviour of a two-dimensional charge carrier system indicated by Shubnikov-de Haas oscillations and quantum-Hall plateaus. Investigations at milli-Kelvin temperatures show a metal-insulator transition in the low field region. The fully spin-polarized quantum Hall state at filling factor $\nu = 1$ is very pronounced, i.e. over a field range of more than 4 T the longitudinal resistance vanishes and the Hall resistance is constant. Surprisingly, the $\nu = 2$ state seems to be fully suppressed whereas the $\nu = 3$ state is clearly resolved by an indistinct structure in the Hall resistance and a minimum in the longitudinal resistance. Transport measurements in tilted magnetic fields are carried out to resolve the nature of the observed quantum-Hall states.

HL 9.79 Mon 14:30 P2

Magnetotransport on evenly curved graphene and thin graphite — •Karen Peters, Ursula Wurstbauer, Stefan Mendach, and Wolfgang Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg,

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We study evenly curved conventional and massless dirac fermions in graphite and graphene with transport measurements. To experimentally realise evenly curved graphene and thin graphite sheets with metal contacts for transport experiments we use semiconductor-graphene metal hybrid microscrolls with rolled-in sheets of thin graphite. The specific semiconductor substrates are grown on semi-insulating (001) GaAs by means of molecular beam epitaxy and include a degenerate doped back-electrode to tune the position of the Fermi energy via field effect. Further the established method of preparation, electrical and morphological characterisation of graphene layers on SiO2 is transferred to graphite deposited on GaAs substrates. Graphene on GaAs is characterized by scanning electron microscopy (SEM) and patterned with optical as well as electron beam lithography or by local oxidation with an AFM tip. Transport will be studied as function of the carrier type and density adjusted by the gate electrode and of a magnetic field which perpendicular component is sinusoidally modulated along the perimeter of the microscroll. In first experiments we use thin graphite in two-terminal geometry for optimisation of the fabrication process.

HL 9.80 Mon 14:30 P2

PLD-growth of ZnO-based planar and cylindrical microresonators — •Helena Hilmer, Chris Sturm, Rüdiger Schmidt-Grund, Jesús Zúñiga-Pérez, Jan Sellmann, Annekatrin Hinkel, Christian Czekalla, Jörg Lenzner, Gregor Zimmermann, Holger Hochmuth, Michael Lorenz, Bernd Rheinländer, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We have grown planar and cylindrical microresonators by means of pulsed laser deposition containing as active medium a half wavelength ZnO-cavity and free-standing ZnO-nanopillars with diameters of $(50-500)$ nm and $(5-10)\,\mu$m in length, respectively. These cavities are embedded between two all-oxide Bragg reflectors (BR) respective coated with coaxial BR made of quarter-wave stacks of yttria stabilised zirconia (YSZ) and Al_2O_3. Atomic force microscopy and scanning transmission electron microscopy show very smooth interfaces for the planar BR (average roughness $R_a = 1$ nm). For the cylindrical BR we have reached excellent quality of lateral and longitudinal homogeneous layers around the ZnO-nanopillars.
Photoluminescence spectroscopy (PL) and reflectivity (R) measurements have revealed the planar resonator to be in the strong coupling regime up to 410 K with a maximum Rabi splitting of the polariton branches of about 90 meV (PL) and 95 meV (R) at 10 K. Room-temperature spatially resolved PL and R spectra of the coated nanopillars show structures related to exciton-polariton branches in photonic wires.

HL 9.81 Mon 14:30 P2

GaN-based heterostructures for future spin electronic applications — •D. Broxtermann, C. Zube, A. Bedoya Pinto, J. Malindretos, and A. Rizzi — IV. Physikalisches Institut, Georg-August Universität Göttingen, D-37077 Göttingen, Germany

In combination with GaN based diluted magnetic semiconductors GaN/AlN resonant tunneling diodes are potential candidates for spin injectors/detectors. Furthermore 2DEG heterostructures consisting of the same materials could be utilized as diffusion channels in future spintronic applications. In this work we first optimize the MBE growth of GaN and thin AlN on MOCVD GaN templates to achieve good crystal quality and smooth GaN/AlN interfaces. Both are necessary to obtain highly efficient RTDs as well as high electron mobility 2DEGs. Effects of growth parameters on electrical properties are analyzed by magneto transport measurements and compared to calculations of a self-consisted Schrödinger-Poisson solver.

HL 9.82 Mon 14:30 P2

Spin-transitions in semiconductor quantum rings — •Benjamin Baxevanis and Daniela Pfannkuche — 1. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, D-20355 Hamburg, Germany

The path integral Monte Carlo (PIMC) method is a numerically exact method to investigate properties of quantum systems in thermal equilibrium which are not in the range of other numerical methods. The main advantage of PIMC is its ability to treat strongly correlated electron systems at finite temperature. Usual approaches preserve only S_z symmetry and result in thermal averages of states with different S^2 quantum numbers. In order to avoid this spin contamination problem we extend the PIMC method to study magnetic transitions in a semiconductor quantum ring: using Young diagrams we explicitly construct eigenstates of the S^2 operator. In our model of a quantum ring diameter, width and elliptical deformation can be tuned. At a given electron number the ground state exhibits spin-transitions depending on the ring geometry.

HL 9.83 Mon 14:30 P2

Polymer field effect transistor with contact modification by organic molecules — •Rebecca Winter[1], Maria S. Hammer[1], Carsten Deibel[1], and Jens Pflaum[1,2] — [1]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

In recent years organic electronics processed from solution received a lot of attention due to their low cost potential. The performance of field effect transistors (FET) influenced the quality of electronic curcuits. In order to get high on/off ratios and low threshold voltages the organic FET has to be optimized. The output current is strongly affected by injection of charge carriers at the contacts. Here we discuss the limitation of the performance of the organic FETs due to this contact/channel interface. Therefore we examine the influence of a monolayer of organic molecules on the Au- contacts before spin-coating rr-poly-3-hexyl-thiophene(rr-P3HT) on the contact resistance and the threshold voltage. From our presented data we will conclude on changes of the respective work functions with and without functionalization. By temperature dependent measurements we are able to discriminate between tunnelling assisted injection processes and those based on thermally activation.

HL 9.84 Mon 14:30 P2

Deposition of PTCDA on an Ultra Thin Optical Fibre from a Helium Nanodroplet Beam — •Tobias Knoblauch, Matthieu Dvorak, Oliver Bünermann, and Frank Stienkemeier — Physikalisches Institut, Universität Freiburg, 79104 Freiburg

Helium nanodroplet isolation (HENDI) spectroscopy is a powerful technique to analyse the electronic structure of molecules. Because of the very low temperature of the droplets (0.4 K) and their superfluid property, helium nanodroplets provide a cold and weakly interacting matrix. Furthermore, it can be used to form peculiar complexes of molecules inside the droplets. The high spectral resolution of this technique allows disentangling the contributions of different complex sizes.

Vibronic spectra of PTCDA isolated in helium droplets have been extensively studied in our group [1]. To link our results with film spectroscopy we extended our molecular beam apparatus in order to deposit molecules and complexes formed in the droplets on an ultra thin optical fibre. Light passing through the optical fibre exhibits a pronounced evanescent field that interferes with the deposited material on its surface and allows high sensitive transient absorption spectroscopy [2]. We will present the status and first results of this setup.

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HL 9.85 Mon 14:30 P2

Influence of F8BT/P3HT blend composition on organic field-effect transistors — •Eva Johanna Feldmeier, Christian Melzer, and Heinz von Seggern — Electronic Materials Department, Institute of Materials Science, TU Darmstadt, Petersenstraße 23 , 64287 Darmstadt, Germany

The ambipolar poly(9,9-di-n-octylfluorene-alt-benzothiadiazole) (F8BT) and p-type regioregular poly(3-hexylthiophene) (P3HT) are well known in the field of photovoltaic cells, where they act as electron acceptor and electron donor, respectively. Here ambipolar top-gate organic field-effect transistors from different blends of F8BT and P3HT with Au source and drain contacts are analysed with respect to charge-carrier transport properties in dependence of the blend composition. The change in transistor performance will be investigated on basis of the respective transfer characteristics and of the device parameters extracted from the saturation regimes. The evolution of the extracted field-effect mobilities and threshold voltages of both charge carrier species will be discussed considering the injection and transport properties of the individual materials as well as the energetics of the investigated blend.

HL 9.86 Mon 14:30 P2

Transfer mechanisms between emitter molecules for OLED applications — •Frank Steinbacher[1,2], Chien-Shu Chiu[3,2], Ralf Krause[2], Arvid Hunze[2], and Albrecht Winnacker[1] — [1]Department of Materials Science VI, University of Erlangen-Nuremberg, Germany — [2]Siemens AG, CT MM 1, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [3]Department of Electrical Engineering & Information Technology, Technical University of Braunschweig, Germany

Within the last few years white organic light emitting diodes based on small molecules have shown the potential to have a promising future in the field of lighting technology. Nevertheless there is still room for improvement of the overall efficiency and lifetime of white OLEDs. A deeper understanding of the energy transfer mechanisms between different matrix and emitter molecules used in the OLED stack concept can help to optimize the layout and reduce driving voltage thus increasing the power efficiency and color stability of the device. To simplify the complex interactions within a complete white OLED we start out with a basic model system only containing the molecules of interest. This enables us to predict the fundamental concepts causing the behavior of more intricate systems. Using photoluminescence, excitation spectra and time-resolved photoluminescence we investigated the exciton transfer between different dyes for a variety of emitter systems. Our results indicate a dependence of exciton transfer probability on the total concentrations and therefore the distance between the molecules involved.

HL 9.87 Mon 14:30 P2

Structural and electronic properties of melanin-like materials — •Falk Tandetzky, Frank Ortmann, Karsten Hannewald, and Friedhelm Bechstedt — IFTO & ETSF, Friedrich-Schiller-Universität Jena, Jena, Germany

The macromolecule melanin which is primarily known as a pigment has also attracted recent interest as a possible high-tech functional material with potential electronic applications. However, the complexity of its structure as well as the relationship to its electronic properties is still not fully understood [1]. Here, we present ab initio studies for the structural, energetic, and electronic properties of various molecular building blocks (monomers, dimers, and tetrameric rings) of eumelanin. The band structure of one-dimensional stacks composed of such units are calculated and consequences for the charge transport along the stacks are discussed.

HL 9.88 Mon 14:30 P2

Measurements of absorption, fluorescence and lifetimes of Cl4MePTCDI in different solvents and crystalline phases — •Frank Friedriszik, Harald Graaf, and Christian von Borczyskowski — Center of Nanostructured Materials and Analysis, TU Chemnitz, 09107 Chemnitz, Germany

Perylene dye molecules are well know organic semiconductors with n-type behaviour. Most of the small perylene derivates consist of planar aromatic system, which leads to high molecular order in the solid state accompanied with strong intermolecular interactions. These chromophore couplings cause high electron mobility within the stack and lead to quenching of luminescence.

By chemical substitution in the bay position with chlorine a twist of the aromatic core can be found, which drastically lowers the molecular interactions. We show the changes in the photo-physical properties in solution and in the solid state using our model substance 1, 6, 7, 10-tetra-chloro-N, N'-dimethyl-perylene-tetracarboxylic-bisimide (Cl4MePTCDI). Directly after preparation an amorphous state is detected , which shows slow ordering under ambient conditions. The rate of this self-organization process depends on the temperature and is characterized by intermolecular interaction causing changes in optical absorption and luminescence. Lifetime measurements of the excited states in the crystalline and amorphous phase complete our investigations.

HL 9.89 Mon 14:30 P2

Photoluminescence Detected Magnetic Resonance (PLDMR) studies on oxygen doped P3HT — •Hannes Kraus[1], Andreas Sperlich[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, D-97074 Würzburg

Poly(3-hexylthiophene) (P3HT) is one of the most promising semiconducting polymers for applications in organic optoelectronics and solar cells. To improve the overall stability of polymer devices, the intrinsic stability of P3HT has to be further investigated. The excited states in P3HT subjected to oxygen were studied with optical (PL excited by 532nm) and spin-sensitive (X-band electron spin resonance, ESR) techniques, and furthermore with a combination of these: photoluminescense detected magnetic resonance (PLDMR). With PLDMR, the sample's spin state can be identified by measuring the photoluminescense change due to resonant microwave irradiation. By comparing the data obtained with ESR, PL and PLDMR on P3HT, before and after oxygen exposition, a more complete picture of oxygen-P3HT interaction can be achieved.

HL 9.90 Mon 14:30 P2

Modification of the injection properties in small molecule thin film transistors — •Florian Wörner[1], Peter Nill[2], and Jens Pflaum[1,3] — [1]Experimental Physics VI, Julius-Maximilians University Würzburg, 97074 Würzburg — [2]Inst.for Appl. Physics, University Tübingen, 72076 Tübingen — [3]Bavarian Center for Applied Energy Research e.V. (ZAE Bayern)

Over the past, the electronic characteristics of thin film transistors based on small molecules have continuously improved making their implementation in all-organic devices close to the market. Still, one of the bottlenecks is the injection of charge carriers into the conduction channel, hampered by charge transfer and the formation of dipoles at the metal-organic interface. In our contribution we discuss a possible strategy to overcome this limitation by use of metal contacts coated with monolayers of small molecules, namely oxides of the organic semiconductor pentacene. We demonstrate that this functionalization leads to a significant improvement of the transistor performance in terms of the contact resistance and the threshold voltage. Temperature dependent transport studies enable us to analyze the underlying microscopic mechanisms determining the injection behavior and to discriminate between a tunneling and a thermally assisted injection process. Finally, we discuss the applicability of our approach to molecular materials preferentially showing an n-type semiconducting behavior.

HL 9.91 Mon 14:30 P2

Temperature-dependent bias stress effects in organic thin-film transistors — •Nicole Killat, Ingo Hörselmann, Susanne Scheinert, and Gerhard Gobsch — TU Ilmenau, 98684 Ilmenau, PF 100565, Germany

An investigation of the stability of organic thin-film transistors (OTFT) was carried out by bias stress measurements. OTFTs with bottom- and top- source/drain-contacts (W/L=1000/30) were fabricated with 30nm SiO_2 as gate dielectric and the polythiophene P3HT or the polyvinylene TPD(4M)-MEH-PPV as active layer. The transfer characteristics after each stress sequence as well as the time-dependent drain-current at constant gate bias were measured in the linear regime at a constant temperature between 240K and 340K and in nitrogen atmosphere. For both polymers a negative gate bias caused a negative threshold voltage shift during stress time, which increased with higher temperatures. In contrast to P3HT, PPV showed no complete reversibility of the negative threshold voltage shift after applying a positive gate bias, which is not affected by heating. However, the positive threshold voltage shift of a top-contacted transistor with P3HT, caused by a positive gate bias, increased significantly with higher temperatures. Measurements in air enforced the bias stress effect in the PPV-OTFT. In P3HT the acceptor-like doping by oxygen amplified the positive threshold voltage shift during positive bias stress and was hardly compensated by negative bias stress. As a conclusion, the bias stress effect in OTFTs increases with higher temperatures, but principle tendencies are not affected.

HL 9.92 Mon 14:30 P2

Exciton binding energy in conjugated polymers — •Daniel Mack, Julien Gorenflot, Carsten Carsten, and Vladimir Dyakonov — Experimental Physics VI, Julius-Maximilians-University of Würzburg, , D 97074 Würzburg

One important parameter governing the efficiency of organic donor:acceptor solar cells is the open-circuit voltage. The relative energy levels of donor and acceptor are a trade-off between efficient charge transfer, i.e., exciton dissociation, and large open-circuit voltage. A deeper understanding of the exciton binding energy and factors influencing it are therefore important in view of an optimisation of the performance of organic solar cells. We studied the exciton binding energy in the conjugated polymer poly(3-hexylthiophene) by field-dependent

photoluminescence (PL) quenching. A laser generates singlet excitons within the polymer matrix; an electric field is then applied in order to dissociate these excited states into electron*hole pairs. The field-induced separation of the excitons, corresponding to a reduction of ratiative recombination, is investigated by monitoring a decrease of the PL signal. Our experimental results are discussed and compared with calculations after the models of Arkhipov [1] and Emilianova [2].

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HL 9.93 Mon 14:30 P2

Switching of drain potential in organic field effect transistor — •Ingo Hörselmann and Susanne Scheinert — TU Ilmenau

An organic field effect transistor (OFET) with source/drain electrodes self-aligned to bottom gate contact was prepared, resulting in a low overlap capacitance C_{GD} of 10pF for a channel width to length ratio of 8000. The gate insulator is a 200nm Si_3N_4 layer grown by chemical vapor deposition (CVD). As active semiconductor material poly(3-hexylthiophene) (P3HT) was used to produce a p-channel transistor. The drain and gate potential was switched with square-wave pulses and the transient response of the source and drain currents was recorded to investigate the transient behavior. Switching the drain potential between 0 and -10V with a ramptime of 50μs at constant gate-source voltage, which deplets the semiconductor layer, the measured transient source current is 5 orders higher then the expected displacement current originating from the geometry capacitance between source and drain. Numerical 2D simulation affirmed this tendency in case of acceptor-like bulk trap densities of about $5 \times 10^{17}\mathrm{cm}^{-3}$. The simulated decay behavior for switching the drain potential from -10 to 0V showed a strong dependency on the energy of the trap level, which is supported by an observed current decay during the measurements.

HL 9.94 Mon 14:30 P2

Packing of Planar Organic Molecules: Interplay of van der Waals and Electrostatic Interaction — •Mira El Helou[1,2], Daniel Käfer[2], Christian Gemel[3], and Gregor Witte[1,2] — [1]Molekulare Festkörperphysik, Philipps-Universität Marburg, D-35037 Marburg, Germany — [2]Physikalische Chemie I, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [3]Anorganische Chemie II, Ruhr-Universität Bochum, D-44780 Bochum, Germany

The molecular packing and thermal stability of pentacene and its two oxo-derivatives (6,13-pentacenedione and 5,7,12,14-pentacenetetrone) in their crystalline phase have been analyzed and compared with quantum chemical calculations of the electronic structure of the molecular entities. While pentacene reveals a face-on-edge herringbone packing, both oxygen containing species adopt an almost coplanar stacking. Quantum chemical calculations reveal discernible charge localization at the oxygen atoms which in turn causes an electrostatic O-π-interaction and hence favours a planar stacking. On the other hand, the polarizability of the conjugated systems of both oxo-species is reduced and their intermolecular distance is enlarged, due to the bulky oxygen atoms, both leading to a lower van-der Waals interaction and thus explains the decreased thermal stability of the studied oxidized entities. The present study emphasizes the importance of the balance of electrostatic and van-der Waals interactions [1].

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HL 9.95 Mon 14:30 P2

Deviations from the Einstein relation in organic semiconductors — •Vera Stehr[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, D-97074 Würzburg — [2]Functional Materials for Energy Technology, Bavarian Centre for Applied Energy Research (ZAE Bayern), D-97074 Würzburg

During the last years, increasing attention is drawn to organic semiconductors, since they capture more and more fields of application (e. g. light emitting diodes, organic photovoltaics). It is known that the Einstein relation, which states that the ratio of the diffusion to the mobility equals the thermal voltage, does not hold for organic semiconductors with a gaussian density of states distribution. Deviations were observed in the case of high energetic disorder and low temperatures. We studied these deviations by means of Monte Carlo simulations, paying particular attention to the so far mostly neglected electric field. We discuss the relevance of our findings to the physical description of organic devices.

HL 9.96 Mon 14:30 P2

Observation of single quantum dots in GaAs/AlAs micropillar cavities — •Philipp Burger, Matthias Karl, Dongzhi Hu, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

In our contribution we present the fabrication steps of micropillar cavities and their optical properties. The layer structure consisting of a GaAs-based lambda-cavity sandwiched between two GaAs/AlAs distributed Bragg reflectors is grown by molecular-beam epitaxy. In(Ga)As quantum dots, emitting at around 950 nm, are embedded as optically active medium in the middle of the cavity. The pillars are milled out of this structure with a focused ion-beam. A confocal micro-photoluminescence set-up allows to measure optical cavity modes as well as single quantum dots in the pillars when using low excitation intensity. This enables us to observe a (thermal) shift of the single quantum dot peaks relative to the cavity mode. In addition, we increased the numerical aperture of the set-up (originally 0.4) with a solid immersion lens up to 0.8. Thus we are able to detect the fundamental mode of pillars with very small diameters. Furthermore, the collection efficiency increases substantially.

HL 9.97 Mon 14:30 P2

Few-Photon-Quantum Transport Through a Photonic-Crystal Waveguide With A Two-Level System — •Paolo Longo[1], Kurt Busch[1,2], and Peter Schmitteckert[2] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe (TH) — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe

Quantum optics in photonic crystals is a very fascinating field of research. Recent work [1] shows that scattering of a two-photon state with a two-level impurity is qualitatively different from single-particle physics which effectively enables the possibility to induce interactions between photons.

Exact numerical studies of the interaction of a multi-photon, multi-moded, quantized light field with a single two-level impurity are presented. The time evolution of photonic wave-packets, observables and correlation functions can be calculated by using a discrete finite-lattice version of a generalized Dicke-Hamiltonian.

For first considerations the Hamiltonian is reformulated as a tight-binding model,

$$H = -t \sum_{i=1}^{M-1} (a_{i+1}^\dagger a_i + a_i^\dagger a_{i+1}) + \frac{\Omega}{2}\sigma_z + V(a_l^\dagger \sigma^- + a_l \sigma^+),$$

with which we evolute photonic quantum states in time in order to calculate scattering properties of single- und multi-photon states.

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HL 9.98 Mon 14:30 P2

Untersuchungen von Metamaterialien aus Split-Ring-Resonatoren bei Millimeterwellen — •Andreas Schneider, Sebastian Engelbrecht, Alexey Shuvaev und Andrei Pimenov — Experimentelle Physik 4, Universitaet Wuerzburg, Am Hubland D-97074 Wuerzburg

In dieser Arbeit wurden Millimeterwellen-Eigenschaften von Metamaterialien bestehend aus Split-Ring-Resonatoren (SRR) in einem Frequenzbereich von ca. 60 GHz bis 260 GHz untersucht. Split-Ring-Resonatoren sind wegen ihrer ungewöhnlichen Eigenschaften, wie Magnetismus, Bianisotropie oder negativer Brechung besonders interessant. Konventionelle Methoden des Elektromagnetismus eignen sich nicht zur Charakterisierung der SRR, da sie zusätzlich zur ihrer dielektrischen Funktion (ϵ) und ihrer Permeabilität (μ) einen Kreuzterm, den sog. Bianisotropie-Term (ξ), besitzen. Die daraus resultierenden Zusatzeffekte können nicht vernachlässigt werden und erfordern spezielle Verfahren zur Bestimmung der elektromagnetischen Eigenschaften. Für die Millimeterwellen Experimente wurden die SRR mit einem Standardverfahren der Photolitographie auf Textolitplatinen hergestellt. Zur Charakterisierung der Split-Ring-Resonatoren wurden Transmissionsspektren und ihre zugehörigen Phasen für sechs verschiedene Anregungsgeometrien der Ringe gemessen. Mittels einer Transfermatrixmethode wurden komplexe Transmissionsfunktionen berechnet. Die komplexen Größen ϵ, μ und ξ wurden direkt aus den Transmissions- und Phasenwerten in der Nähe der Resonanzfrequenz bestimmt.

HL 9.99 Mon 14:30 P2

Sources as an Extension of the Fourier Modal Method — •Christian Klock[1], Thomas Zebrowski[1,2,3], Sabine Essig[1,2,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Karlsruhe School of Optics & Photonics (KSOP) — [3]DFG Center for Functional Nanostructures (CFN)

The Fourier Modal Method (FMM) enables the study of electromagnetic field distribution in structures with periodicity in the lateral plane. A nonlinear conformal coordinate mapping realizes absorbing boundaries and also allows us to treat aperiodic, finite-sized structures. Commonly, the method is used to simulate a system's response to an incoming wave.

Our poster illustrates how to extend the method to include the emission from line sources in 2D and point sources in 3D. We present comparisons of numerical and analytical field distributions for the case of an emitter in an infinite dielectric cylinder. Furthermore, we demonstrate the method's potential for applications related to the designs of structured, plasmonic enhanced light emitting diodes.

HL 9.100 Mon 14:30 P2

Modelling of metamaterials using a coupled dipole approach — •Jens Küchenmeister[1], Sabine Essig[1,2,3], Lasha Tkeshelashvili[1,3], and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe — [3]DFG Centrum für Funktionelle Nanostrukturen (CFN), Universität Karlsruhe

Controlling the properties of metamaterials using different sizes and shapes of the basic building blocks, i.e. metallic nanostructures allows for a far-reaching control of the effective material properties. Fully numerical approaches via, e.g., the Fourier Modal method (FMM) or the Finite Element Method that directly solve Maxwell's equations require siginificant computational resources and are usually not suitable for design studies.

We present a coupled-dipole approach to metamaterials which allows for efficient parameter studies. The model contains few free parameters that are determined by comparison with exact numerics via FMM for simple systems such as periodic arrays of metallic rods. More complex structures can be systematically constructed, thus providing physical insights and allowing for rapid designs studies. We apply this approach to certain (chiral) multi-layer structures.

HL 9.101 Mon 14:30 P2

Transmission line circuit analysis of split-ring resonator metamaterials — •Liwei Fu, Heinz Schweizer, and Harald Giessen — 4th Physics Institute, University of Stuttgart, 70550 Stuttgart, Germany

Split-ring resonators (SRRs) are well studied due to their application potentials for superlenses, cloaking devices, perfect absorbers, and magnetic levitation. There are different interpretations about the dependence of their resonance frequency on structure parameters using LC circuit models. However, these models can not explain the blue-shift of the resonance frequency with the metal thickness [1]. In this report, we show that by distinguishing between series impedance and shunt admittance and by fitting the numerical results using transmission line circuit models [2,3], we can quantitatively derive the dependence of the circuit parameters on the SRR structure parameters. Novel thickness dependent interpretations will be given. Clear physical insight in SRR-based metamaterials is obtained.

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HL 9.102 Mon 14:30 P2

Modification of emission of internal emitters in Photonic Crystals — •Rebecca Wagner, Sven Zimmermann, and Frank Cichos — Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

In a photonic crystal the dielectric constant varies spatially on the length scale of optical wavelengths which leads to the formation of a photonic band structure. In weak dielectric systems there exist no complete gaps but stop bands for certain directions. This results in a spectral and angular redistribution of the emission of internal emitters.

We use dye beads that are homogeneously distributed within a 3D crystal in a low concentration to locally probe the band structure. The emitters are detected by defocused imaging microscopy. The diffraction patterns show a three-fold symmetry that is connected to the local structure of the crystal. The intensity I(z) of single beads in depth z inside a PC follows the usual Lambert-Beer-law for emission wavelengths outside the band gap. For beads emitting in the band gap there is a modification of the law. The enhanced attenuation is caused by a stop band that inhibits emission into direction of the detection.

HL 9.103 Mon 14:30 P2

Wet chemical grown ZnO nanowires for use in polymer-hybrid-LEDs — •Jan-Peter Richters, Apurba Dev, and Tobias Voss — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Due to their large surface-to-volume ratio and the photon confinement, ZnO nanowires are good candidates for applications in nanoscaled sensor technology and optoelectronics in the blue-UV spectral region. Especially low-temperature grown ZnO nanowires are very promising candidates for the production of environmentally friendly and cost-efficient solar cells and light emitting diodes. The difficulties in p-type doping of ZnO have led to a huge variety of approaches to replace the missing p-type component by e.g. ionic liquids or p-type conductive polymers.

We report on wet-chemically grown ZnO nanowire arrays grown on various substrates with very good homogeneity for areas as large as 1.5×1.5 cm^2. The typical dimensions of the nanowires are about 100 nm in diameter and 2 μm in length. The crystalline structure is investigated by using TEM measurements. Photoluminescence measurements (4K up to room-temperature) show clear excitonic features which indicate an overall good optical quality with low visible deep-level luminescence. We processed ZnO nanowire / PEDOT:PSS compound structures that act as light emitting diodes and report a high rectification ratio of about 10^5 and current densities up to 50 mA/mm^2.

HL 9.104 Mon 14:30 P2

Energy Dynamics in Polymer-Coated Quantum Dots with Integrated Dye Molecules — •Tobias Niebling, Ali Zulqurnain, Feng Zhang, Wolfram Heimbrodt, and Wolfgang J. Parak — Department of Physics and Material Sciences Center, Philipps University Marburg, Germany

Semiconductor nano-particles have emerged as promising candidates for the basis of sensors in bioanalytics and markers for biolabeling. Inorganic CdSe quantum dots are coated with amphiphilic polymers in order to transfer them to aqueous solutions. Additionally, it is possible to embed ATTO-dye molecules in the polymer shell. The spectral overlap between the emission of the nano-particles and the absorption of the dye molecules can be modified by choosing different sizes of the quantum dots. Continuous-wave measurements as well as time-resolved photoluminescence measurements show that the emission properties of the quantum dot-dye molecule system are dominated by energy transfer processes. The presence of the quantum dots decelerates the decay of the dye emission, due to (i) re-absorption of photons emitted by the nano-particles and (ii) non-radiative energy transfer. The latter becomes more important the smaller the distance between the nano-particles and the dye molecules and the larger the spectral overlap between quantum dot emission and dye absorption. The measurements can be described within a model that accounts for the interplay of the excitation dynamics of the quantum dot and the dye molecules with respect to the different transfer processes.

HL 9.105 Mon 14:30 P2

MBE growth and characterisation of Heusler Alloy Ni_2MnIn on (001) InAs — •Sascha Bohse, Andriy Zolotaryov, Andreas Volland, Christian Heyn, and Wolfgang Hansen — Universität Hamburg, Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, D-20355 Hamburg, Germany

We study the morphological, structural, and magnetic properties of thin Ni_2MnIn Heusler films grown on (001) InAs by molecular beam epitaxy (MBE) at temperatures between 80 °C and 360 °C. The structural properties of the films with thicknesses of 20, 60, and 100 nm are studied with atomic force microscopy (AFM), X-ray reflectivity measurements (XRR), and transmission electron microscopy (TEM). For magnetization measurements SQUID magnetometry has been used. Furthermore a composition analysis of TEM crossections is provided with energy dispersive X-ray spectroscopy (EDX). The TEM investigations reveal the formation of an intermixed layer on the film/substrate interface by diffusion of As from the substrate into the Heusler deposit.

The intermixing process is accompanied by a B2 to $L2_1$ phase transition between 250 °C - 300 °C and a fast morphological degradation of the Heusler films at temperatures higher than 300 °C. The Ni_2MnIn films grown within the 250 °C - 300 °C temperature window are found to be single-crystalline with best morphological and structural quality. Interestingly, films in $L2_1$ phase are found to have a (110) surface orientation in contrast to the InAs (001) substrate crystal.

HL 9.106 Mon 14:30 P2

Electron Dynamics in Light Emitting Quantum-Dot Heterostructures with Momentum Resolved Carrier-Phonon Scattering — •Janik Wolters[1], Matthias–René Dachner[1], Ulrike Woggon[2], Andreas Knorr[1], and Marten Richter[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin

We present a microscopic theory of the light emission dynamics of an electrically pumped quantum dot emitter below laser threshold. The structure consists of a bulk semiconductor and Stranski-Krastanov grown InGaAs/GaAs quantum dot layers, operating at room temperature. Transport through the structure is driven by scattering with longitudinal-optical phonons, including nonequilibrium phonons.
It appears that even though the phonon distribution remains thermal, there is a substantial carrier heating in the quantum wells.

HL 9.107 Mon 14:30 P2

Microscopic model for the Switch-on Dynamics of Quantum-Dot VCSELs — •Jeong Eun Kim, Ermin Malic, Marten Richter, and Andreas Knorr — Institut für Theoretische Physik, Technische Universität Berlin*Hardenbergstr. 36, 10623 Berlin, Germany

Quantum dots (QDs) as active medium in vertical-cavity surface-emitting lasers (VCSELs) promise improved device performance [1]. We present a microscopically motivated calculation of the switch-on dynamics of an electrically pumped QD-VCSEL. The electric field propagation and the dynamics of the QD and WL charge carrier densities are calculated using spatially one-dimensional Maxwell-Bloch equations. For a detailed understanding, microscopically calculated Coulomb scattering processes [2] and a model for spontaneous emission [3] are incorporated into the Maxwell-Bloch equations. The equations are numerically solved by finite-difference time-domain (FDTD) method to investigate the temporal quantum electrodynamics. After the switch-on of the laser on a ns time scale, relaxation oscillations result from an interplay of carrier filling, induced emission, and absorption processes.

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HL 9.108 Mon 14:30 P2

Pulse propagation in Quantum Dot Semiconductor Optical Amplifiers — •Niels Majer, Miriam Wegert, Ermin Malic, Kathy Lüdge, and Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

We investigate pulse propagation in quantum dot semiconductor optical amplifiers (QD SOA) using travelling wave equations for the electric field amplitude on the basis of Maxwell's equations coupled with Semiconductor Bloch equations. The model includes microscopically calculated Coulomb scattering rates in the dynamic equations for the carrier populations of the quantum dots, and a phenomenological dephasing time.

Simulations of the spatiotemporal dynamics of the system using ultrashort (150 fs FWHM) input pulses reveal the following intensity-dependent effects: As the pulse travels along the SOA, it is deformed and may even develop a two-peak structure (pulse-breakup).

HL 9.109 Mon 14:30 P2

Fabrication and characterization of red AlGaInP-VECSEL — •Thomas Schwarzbäck, Marcus Eichfelder, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funkionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Vertical-external-cavity surface-emitting lasers (VECSELs) have attracted a wide range of applications in biophotonics, television or projectors and spectroscopy. Here VECSELs overcome the disadvantages of common high-power edge-emitting semiconductor lasers which often suffer under insufficient beam quality and catastrophic optical mirror damage. With usage of external cavities and optical pumping VECSELs achieve high continuous-wave output power and near-diffraction-limited beam quality with a TEM_{00} Gaussian beam profile.

We present a fully operating VECSEL system based on a multi-quantum-well structure of the chip with compressively-strained GaInP quantum wells within $Al_{0.55}GaInP$ barriers on an $Al_{0.50}GaAs/AlAs$ distributed Bragg reflector for an operation wavelength of around 660 nm. With simulations based on a transfer-matrix method we produced a resonant periodic gain design of the chip-cavity. The laser system is actively cooled by thermo-electric cooling and key parameters of this laser system were investigated intensively.

After optimization of the VECSEL structure and set-up a future prospective could be frequency-doubling to enter the UV spectral range.

HL 9.110 Mon 14:30 P2

Mode characteristics of red VCSEL with oxide-confined aperture — •Susanne Weidenfeld, Michael Wiesner, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

For optical data transmission over short distances polymer optical fibers (POF) are the preferred low cost medium due to their relatively high mechanical flexibility and the large core diameter. Red vertical-cavity surface-emitting lasers (VCSEL) target one absorption minimum of the POF at around 650 nm and exhibit circular beam profile and low divergence angle for an easy coupling of light into the fiber.

Our AlGaInP-based devices are grown by metal-organic vapor-phase epitaxy (MOVPE). They have low threshold current (<1mA) and an optical output power up to 4 mW. For practical application a stable single transverse mode especially the fundamental mode and a stable polarization of the emission is desirable owing to higher coupling-efficiency in optical fibers.

In the current work we investigate the beam-profile depending on different parameters. The transverse mode profile is analyzed regarding aperture and mesa size. Also the influence of operation current and temperature on the mode shape is investigated. Measurements of the divergence angle and the polarization of the modes are presented.

HL 9.111 Mon 14:30 P2

Spin Injection in GaAs by Cleaved-Edge-Overgrowth — •Arne Ludwig[1], Carsten Godde[2], Sani Noor[2], Hasmik Harutyunyan[2], Stephan Hövel[3], Mingyuan Li[3], Dirk Reuter[1], Andreas D. Wieck[1], Ulrich Köhler[2], and Martin Hofmann[3] — [1]Lehrstuhl für Angewandte Festkörperphysik — [2]Experimentalphysik IV - AG Oberflächenphysik — [3]Lehstuhl für Photonik und Terahertztechnologie, all Ruhr-Universität Bochum

Spin injection in semiconductors is still a challenging topic. Successful spin injection has been demonstrated by the detection of circularly polarized light, resulting from the recombination of spin polarized electrons and unpolarized holes in a n-i-p-diode. In a classic approach, the spins are injected from a ferromagnetic metal grown on top of the n-i-p diode. At the interface either a tailored Schottky barrier or an inserted MgO layer serves as tunnel-barrier into the n-doped region of the device. Some technical problems occur, e. g., protecting the semiconductor surface from impurities before depositing the metal/tunnelling barrier and the need for a magnetic material with out-of-plane anisotropy.

In our approach, the sample is patterned and ohmic contacts are evaporated before transferring the sample to a metal-MBE, where it is cleaved under ultra high vacuum conditions. Then, the FM-contacts are evaporated in situ on the cleavage plane. In addition to Schottky barrier contacts, MgO tunnel-barriers have been prepared. We will discuss the properties of the different contact configurations and first results from Electroluminescence measurements.

HL 9.112 Mon 14:30 P2

Magnetic Anisotropy and Anisotropic Magnetoresistance of (Ga,Mn)As Layers on (113)A GaAs — •Daniela Donhauser, Lukas Dreher, Joachim Däubler, Michael Glunk, Christoph Rapp, Wladimir Schoch, Rolf Sauer, and Wolfgang Limmer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm, Germany

We study the magnetic anisotropy and the anisotropic magnetore-

sistance of compressively strained (Ga,Mn)As films with various Mn concentrations, grown on (113)A-oriented GaAs substrates. High-resolution x-ray diffraction (HRXRD) studies reveal a monoclinic symmetry of the distorted (113)A layers in agreement with an explicit calculation of the strain tensor. Based on this result, general expressions for the resistivity tensor and the free energy of single-crystalline ferromagnets are derived from a series expansion with respect to the magnetization orientation, including terms up to the fourth order. With these expressions we are able to model the measured angular dependences of our magnetotransport data with the assumption of a single ferromagnetic domain model. In order to quantitatively derive the resistivity and anisotropy parameters the longitudinal and transverse resistivities are experimentally studied for magnetic fields rotated within the (113), $(33\bar{2})$, and $(\bar{1}10)$ plane at various field strengths. It turned out that some of the resistivity parameters significantly depend on the strength of the external magnetic field. Furthermore we found that the layers exhibit a uniaxial anisotropy along the [001] crystallographic axis, which can be theoretically explained based on the explicit form of the strain tensor.

HL 9.113 Mon 14:30 P2

Measurement of long spin lifetimes, spin diffusion and spin drift in n-doped GaAs — Andreas Maurer, •Roland Völkl, Andreas Einwanger, Tobias Korn, Mariusz Ciorga, Dieter Schuh, Dieter Weiss, Werner Wegscheider, and Christian Schüller — Universität Regensburg

On the road to spintronic devices it is crucial to develop materials with long spin lifetimes and to determine spin drift/diffusion lengths in these materials. The usual methods for measuring spin lifetimes are time resolved Kerr/Faraday rotation experiments, but this well established technique reaches its limits if the spin lifetime exceeds 10 ns.

Here, we report on Hanle-MOKE-measurements that show spin lifetimes far above 10 ns and mapping of spin drift and spin diffusion on the 50 μm scale. In the Spin-Hanle experiment[1], spins are injected with a circularly polarized CW-Laser and the net spin polarisation perpendicular to the sample plane is measured by detecting the Kerr rotation of a linearly polarized laser. By applying an external magnetic field the spins start to precess and the spin polarisation is reduced. This effect is stronger when the spin lifetime τ is longer. In both cases the width at half maximum of the signal is proportional to $1/\tau$

By focussing the two beams through an optical microscope and scanning the pump beam with a motorized mirror we can measure spin diffusion, and by applying electrical fields spin drift.

[1] Stephens et al, **PRL** 93, 097602 (2004)

HL 9.114 Mon 14:30 P2

Investigation of the de Haas-van Alphen effect in an asymmetric InGaAs/InP quantum well — •Benedikt Rupprecht[1], Tjark Windisch[1], Marc A. Wilde[1], Thomas Schäpers[2], Christian Heyn[3], and Dirk Grundler[1] — [1]Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Str. 1, D-85747 Garching — [2]Institute of Bio- and Nanosystems (IBN-1) and Centre of Nanoelectronic Systems for Information Technology (CNI), Research Centre Jülich, D-52425 Jülich — [3]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Jungiusstrasse 11, D-20355 Hamburg

We report on magnetization measurements on a two-dimensional electron system (2DES) in an asymmetric InGaAs/InP quantum well using a micromechanical cantilever magnetometer. The magnetometer has a noise level of about 10^{-14} J/T at B_{ext} = 1 T, allowing the detection of de Haas-van Alphen oscillations of the 2DES at 300 mK. The magnetization is a thermodynamic quantity that at low temperature directly reflects the ground state energy of the system. From the data we can directly extract material parameters such as the g-factor and the effective mass m^* as well as information about the spin-orbit coupling. Magnetotransport measurements on similar 2DES revealed a clear beating pattern in the Shubnikov-de Haas oscillations due to the Rashba spin-orbit coupling. We present the measurement setup as well as the results of the magnetization measurements focusing on bandstructure parameters and the spin-orbit interaction.
We acknowledge support through GR1640/3 in SPP1285.

HL 9.115 Mon 14:30 P2

Magnetotransport in (Ga,Mn)As on the Verge of the Single Domain Model — •Christoph Rapp, Lukas Dreher, Joachim Daeubler, Daniela Donhauser, Michael Glunk, Wladimir Schoch, Stephan Schwaiger, Rolf Sauer, and Wolfgang Limmer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

We investigate the limits of the single-domain model in (Ga,Mn)As by performing detailed angle- and field-dependent magnetotransport measurements in samples with differing magnetic anisotropies. For this purpose, a series of (Ga,Mn)As layers with Mn concentrations of $\sim$ 5% was grown by low-temperature molecular-beam epitaxy on relaxed (In,Ga)As/GaAs templates with different In-concentrations, realizing different strain conditions from compressive to tensile. In past investigations we have elucidated the strain dependence of the magnetic anisotropy and of the anisotropic magnetoresistance employing a single-domain model. In order to analyze the break-down of the single-domain model, we now study in detail magnetization reversal processes by sweeping an external magnetic field along selected axes. The magnetic-field sweeps are compared with a series of angle-dependent magnetotransport measurements, carried out at weak external magnetic fields.

HL 9.116 Mon 14:30 P2

Spin Coulomb drag in presence of spin-orbit coupling and disorder — •Matthias Lüffe — Institut für Theoretische Physik, Freie Universität Berlin

It is experimentally established (Weber *et al.*, 2005) that electron-electron interactions lead to a decay of spin currents because momentum is transferred between the *up* and *down* spin electrons. This damping of the relative motion of the two spin species is commonly termed *spin Coulomb drag* (D'Amico and Vignale, 2000). The phenomenon has been subject of several theoretical investigations based on both Boltzmann equations (Flensberg, Jensen and Mortensen, 2001) and diagrammatic linear response calculations (Tse and Das Sarma, 2007). We aim at computing the trans-resistivity as the quantity that characterizes the spin Coulomb drag for a 2DEG in presence of Rashba spin-orbit coupling and disorder. Our calculations are in the framework of a kinetic equation for the density matrix in spin space, capturing spin precession and spin coherent scattering from both impurities and electrons. This ensures the validity also in a regime where the D'yakonov-Perel spin relaxation is important.

HL 9.117 Mon 14:30 P2

Electrical measurement of the effective density of states in (Ga,Mn)As — •D. Neumaier[1], A. Vogl[1], U. Wurstbauer[2], M. Utz[1], W. Wegscheider[1], and D. Weiss[1] — [1]Universität Regensburg — [2]Universität Hamburg

In ferromagnetic (Ga,Mn)As the conductivity σ decreases with decreasing temperature below 10 K. Preliminary experiments have shown that enhanced electron-electron interaction (EEI) [1] is the origin of this conductivity decrease [2]. The size of the conductivity correction due to EEI is depending on the diffusion constant D. Hence a detailed analysis of the conductivity correction provides experimental access to the diffusion constant. The diffusion constant is connected to the effective density of states at Fermi's energy $N(E_F)$ by Einstein's relation: $\sigma = e^2 N(E_F) D$. For (Ga,Mn)As it is still an open issue whether Fermi's energy is in the valence band or in a detached impurity band [3]. Here we present measurements of the conductivity correction in quasi 1D and quasi 3D (Ga,Mn)As, as well as in the crossover regime from quasi 2D to 1D, to get knowledge about the diffusion constant and the effective density of states. The measured values of $N(E_F)$ will be compared with recent theoretical calculations [4]. The good agreement shows, that the transport in (Ga,Mn)As can be described well within the picture, that Fermi's energy is in the valence band.

[1] P. A. Lee and T. V. Ramakrishnan , Rev. Mod. Phys. 57, 287 (1985). [2] D. Neumaier *et al.*, Phys. Rev. B 77, 041306(R) (2008). [3] T. Jungwirth *et al.*, Phys. Rev. B 76, 125206 (2007). [4] M. Turek *et al.*, Phys. Rev. B 78, 085211 (2008).

HL 9.118 Mon 14:30 P2

Coulomb blockade dominates transport across lateral (001)-(Ga,Mn)As nanoconstrictions — •Markus Schlapps[1], Teresa Lermer[1], Stefan Geissler[1], Daniel Neumaier[1], Rashid Gareev[1], Janusz Sadowski[2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Universität Regensburg — [2]Max-Lab, Lund University, Sweden

Narrow constrictions in GaMnAs films display large magnetoresistance (MR) effects [1-6]. Explanations of these effects involve the formation of a tunneling barrier [1,2]. A pronounced dependence of the resistance on the magnetization direction was ascribed to the tunneling

anisotropic MR [2] and, more recently, to a metal-insulator transition [4,5]. On the other hand, experiments on a narrow GaMnAs channel revealed a Coulomb blockade anisotropic MR effect[6]. Hence the microscopic origin of the huge MR effects is still under discussion. Here we present experiments on single-constricted GaMnAs wires. Based on measurements of the resistances' bias voltage and temperature dependence down to millikelvin temperatures we compare the models currently used. We show that the large MR jumps of up to several thousand percent are solely connected to the magnetization alignment in the constriction and that the transport mechanism is dominated by Coulomb blockade. Using additional side-gates the device acts as a single electron transistor. [1] C. Ruester et al. , PRL 91, 216602 (2003) [2] A. D. Giddings et al. , PRL 94, 127202 (2005) [3] M. Schlapps et al. , phys. stat. sol. (a) 203, No. 14, 3597 (2006) [4] M. Ciorga et al. , New J. Phys. 9, 351 (2007) [5] K. Pappert et al. , Nature Physics 3, 573 - 578 (2007) [6] J. Wunderlich et al. , PRL 97, 077201 (2006)

HL 9.119 Mon 14:30 P2

Investigation of Quantum Hall arrays for resistance standards — •Jens Könemann, Günter Hein, Bernhard Schumacher, Klaus Pierz, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Today's quantum resistance standards are generally implemented using the integer Quantum Hall effect at filling factor $i = 2$ corresponding to a quantized resistance value of $R_Q = 12.9$ kΩ. Arranging several Hall bars in series or in parallel promises extending the range of quantized resistance values between 100 Ω and 1 MΩ, whilst maintaining low uncertainties within the order of some parts in 10^9. In this work, we test the feasibility of such a resistance standard based on Quantum Hall arrays by interconnecting Hall bars with standard bonding technique. Additionally, we have realized a serial array of ten Hall bars with lithographically defined connections on chip. First high-precision measurements of such a device are presented on our poster.

HL 9.120 Mon 14:30 P2

Gap measurements at filling factors 1/3 and 2/5 in the FQHE regime — •Oliver Gerberding[1], Lina Bockhorn[1], Annelene F. Dethlefsen[1,2], Werner Wegscheider[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Centre for Atom Optics and Ultrafast Spectroscopy, Faculty of Engineering and Industrial Science, Swinburne University of Technology — [3]Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We study the fractional Quantum-Hall effect in high mobility twodimensional electron systems (2DES). The Hall geometries are created by photolithography on a GaAs/GaAlAs heterostructure containing a 2DES.

The activation gaps of the fractional Quantum-Hall state at constant filling factors 1/3 and 2/5 have been measured as a function of a perpendicular magnetic field B. The mobility and the density of electrons are manipulated by using a topgate. For a given density of electrons we study the Shubnikov-de Haas oscillations for different temperatures to extract the activation energies.

For several filling factors we find an astonishing linear dependence for small magnetic fields and a cross over to square root dependence for high magnetic fields.

HL 10: Invited Talk Dietsche

Time: Monday 14:45–15:30 Location: HSZ 01

Invited Talk HL 10.1 Mon 14:45 HSZ 01

The Bose-Einstein condensation of excitons in quantum-Hall bilayers — •Werner Dietsche and Lars Tiemann — MPI für Festkörperforschung, Stuttgart

The possibility of Bose-Einstein condensation of excitons (BEC) in semiconductors has long been debated but proved to be elusive so far. There is now mounting evidence of a BEC in a rather unusual exciton system: two 2-dimensional electron gases separated by a few nm residing in GaAs based quantum wells. The densities and a perpendicular magnetic field are adjusted so that just half a Landau level is filled in each layer. Occupied and unoccupied electron states in the two layers interact via Coulomb forces and behave now like excitons. Unusual transport properties like a quantized Hall drag and a vanishing resistance in the counter flow geometry have already shown unusual properties of this system. Unfortunately, the existence of a BEC was not evident because it is difficult to demonstrate the superflow of charge-neutral excitations in a solid. Recent experiments, however, show an increase of the tunnel conductance between the two layers by more than four orders of magnitude, a nearly vanishing interlayer bias voltage and a distinct critical current resembling the one of the DC-Josephson effect between superconductors. These phenomena are a very strong evidence of an excitonic superfluid where tunneling would be equivalent to Andreev reflection demonstrating the phase coherence of the excitons.

HL 11: Focused Session: Semi- and nonpolar group III nitrides I

Time: Tuesday 9:30–12:45 Location: HSZ 01

Topical Talk HL 11.1 Tue 9:30 HSZ 01

Characterization and Control of Recombination Dynamics in Low-dimensional InGaN-based Semiconductors — •Yoichi Kawakami, Akio Kaneta, Masaya Ueda, and Mitsuru Funato — Department of Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan

We have recently proposed the re-growth technique, where c-oriented (0001) GaN is used as a seed, where the growth on GaN templates patterned with a striped geometry along the [1-100] direction form (0001), <11-22>, and <11-20> facets. We found that the InGaN/GaN QWs on the <11-22> semipolar facets show higher photoluminescence (PL) efficiency, compared with conventional (0001) QWs. Consequently, nanoscopic optical characterization was performed on <11-22> microfacet QWs using scanning near field optical microscopy (SNOM). Unlike the phenomena observed in (0001) QWs, there is not a difference between the PL spectra acquired under the illumination-collection and illumination modes, which indicates that the carrier diffusion length in the <11-22> QW is less than the probing fiber aperture of 160 nm due to a much faster radiative recombination processes as a result of a well-reduction of internal electric field. The correlation between IQE and emission wavelength shows that the highest internal quantum efficiency (IQE) is approximately 50% at 520 nm, which is about 50 nm longer than in (0001) QWs, suggesting that the <11-22> QW is a suitable green emitter with a controllability of polarization direction. Moreover, tailored emission color synthesis has been achieved using the combination of microfacet QWs without phosphors.

Topical Talk HL 11.2 Tue 10:00 HSZ 01

Optical polarization properties of nonpolar-oriented GaN films for polarization-sensitive and narrow-band photodetectors — •Holger T. Grahn — Paul-Drude-Institut, Berlin

The optical polarization properties of unstrained and strained GaN films with a nonpolar orientation are reviewed. In unstrained *A*-plane GaN films, the *A* exciton becomes completely linearly polarized perpendicular to the *c* axis, while the *B* and *C* excitons are only partially polarized. In *M*-plane or *A*-plane GaN films under anisotropic in-plane compressive strain, all three interband transitions between the three uppermost valence bands and the conduction band can become completely linearly polarized for sufficiently large strain values. The complete linear polarization can be directly observed in reflection, transmission or photo-reflectance by a polarization-dependent energy gap. This complete linear polarization can be used to realize polarization-sensitive photo-detectors in the ultraviolet spectral range, which do not need a polarization filter in front of the photo-detector. By combining

a polarization filter and photo-detector or two photo-detectors from the same material with their c axes oriented perpendicular to each other, a narrow-band photo-detection configuration can be achieved in the ultraviolet spectral range with a band width below 8 nm. Since both realizations are also polarization sensitive, a configuration with four photo-detectors is necessary to achieve narrow-band sensitivity regardless of the polarization state of the incident light. At the same time, the configuration with four photo-detectors allows for the determination of the absolute angle of polarization.

15 min. break

Topical Talk HL 11.3 Tue 10:45 HSZ 01

Growth and characterisation of planar (11-20) and (11-22) GaN-based multiple quantum well structures — •Menno Kappers — Department of Materials Science and Metallurgy, Pembroke Street, University of Cambridge, Cambridge, CB2 3QZ, UK

The effects of polarisation charges observed in polar (0001) GaN-based heterostructures can be eliminated or reduced by growing on the non-polar (11-20) and semi-polar (11-22) planes, respectively. This may result in improvements to the recombination efficiency in QW structures where the reduced overlap between the electron and hole wavefunctions caused by electric fields leads to long radiative lifetimes. However, planar non- and semi-polar GaN-based structures grown on sapphire substrates are burdened by a high defect density, which are possible sources of non-radiative recombination that compromises the predicted high IQE of QW structures. Indeed, great advances in device efficiencies have been made by a few groups around the world using non- and semi-polar GaN bulk substrates with very low dislocation densities. The challenge for the rest of us is to improve the quality of hetero-epitaxial GaN-based structures. Some have chosen to study heterostructures on non- and semi-polar facets grown on basal-plane substrates, others prefer the growth of planar epilayers on R- and M-plane sapphire. Part of the combined research efforts at the Universities of Cambridge and Manchester is to find methods of defect reduction in planar (11-20) and (11-22) GaN and the structural and optical characterization of GaN/AlGaN and InGaN/GaN MQW structures. An up-to-date overview of our research progress will be given.

Topical Talk HL 11.4 Tue 11:15 HSZ 01

Materials issues towards green laser diodes — •Andreas Hangleiter — PolarCoN Research Group & Institute of Applied Physics, TU Braunschweig

For the past 15 years, group-III nitrides have shown an unprecedented development. Driven by applications in lighting and optical data storage quantum well heterostructures with high efficiency in the violet-blue spectral region have been realized. For green wavelengths, however, the efficiency of light-emitting diodes encounters the "green gap", laser diodes are still limited to a greenish blue. Among the problems responsible for that are the huge piezoelectric fields as well as the large strain arising from the large Indium mole fraction required to reach the green region. The diminishing refractive index contrast between GaN and AlGaN represents an additional challenge for laser waveguide structures.

In order to reduce the internal fields we are studying semipolar and nonpolar growth planes instead of the polar c-plane. Careful low-temperature growth of GaInN turns out to be the key to achieve homogeneous high In incorporation. Additional care needs to be applied to the growth of cladding layers in order to avoid thermal damage to those high-In layers. We use high-resolution XRD to control relaxation as well as transmission electron microscopy to study defects in those layers. Important information regarding homogeneity comes from micro-photoluminescence as well as from cathodoluminescence studies. Optical gain measurements reveal key laser properties such as peak gain, carrier losses, and optical losses.

15 min. break

HL 11.5 Tue 12:00 HSZ 01

Thermal trap emissions associated with stacking faults in undoped non c-plane GaN — •Kay-Michael Günther, Hartmut Witte, Matthias Wieneke, Jürgen Bläsing, Armin Dadgar, and Alois Krost — Otto-von-Guericke-Universität Magdeburg

Recently, GaN-based materials are used in optoelectronic and microelectronic devices like LEDs, vertical cavity surface emitting laser or high electron mobility transistors. In some applications strong piezoelectric fields in c-plane GaN are undesired evoking for instance the quantum confined stark effect (QCSE). In this case the reduced polarization of non c-plane GaN layers is useful for better radiative efficiency. Unfortunately, due to its anisotropic nature the growth of semipolar GaN produces much more stacking faults than in c-axis oriented GaN. The basal and prismatic plane stacking faults act as deep defects which are well known from photoluminescence measurements. However, little is known on their thermal emission and trapping behavior. Therefore, we have characterized deep defects of a series of high resistance and undoped semipolar GaN samples grown by MOVPE on sapphire substrates by comparison of defect-related transitions in photoluminescence, thermal emissions in photocurrent spectroscopy and in thermally stimulated currents (TSC). These results are compared to measurements on polar c-plane GaN samples and the correlation between the stacking faults and thermal trap emissions is discussed.

HL 11.6 Tue 12:15 HSZ 01

Facet formation and ohmic contacts for laser diodes on non- and semipolar GaN — •Jens Rass[1], Simon Ploch[1], Tim Wernicke[2], Luca Redaelli[2], Patrick Vogt[1], Sven Einfeldt[2], and Michael Kneissl[1,2] — [1]Technische Universitaet Berlin, Institute of Solid State Physics, Secretariat EW6- 1, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Ferdinand- Braun-Institut fuer Hoechstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Group-III-Nitride heterostructures grown on nonpolar and semipolar planes allow the realization of highly efficient devices such as laser diodes and LEDs due to the reduction or elimination of the quantum confined stark effect. However, the realization of these devices poses a number of challenges, in particular the formation of smooth laser facets and the fabrication of ohmic contacts.

In this talk optimized schemes for facet formation and contact resistance reduction for nitride based devices on non- and semipolar planes will be presented and various concepts will be discussed. We will discuss a laser scribing process that allows the cleaving of facets along the c- and a-plane for devices grown on nonpolar substrates. For semipolar planes there is no low-index cleavage plane in order to form resonators along the projection of the c-axis. Therefore we have investigated etching techniques in order to produce flat facets perpendicular to the plane of growth. For the challenging formation of p-type contacts to GaN we will discuss different methods such as chemical treatments, different metallization schemes and capping layers to reduce the contact resistivity.

HL 11.7 Tue 12:30 HSZ 01

Growth of nonpolar a-plane GaN on r-plane Sapphire via HVPE — •Stephan Schwaiger, Thomas Wunderer, Frank Lipski, and Ferdinand Scholz — Institut für Optoelektronik, Universität Ulm

We report on the growth of a-plane GaN on r-plane sapphire via hydride vapor phase epitaxy (HVPE). Prior to the HVPE growth the substrates were loaded into a MOVPE reactor to deposit a template GaN layer on an AlN nucleation layer. The MOVPE growth parameters have been optimized and SiN interlayers for defect reduction have been investigated and successfully introduced. By varying typical growth parameters like the V/III ratio, the temperature, and the pressure during the HVPE growth just small influences on the crystal quality could be observed. The improvement of the MOVPE grown templates seems to have more impact on the resulting nonpolar layers. These layers have been characterized by x-ray rocking curve as well as photoluminescence (PL) measurements. Our optimized layers showed a comparably strong near-band-edge excitonic line as compared to the commonly observed lower energy defect signals caused by stacking faults.

HL 12: Spin controlled transport I

Time: Tuesday 9:30–12:30 Location: BEY 81

HL 12.1 Tue 9:30 BEY 81

Electrical detection of coherent spin currents across an Fe/GaAs Schottky contact — •I. Burkart[1,2], C. Schwark[1,2], G. Güntherodt[1,2], C. Adelmann[3], C.J. Palmstrøm[3,4], X. Lou[5], P.A. Crowell[5], and B. Beschoten[1,2] — [1]Physikalisches Institut IIA, RWTH Aachen University, Templergraben 55, 52056 Aachen, and JARA-Fundamentals of Future Information Technology, Germany — [2]Virtual Institute for Spin Electronics (ViSel), Aachen - Jülich - Göttingen — [3]Department of Chemical Engineering and Material Science, University of Minnesota, Minneapolis 55455, USA — [4]Departments of Electrical and Computer Engineering and Materials, University of California, Santa Barbara, CA 93106, USA — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

Most previous experiments on electrical detection of spin currents in ferromagnet/semiconductor devices focus on the DC transport regime. Here, we present a new time-resolved method, which allows to electrically probe coherent spin currents across an Fe/GaAs Schottky contact, after optical excitation by circularly polarized laser pulses. Coherent spin precession can be identified in the magnetic-field dependent photo-current using resonant spin amplification. Based on this technique we are able to observe multiple Larmor precessions which can be associated with electron spin precession in the GaAs layer.

Work supported by BMBF, HGF and DFG.

HL 12.2 Tue 9:45 BEY 81

Magnetic field dependence of the tunneling anisotropic magnetoresistance effect in Fe/GaAs/Au tunnel junctions — •Michael Wimmer[1], Michael Lobenhofer[2], Alex Matos-Abiague[1], Jaroslav Fabian[1], Dieter Weiss[2], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

Recent experiments on the tunneling anisotropic magnetoresistance (TAMR) effect in Fe/GaAs/Au tunnel junctions found a peculiar magnetic field dependence in high fields: Depending on the bias voltage, the TAMR effect may increase or decrease linearly with magnetic field.

We explain these findings by including the orbital effects of the magnetic field in a previously developed theoretical description of the TAMR effect in terms of Rashba and Dresselhaus spin-orbit coupling [1]. Both numerical simulations as well as a phenomenological model agree well with experiment. The high-field behavior is found to be dominated by an interplay between the Dresselhaus spin-orbit coupling in the GaAs barrier and the orbital effects of the magnetic field.

[1] J. Moser *et al.*, Phys. Rev. Lett. **99**, 056601 (2007).

HL 12.3 Tue 10:00 BEY 81

Electrical triggering of phase-coherent spin packets by pulsed electrical spin injection across an Fe/GaAs Schottky contact — •C. Schwark[1,2], I. Burkart[1,2], J. Moritz[1,2], L. Schreiber[1,2], G. Güntherodt[1,2], C. Adelmann[3], C. Palmstrøm[3,4], P.A. Crowell[5], and B. Beschoten[1,2] — [1]Physikalisches Institut IIA, RWTH Aachen University, Templergraben 55, 52056 Aachen, and JARA-Fundamentals of Future Information Technology, Germany — [2]Virtual Institute for Spin Electronics (ViSel), Aachen - Jülich - Göttingen — [3]Department of Chemical Engineering and Material Science, University of Minnesota, Minneapolis 55455, USA — [4]Departments of Electrical and Computer Engineering and Materials, University of California, Santa Barbara, CA 93106, USA — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

Efficient electrical spin injection from a ferromagnet into a semiconductor has been demonstrated for various material systems by steady-state experiments. Here, we introduce a novel time-resolved technique based on electrical pumping and optical probing. Coherent spin packets are injected from an Fe layer through a reverse biased Schottky barrier into an n-GaAs layer by applying ultrafast current pulses at low temperature (20K). Spin coherence is probed by time-resolved Faraday rotation. Based on this technique we are able to observe multiple Larmor precessions and spin dephasing times greater than 50ns.

Work supported by BMBF, HGF and DFG.

HL 12.4 Tue 10:15 BEY 81

Prediction of giant intrinsic spin-Hall effect in strained p-GaAs quantum wells — •Christoph Schindler, Tillmann Kubis, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

We present a systematic study of the intrinsic spin-Hall effect and its inverse effect in various two dimensional nanostructures using the non-equilibrium Green's function technique. We include elastic impurity scattering as well as inelastic acoustical phonon scattering. The parameters for the Dresselhaus and Rashba spin-orbit coupling are obtained from an atomistic tight binding calculation. We predict exceptionally large spin polarization effects in specially band engineered and geometrically designed nanostructures. In strained p-GasAs, we find a k-linear spin splitting that is enhanced by a factor of 50 compared to the unstrained case. We propose a "T" shaped three-terminal device that acts as a spin polarizer without external magnetic field. Optimizing the geometry with respect to the spin-precession length results in a spin accumulation at the drain contacts of up to 25%. We also study the inverse intrinsic spin-Hall effect. In a four-terminal "H" shaped structure it can be used to measure the direct spin-Hall effect by simply applying a gate voltage. For such a measurement, we predict a threshold value for the spin-orbit coupling strength that cannot be met by simple n-GaAs systems.

15 min. break

HL 12.5 Tue 10:45 BEY 81

Time-resolved studies of current induced spin polarization in strained InGaAs structures — •Markus Hagedorn[1,2,3], Marten Patt[1,3], Klaus Schmalbuch[1,3], Gernot Güntherodt[1,3], Mihail Lepsa[2,3], Thomas Schäpers[2,3], and Bernd Beschoten[1,3] — [1]II. Physikalisches Institut, RWTH Aachen — [2]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich — [3]JARA - Fundamentals of Future Information Technology

The fundamental understanding of electron spin interactions in non-magnetic semiconductor heterostructures and the controlled manipulation of spins are crucial for realizing novel spintronic devices.

The well established all-optical pump/probe schemes as experimental methods for the creation and detection of coherent spins are nowadays supplemented by means of electrical pumping.

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

We report on detection and manipulation of electron spins by time-resolved CISP. Spins are generated by ultrafast current pulses. The spin polarization is probed spatio-temporally by Faraday rotation in polar geometry.

Work supported by DFG through FOR912.

HL 12.6 Tue 11:00 BEY 81

Observation of the orbital circular photogalvanic effect in Si-MOSFETs — •J. Karch[1], P. Olbrich[1], C. Reitmaier[1], D. Plohmann[1], S. A. Tarasenko[2], Z. D. Kvon[3], and S. D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A. F. Ioffe Physico-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

We report on the observation of the orbital circular photogalvanic effect (CPGE). The experiments are carried out on (001) oriented and miscut Si-MOSFETs. The fact of the existence of the CPGE in such structures is of particular importance. So far, the CPGE has only been detected in materials with strong spin-orbit coupling and described by microscopic mechanisms based on spin-related processes. In Si-MOSFETs the spin-orbit coupling is known to be vanishingly small, therefore, these mechanisms of the CPGE become ineffective. We demonstrated that in our structures in spite of the fact that the photocurrent is caused by transfer of the photon angular momentum to free carriers, it is not due to spin orientation but has a pure orbital origin. It results from the quantum interference of different pathways contributing to the free-carrier absorption of monochromatic radiation. For excitation

we use terahertz radiation of a molecular optically pumped laser in the wavelength range between 77 and 280 μm. Depending on temperature and gate voltage, which varies the separation between size-quantized subbands, we induce Drude-like as well as direct intersubband transitions. We developed both microscopic and phenomenological theories well describing all observed features of the orbital CPGE.

HL 12.7 Tue 11:15 BEY 81

Observation of tunnel rates of phosphorus dopants using silicon SETs — •H. Huebl[1], C. D. Nugroho[1], A. Morello[1], C. Escott[1], C. Yang[2], J. van Donkelaar[2], A. Alves[2], D. Jamieson[2], A. S. Dzurak[1], R. G. Clark[1], and M. Eriksson[3] — [1]Centre for Quantum Computer Technology, University of New South Wales, Sydney, Australia — [2]Centre for Quantum Computer Technology, University of Melbourne, Melbourne, Australia — [3]Department of Physics, University of Wisconsin, Madisson, Wisconsin, USA

Charge centres, such as donors in semiconductors, have significant potential for quantum information processing. In silicon, which can be produced nuclear-spin free, phosphorus donors are a prime candidate for implementation of a qubit, due to their long spin coherence times. In this presentation we will discuss a hybrid structure, consisting of implanted phosphorus donors controlled by a gate potential in close vicinity to a gate-induced, MOS-based silicon single electron transistor (Si-SET). We study the dual functionality of the nearby Si-SET as a sensitive charge detector as well as a gate-induced electron reservoir. Experimentally, we observe shifts in the position of the Coulomb peaks of the Si-SET corresponding to 20% of an electron charge. We attribute these shifts to charge transfers between the Si-SET island reservoir and the nearby phosphorus donors. Pulsed voltage spectroscopy on one of these charge transitions allows us to investigate the capture and emission times of a donor resulting in a capture rate of 3000 s^{-1} and an emission rate of 1000 s^{-1} corroborating expectations from device modelling.

15 min. break

HL 12.8 Tue 11:45 BEY 81

Controlable Manipulation of Structure Inversion Asymmetry (SIA) of Quantum Wells (QWs) by Shifting the Position of δ-doping Layer — •V. Lechner[1], S.D. Ganichev[1], V.V. Belkov[2], P. Olbrich[1], L.E. Golub[2], S.A. Tarasenko[2], D. Schuh[1], W. Wegscheider[1], D. Weiss[1], and W. Prettl[1] — [1]Terahertz Center, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

We demonstrate that the growing of semiconductor QWs with various δ-doping layer positions accompanied by measurements of magnetogyrotropic photogalvanic effect (MGPE) [1] allows the controle of SIA. The MPGE originates from bulk inversion asymmetry (BIA) and SIA and therefore reflects their behaviour. We show that for a proper experimental geometry, currents measured along and perpendicular to B, are proportional to BIA and SIA, respectively. Our experiments prove that shifting the δ-doping layer from one side of the QW to the other results in a change of sign of the SIA-caused MPGE. Our measurements show that while nominally symmetrically doped (001)-grown structures have an essential structural asymmetry, (110)-grown structures are almost symmetrical. Our results allow the growth of perfectly symmetric structures without Rashba constant and structures with equal Rashba and Dresselhaus spin splittings. Experiments were carried out at room temperature on n-type GaAs quantum wells.

[1] V.V. Bel'kov, and S.D. Ganichev, review in Semicond. Sci. Technol. **23**, 114003 (2008).

HL 12.9 Tue 12:00 BEY 81

Weak Value of electrons spin in a double quantum dot — •Alessandro Romito[1], Yuval Gefen[1], and Yaroslav Blanter[2] — [1]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft

The measurement of an observable in quantum mechanics is described by the projection postulate. In contrast, a weak measurement (i.e. a continuos measurement performed by a weakly coupled detector) allows us to weakly disturb the system, while acquiring only partial information about the state of the system. It has been shown that a weak measurement performed on pre and post-selected states consistently defines a new kind of value, the " weak value", of the measured quantum variable [1]. Weak values may lie well beyond the range of strong values and may happen to be complex.

Here we present the first proposal to observe the weak value of electron spin in a double quantum dot with a quantum point contact to be used as a detector. The required control on the electons' spin state has been demonstrated experimentally. Anomalously large values of the electronic spin are predicted, as well as negative values for the total spin. We also show how to incorporate the adverse effect of decoherence into this procedure.

[1] Y. Aharonov, D. Z. Albert, L. Vaidman, Phys. Rev. Lett. 60, 1351-1354 (1988).

[2] A. Romito, Y. Gefen, and Ya. Blanter, Phys. Rev. Lett. 100, 056801 (2008).

HL 12.10 Tue 12:15 BEY 81

All-electrical detection of the relative strength of Rashba and Dresselhaus spin-orbit interaction in quantum wires — •Matthias Scheid[1,2], Makoto Kohda[1], Yoji Kunihashi[1], Klaus Richter[2], and Junsaku Nitta[1] — [1]Graduate School of Engineering, Tohoku University, 6-6-02 Aramaki-Aza Aoba, Aoba-ku, Sendai 980-8579, Japan — [2]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

We numerically study the conductance of diffusive quantum wires with Rashba and/or Dresselhaus spin-orbit interaction based on the Landauer formalism. We confirm previous results showing the suppression of weak antilocalization in narrow quantum wires [1] or at equal strength of Rashba and Dresselhaus spin-orbit interaction [2].
As a main result, we propose a method to determine the relative strength of Rashba and Dresselhaus spin-orbit interaction from transport measurements without the need of fitting parameters. To this end, we make use of the conductance anisotropy in narrow quantum wires with respect to the directions of an in-plane magnetic field, the quantum wire and the crystal orientation. We show the applicability of the method in a wide range of parameters (elastic mean free path, spin-orbit interaction strength, Fermi energy).
[1] Th. Schäpers, V. A. Guzenko, M. G. Pala, U. Zülicke, M. Governale, J. Knobbe and H. Hardtdegen, Phys. Rev. B 74, 081301 (2006).
[2] F. G. Pikus and G. E. Pikus, Phys. Rev. B 51, 16928 (1995).
[3] M. Scheid, M. Kohda, Y. Kunihashi, K. Richter and J. Nitta, Phys. Rev. Lett. (in press).

HL 13: Optical properties

Time: Tuesday 9:30–13:00 Location: BEY 118

HL 13.1 Tue 9:30 BEY 118

THz sideband generation in multi quantum wells — Martin Wagner[1], Harald Schneider[1], Manfred Helm[1], •Stephan Schartner[2], Aaron Maxwell Andrews[2], Tomas Roch[2], and Gottfried Strasser[2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden-Rossendorf, Postfach 51 01 19, 01314 Dresden — [2]Institut für Festkörperelektronik, TU Wien, Floragasse 7, 1040 Wien, Austria

THz sideband generation is a nonlinear mixing process where a near-infrared (NIR) laser beam is mixed with a THz beam to generate new frequencies (sidebands) $\omega = \omega(\text{NIR}) * n * \omega(\text{THz})$ (with integer n). This effect has been investigated in various semiconductor systems (e. g., in bulk GaAs [1] and in multi quantum wells [2]).

We report on third-order nonlinear mixing between a NIR laser and a free-electron laser (FEL) in an undoped AlGaAs/GaAs multi quantum well. Differently from the literature where electronic and heavy-hole intersubband transitions were used, we are covering different transitions by tuning the FEL wavelength. We directly compare the n=+2 sideband generation efficiency when the FEL pumps the heavy-hole light-hole transition with the efficiency when the intraexcitonic 1s-2p transition of the heavy-hole is pumped. In the latter case the efficiency increases up to 0.2%, which is comparable to the best values achieved

for an even stronger n=+1 sideband process [2].

[1] M. A. Zudov et al., Phys. Rev. B 64, 121204, 2001
[2] S. G. Carter et al., Appl. Phys. Lett. 84, 840, 2004

HL 13.2 Tue 9:45 BEY 118

Excitonic signatures in the intersubband THz absorption of optically excited semiconductor quantum wells — •Daniel Golde, Mackillo Kira, and Stephan W. Koch — Fachbereich Physik, Philipps-Universität, Renthof 5, D-35032 Marburg

We present a theoretical study of the intersubband absorption of an optically excited undoped semiconductor quantum well using our recently developed microscopic THz theory [1]. In the past, intersubband transitions were often studied using doped quantum wells. In this case, the absorption follows entirely from the equilibrium carrier distribution in the lowest subband. For photoexcited quantum wells, however, there are two distinct contributions to the intersubband response. The optically generated charge carriers can be excited to a higher subband giving rise to usual *band-to-band transitions*. The optical pump pulse can also create an excitonic polarization which is under certain conditions converted into an incoherent exciton population [1]. We show that the presence of such coherent or incoherent excitons yields additional *excitonic THz transitions* that are spectrally different from the band-to-band transitions.

In my talk, I will show how the intersubband absorption is influenced by excitons and for which experimental conditions one can expect to observe them in a measurement.

[1] M. Kira and S. W. Koch, Prog. Quantum Electron. **30,** 155 (2006).

HL 13.3 Tue 10:00 BEY 118

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

We calculate the dielectric function including the A-, B-, and C-excitons of hexagonal GaN in the presence of an external electric field by using a multi-valence band formalism. The importance of excitons for the interpretation of electroreflectance spectroscopy of GaN was emphasized by several experimental groups, but only recently theoretical calculations were presented [1]. We derive the dielectric function from a numerical solution of an initial value problem [2] via an exponential split-operator method, taking into account the full 6x6 valence band structure of Chuang and Chang [3]. We present the complex dielectric function as well as the deduced reflectivity and absorption spectra of the excitons in GaN. These and the electroreflectance spectra are compared with recent experimental studies.

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

[2] S. Glutsch, *Excitons in Low−Dimensional Semiconductors*, Springer Heidelberg (2004).

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

HL 13.4 Tue 10:15 BEY 118

Two-color pump-probe spectroscopy of self-assembled GaAs/AlGaAs quantum dots — •Christian Wolpert[1,2], Manuel Huber[1,2], Markus Lippitz[1,2], Lijuan Wang[3], Armando Rastelli[3], and Oliver G. Schmidt[3] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Germany — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Germany

Semiconductor quantum dots (QDs) are a promising candidate for the realization of qbits in quantum computing. With coherence times of below 1 ns, manipulation and read-out of the quantum mechanical state requires ultrafast laser pulses. In order to address single QDs, we can restrict ourselves to optical far-field microscopy, as our GaAs/AlGaAs QD samples show QD densities well below $1/\mu m^2$. We present a scheme for ultrafast spectroscopy of single QDs using a pump-probe technique with a confocal laser-scanning microscope. Pump and probe pulses are derived from a 150 fs pulse by spectral pulse shaping. Single exciton transitions were identified in μ-photoluminescence (μ-PL) measurements around 1.73 eV. Our approach is to resonantly pump and probe excitonic states, enabling us to directly control the phase and population dynamics in the QD. We present the experimental setup as well as first results.

HL 13.5 Tue 10:30 BEY 118

Microscopic Theory of the optical properties of Ga(AsBi) quantum wells — •Sebastian Imhof[1], Christina Bückers[2], Angela Thränhardt[1], Jörg Hader[3], Jerome V. Moloney[3], and Stephan W. Koch[2] — [1]Fakultät für Naturwissenschaften, Technische Universität Chemnitz, 09107 Chemnitz — [2]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps Universität Marburg, Renthof 5, 35032 Marburg — [3]Optical Sciences Center, University of Arizona, Tucson, Arizona 85721, USA

Ga(AsBi) is a serious candidate for infrared diode lasers because the bandgap of GaAs is reduced by as much as 60–80 meV per percent Bi that is incorporated. Thus, a wide wavelength range in the infrared region can be reached.

Although the growth of heterostructures is still not feasible in this material system, we have access to the optical properties, e.g. material gain and photoluminescence as well as radiative and non-radiative laser loss processes of Ga(AsBi)/(AlGa)As quantum wells, by using a consistent microscopic theory. We calculate the bandstructure by using a valence band anticrossing model and investigate the influence of the anticrossing parameters on the optical properties.

HL 13.6 Tue 10:45 BEY 118

Electronic coupling in ZnO/MgZnO Double Quantum Wells — •Jan Zippel, Martin Lange, Gabriele Benndorf, Jörg Lenzner, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II,Linnéstraße 5, 04103 Leipzig

The band-gap of ZnO can be tuned from about 3 eV to 4.5 eV by alloying with Cd or Mg, respectively. This allows the realization of quantum well (QW) structures emitting between the blue and the near UV (NUV) part of the electromagnetic spectrum. In this contribution we focus on the electronic coupling of $ZnO/Mg_xZn_{1-x}O$ double quantum well (DQW) structures. Besides structures with two identical wells, we fabricated DQW*s with different thickness. All samples were grown by pulsed-laser deposition on *a*-plane sapphire substrate. The thickness of the barrier between the two QWs was varied from 1 nm up to 6 nm for well widths of 2 nm and 4.5 nm. The magnesium content (x) in the barrier was determined by photoluminescence measurements to be about 14% for all samples [1].

All samples are investigated using cathodoluminescence at room temperature and at 10 K. With decreasing barrier thickness between the two QWs we observed a clear red shift of the QW luminescence proving the coupling between the QWs at room temperature. The observed shift is in good agreement with effective mass theory. For the structures with different well width, an additional peak between the two direct excitonic transitions occurs.

[1] S. Heitsch et *al.*, J. Appl. Phys. **101**, 083521 (2006).

HL 13.7 Tue 11:00 BEY 118

Temperature dependent dielectric function of nonpolar ZnO — •Philipp Kühne, Rüdiger Schmidt-Grund, Chris Sturm, Matthias Brandt, and Marius Grundmann — Universität Leipzig Institut für Experimentelle Physik II Halbleiterphysik Linnéstraße 5 04103 Leipzig Germany

ZnO is a direct semiconductor which crystallizes in the wurtzite structure. Due to its wide band gap of 3.4 eV and a high exciton binding energy of 60 meV, ZnO is a promising material for optoelectronic devices. Non-polar surfaces like m-plane (1-100) are of special interest since they avoid electric fields at interfaces, which can negatively influence the performance of optoelectronic devices grown on these surfaces.In this work we study the temperature dependence of the tensor of the dielectric function of nonpolar m-plane bulk ZnO single crystals by means of spectroscopic ellipsometry in the spectral range 1 eV−4.5 eV and for temperatures 5 K−470 K. The independent components parallel $\epsilon_{||}$ and perpendicular $\epsilon_{\perp}$ to the crystal axis were found by layer stack model analysis, using parameterised model dielectric functions.

Ellipsometry is very sensitive to surface morphology and surface contamination. We gave emphasis to the sample preparation. After an annealing process the sample exhibits atomic steps at the surface. To avoid the growth of films by resublimation of residual gases at low temperatures, we are working in an UHV system at $p < 10^{-9}$ mbar. For this pressure the growth rate is reduced to maximal one mono-layer per hour. Finally we derive the near band gap band-to-band transition energies, exciton binding energies and broadening parameters.

15 min. break

HL 13.8 Tue 11:30 BEY 118

Measurements in Voigt configuration on PLD grown NiO thin films — •Kah Ming Mok[1], Camelia Scarlat[1], Lars Hartmann[2], Shengqiang Zhou[1], Mycola Vinnichenko[1], Michael Lorenz[3], Marius Grundmann[3], Manfred Helm[1], Mathias Schubert[4], and Heidemarie Schmidt[1] — [1]Forschungszentrum Dresden-Rossendorf, Germany — [2]Solarion AG/Photovoltaics, Germany — [3]University of Leipzig, Germany — [4]University of Nebraska-Lincoln, USA

NiO has great potential applications in gas sensors, optical fibers, solar thermal absorbers, or in non-volatile resistive random memories. In our study NiO, NiMnO, and NiMnLiO have been grown on double-side polished r-plane sapphire substrates by pulsed laser deposition. In contrast to the antiferromagnetic behaviour of bulk NiO, we probed weak ferromagnetism with a coercivity ranging between 150 and 250 Oe by means of SQUID magnetometry. We measured the complex Voigt angle using a HeCd laser, a Glan Taylor polarizer, a Hinds PEM-100 and two LockIns. The polarization state of light after transmission through a sample consisting of ca. 1 μm thick, weak ferromagnetic and diamagnetic NiO thin films on diamagnetic r-plane sapphire substrates has been modelled using the 4*4 matrix formalism in dependence of an external magnetic field applied in-plane. The modelling results revealed that for the bare diamagnetic substrate the Voigt angle depends parabolically on the external magnetic field and that the weak ferromagnetic and diamagnetic NiO thin films changed the parabolic dependence of the Voigt angle in the range of $\pm$0.1 T to a flat-top shape in agreement with the experimentally determined Voigt angle.

HL 13.9 Tue 11:45 BEY 118

Time-resolved photoluminescence on ZnO based quantum well structures — •Marko Stölzel, Alexander Müller, Jan Zippel, Gabriele Benndorf, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We have investigated the optical properties of MgZnO/ZnO QW structures using time-resolved photoluminescence (TRPL) to understand recombination in these heterostructures. The layers have been grown with a ZnO buffer layer on a-plane sapphire substrate by pulsed laser deposition.

TRPL was excited by a frequency-doubled/tripled femtosecond Ti:Sa laser tuned to resonant and nonresonant excitation. For resonant excitation the QW behaves mono-exponential. When the barrier is excited, the QW decay is superposed by a slow non-exponential decay which matches the temporal behavior of the barrier luminescence. Temperature dependent measurements show a decrease of the exciton lifetime in the QW for increasing temperatures due to nonradiative recombination.

We compare this single QW with a set of symmetric double-QWs seperated by barriers of different thicknesses. For large barriers they behave like a single QW. In the case of small barriers ($<$ 6nm) the peak of the QW luminescence shifts towards lower energies and a second non-exponential decay appears in addition to the mono-exponential decay of the QW. This is taken as an indication for the coupling.

HL 13.10 Tue 12:00 BEY 118

Optical Microtube Bottle Resonators — •Christian Strelow, Christoph M. Schultz, Hagen Rehberg, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

Using the self-rolling mechanism of strained InGaAs/GaAs bilayers freestanding microtube bridges can be fabricated acting as optical ring resonators [1]. Here, we report on the realization of novel microtube resonators with a bottlelike geometry [2]. Spatially and energetically resolved photoluminescence (PL) measurements show that the PL light of self-assembled InAs quantum dots embedded in the tube wall is confined similar to charged particles in a magnetic bottle. The measured eigenenergies and the measured axial field distributions resemble the eigenenergies and the probability densities of particles in a one dimensional potential. This can be described by a straight and intuitive model using an adiabatic separation of the circulating and the axial propagation. The dispersion of the axial mode energies follows a photonic quasi-Schrödinger equation including a quasipotential. We demonstrate that the quasipotential and, consequently, the dispersion of the axial modeenergies can be tailored precisely by simple adjustments of the microtube geometry. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508 "Quantum Materials"and GK 1286 "Functional Metal-Semiconductor Hybrid Systems".

[1] T. Kipp et al., Phys. Rev. Lett. **96**, 077403 (2006)
[2] Ch. Strelow et al., Phys. Rev. Lett. **101**, 127403 (2008)

HL 13.11 Tue 12:15 BEY 118

Cyclotron resonance of a massless quasi-particle in graphene — •Sergey A. Mikhailov — Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany

The classical motion of a massless graphene quasi-particle in a magnetic field and under a weak electromagnetic radiation with the frequency ω is considered. It is shown that, due to the non-parabolic, linear energy dispersion of the quasi-particle, it responds not only at the frequency ω but generates a broad frequency spectrum around it. The linewidth of the cyclotron resonance turns out to be very broad *even in a perfectly pure material* which allows one to explain recent experimental data [1,2]. It is concluded that the *linear response theory does not work in graphene* in finite magnetic fields and the electromagnetic response of graphene should be studied by the methods of non-linear dynamics and chaos.

[1] Z. Jiang et al, Phys. Rev. Lett. **98**, 197403 (2007)
[2] R. S. Deacon et al, Phys. Rev. B **76**, 081406 (2007).

HL 13.12 Tue 12:30 BEY 118

Determination of the stress evolution in strained semiconductor lamellae — •Matthias Grave, Sven Wildfang, Matthias Klingbeil, Andrea Stemmann, Christian Heyn, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

We investigate the influence of a controlled deformation of thin lamellae containing a quantum well by means of micro-photoluminescence experiments. Our experimental setup allows a reversible in situ deformation. The induction of stress in a lamella leads to significant changes in the obtained emission spectra of the quantum well. The removal of stress leads to a return of the spectra to the initial state. We obtained spatial images of the strain distribution in the lamella by scanning the photoluminescence spot over the sample and monitoring the locally varying energetic position of the quantum well signal. We simulated the influence of external applied stress to a quantum well potential [1] via COMSOL Multiphysics. We compared the results to our experiment and found a good agreement.

We acknowledge financial support by the Deutsche Forschungsgemeinschaft via GrK 1286 and SFB 508.

[1] C. G. Van de Walle, Phys. Rev. B 39, 1871 (1989).

HL 13.13 Tue 12:45 BEY 118

Resonant bonding in crystalline phase-change materials — •Stephan Kremers[1], Kostiantyn Shportko[1], Michael Woda[1], Dominic Lencer[1], John Robertson[2], and Matthias Wuttig[1] — [1]I. Physikalisches Institut (IA), RWTH Aachen, Deutschland — [2]Engineering Department, Cambridge University, UK

Phase-change materials are of considerable scientific and technological interest. These materials are already employed for rewriteable optical data storage and are strong contenders to replace non-volatile flash memory. They are based on a unique class of materials, which feature a special property combination. The two phases, amorphous and crystalline, show a pronounced contrast of electrical and optical properties. They are stable on a long time scale and at the same time, they can be rapidly switched on a time scale of some ten nanoseconds when heated to appropriate elevated temperatures. To improve these materials for dedicated applications, an in-depth understanding of the relevant properties is crucial. Therefore we have employed optical spectroscopy in the energy range from 0.025 to 3 eV to probe the electronic states. The optical dielectric constant is 70-200% larger for the crystalline than the amorphous phases. This difference is attributed to a significant change in bonding between the two phases. The optical dielectric constant of the amorphous phases is that expected of a covalent semiconductor, whereas that of the crystalline phases is strongly enhanced by resonant bonding effects. This finding allows us to discuss the physical origin of the unique behavior of this class of materials.

HL 14: Preparation and characterization

Time: Tuesday 9:30–10:00 Location: BEY 154

HL 14.1 Tue 9:30 BEY 154

XPS and NEXAFS Studies of Nitrogen Incorporated into ZnO During Epitaxial Film Growth — •Patrick Hoffmann and Christian Pettenkofer — Helmholtzzentrum Berlin, Albert-Einstein-Strasse 15, 12489 Berlin, Germany

The wide band gap semiconductor ZnO (gap=3.4eV) is heavily n-doped by nature. In the last years it has been shown that ZnO can be p doped by incorporation of nitrogen. Investigations have shown that nitrogen can replace oxygen (N_O, p doping), but can also be incorporated as molecular N_2 ($[N_2]_O$, n doping), and can be bonded to oxygen.

In this work, the ZnO films are grown by metal-organic MBE (MOMBE) on sapphire substrate (r plane). Nitrogen is supplied by an ion source using pure nitrogen (N_2) and nitrous oxide (N_2O). Additionally, a mass filter between the ion source and the sample can be used to reduce the influence of the neutrals (e.g. N_2), and to select certain ions and ion fractions (e.g. N_2^+, N^+).

Our investigation was focussed on the chemical nature of the incorporated nitrogen. Therefore, nitrogen molecules (N_2^+) and nitrogen radicals (N^+) have been implanted into the ZnO. The obtained films were investigated by XPS and NEXAFS. A comparison of the differently prepared films permits the assignment of photoemission peaks to chemical compounds of the nitrogen. Further investigations using N_2O as nitrogen source, showed a different composition of the chemical states of the incorporated nitrogen.

HL 14.2 Tue 9:45 BEY 154

Kelvin probe force microscopy imaging of cross-sections of Si multilayer structures — •Christine Baumgart[1], Anne-Dorothea Müller[2], Falk Müller[2], Manfred Helm[1], Andre Möller[3], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany) — [2]Anfatec Instruments AG, Melanchthonstr. 28, 08606 Oelsnitz, Germany — [3]SGS Institute Fresenius GmbH, Zur Wetterwarte 10, 01109 Dresden, Germany

Kelvin probe force microscopy (KPFM) is a standard technique for the investigation of surface potentials. We present its applicability to cross-sectionally prepared p-p^+ Si multilayer structures. The contact potential difference (CPD) image between tip and sample has been recorded by means of an Anfatec Level-AFM with a 2nd amplifier and NSC15 probes from MikroMash. Using an active mixer, the excitation amplitude of the NSC15 probes is almost independent on the working frequency. The probed CPD signal difference between the layers ranges between 60 meV and 850 meV and can be correlated to the variation of the diffusion potential in the Si multilayer structure. The p-type of majority charge carriers and the corresponding acceptor dopant profile have been pinpointed by scanning capacitance measurements. Starting from the known donor dopant concentration in the NSC15 probe, we simulated the CPD and determined the acceptor concentration in the whole p-p^+ Si multilayer structure. From the frequency dependence of the CPD we can clearly distinguish between surface and bulk effects.

HL 15: C/diamond I

Time: Tuesday 9:30–13:00 Location: POT 51

HL 15.1 Tue 9:30 POT 51

Subtractive combination modes in the intermediate frequency region of the Raman spectrum of carbon nanotubes — •Daniel Niesner, Jonas Röhrl, Ralf Graupner, and Martin Hundhausen — Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erwin-Rommel-Strasse 1, 91058 Erlangen, Germany

Raman spectroscopy has become a widely used tool for the investigation of carbon nanotubes. The Raman spectrum of carbon nanotubes is dominated by the prominent features in the high and low frequency region. Apart from those in the intermediate frequency region between 400 and 1000 cm^{-1} several less intense Raman modes are observed which result from higher order scattering. By measuring the temperature dependence of the intensity of these modes we identified subtractive combination modes which result from processes in which one phonon is created and another one is annihilated. From our measurements we estimate the frequencies of the phonons involved in the process.

HL 15.2 Tue 9:45 POT 51

Characterization of Peapods synthesis from CVD grown Carbon Nanotubes — •Christian Spudat, Carola Meyer, Karin Goss, Paul Kögerler, and Claus M. Schneider — Forschungszentrum Jülich, Institut für Festkörperforschung, Electronic Properties (IFF-9), 52425 Jülich

Because of their ballistic conductance Carbon Nanotubes (CNTs) are a promising material for spintronic devices. Their magnetic and electronic properties can be altered by functionalization. This can be done by side groups sticking on the outside or the inside of the CNTs or by filling the inner hollow of CNTs with guest molecules. When C_{60} is used as a guest molecule the resulting structure is called a "peapod". In this talk we present a characterization of the different step towards peapods synthesized from CVD grown CNTs using HRTEM measurements. But even at electron energies as low as $E = 80\ keV$ individual CNTs and especially C_{60} molecules are destroyed during electron irradiation indicated by the collapse of sidewalls and coalescence of interior C_{60}. Therefore we use Raman spectroscopy as a non-destructive method to characterize nanotubes during different steps of the peapod synthesis and correlate these measurements with our microscopic results. This comparison between spectroscopy and microscopy allows us to investigate changes in the Raman spectra during different synthesis steps and allocate them to the microscopic images to get a better understanding of different changes in the Raman spectra of CNTs during peapod synthesis.

HL 15.3 Tue 10:00 POT 51

A comparison of the temperature-dependent charge carrier dynamics in naturally grown graphite and HOPG probed by time-resolved THz spectroscopy — •Konrad von Volkmann[1], Martin Scheuch[1], Luca Perfetti[2], Tobias Kampfrath[1], Christian Frischkorn[1], and Martin Wolf[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Laboratoire des Solides Irradiés, Ecole polytechnique, 91128 Palaiseau cedex, France

The ultrafast charge carrier dynamics of naturally grown graphite and Highly Oriented Pyrolytic Graphite (HOPG) have been investigated by time-resolved THz spectroscopy in the range of 10 to 30 THz. For both samples, we present temperature dependent measurement of the scattering rates between 10 K and 300 K and give a comparison of the static dielectric function. While HOPG displays a clear rise of the scattering rate with temperature this behavior is hardly noticeable - if at all present - in the case for naturally grown graphite. A discussion of possible origins of this discrepancy will be given.

HL 15.4 Tue 10:15 POT 51

Development of ultra nanocrystalline diamond (UNCD) growth rate and surface roughness: a simulation study — •Hadwig Sternschulte[1,2] and Ulrich Stimming[1,2] — [1]nanotum, Technische Universität München, D-85748 Garching — [2]Physik Department E19, Technische Universität München, D-85748 Garching

The growth of ultra nanocrystalline diamond (UNCD) with grain sizes of 10 nm and less was simulated by a simple geometrical model: diamond spheres with a fixed diameter are statistically distributed over a flat substrate surface. The number of spheres spread by each simulation cycle are defined by the secondary nucleation rate. Before each start of the simulation, the substrate was covered with diamond seeds whose concentration is described by the primary nucleation rate. The

probability to attach a diamond sphere to the bare substrate was set to zero. Distributed diamond spheres which are in contact with yet deposited diamond or with seed nuclei are attached with a probability of one. Two variations of the model are discussed: i) the diamond spheres are attached at the first point of contact (ballistic deposition) resulting in the formation of many voids, and ii) the newly attached diamond spheres are located at the minimum possible z position (solid on solid model) minimising the formation of voids. In this work, a comparison of the early stages of the UNCD growth will be presented. Especially, the development of the minimal film thickness for a continuous closed layer in dependence of the primary nucleation rate, the development of the growth rate with time and of the surface roughness will be discussed with both models and compared with experimental data.

HL 15.5 Tue 10:30 POT 51

Raman Spectroscopy on folded Graphene — •Robert Panknin, Philipp Klar, Cinzia Casiraghi, and Stephanie Reich — Fachbereich Physik, Freie Universität, Berlin

Raman spectroscopy is a non-destructive technique able to identify graphene from graphite, to probe the doping level of graphene and determine the amount of defects [1-3].

Here we investigate the effect of the interaction between graphene layers and their stacking order by Raman spectroscopy. The stacking order affects the second order Raman spectrum, as shown in graphite (AB stacking) and turbostratic (random stacking) graphite [4].

Graphene and few graphene layers are obtained by micromechanical cleavage. Folded flakes are then selected. We show that the folding changes the electronic structure of graphene and this can be uniquely probed by Raman spectroscopy.

[1] Ferrari, A. C. et al., Phys. Rev. Lett. **97**, 187401 (2006)
[2] Pisana, S. et al., Nature Mater. **6**, 198-201 (2007)
[3] Casiraghi, C. et al., Appl. Phys. Lett. **91**, 233108 (2007)
[4] Lespade P. et al., Carbon **22**, 375 (1984)

HL 15.6 Tue 10:45 POT 51

The non-linear optical properties of single and multilayer graphene — •Rainer Stöhr[1], Roman Kolesov[1], Fedor Jelezko[1], Jens Pflaum[2], and Jörg Wrachtrup[1] — [1]3rd Physics Institute, Stuttgart University, D-70659 Stuttgart — [2]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg and Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

By optically exciting graphene flakes with pico- and femtosecond pulses of different wavelengths and with pulse power densities in the order of GW/cm^2 we can not only observe the well known G-line and D'-line but also the anti-Stokes G line. In addition, a broad background can be detected which peaks at the excitation wavelength and which extends by about 3000 wavenumbers into the red and about 2500 wavenumbers into the blue. Both, the anti-Stokes G line and the background were found to be of cubic dependence with respect to incident laser power.

We can explain the occurrence of the anti-Stokes G line as a result of a stimulated Raman process due to the pulsed laser excitation.

It will be evidenced that simple heating effects of the flakes cannot account for the broad continuum radiation; however this feature can be assigned to an electron-hole scattering mechanism which depends primarily on the number of excited charge carrier pairs.

As a possible application we show that the continuum radiation can be used to significantly improve the contrast of a confocal image compared to that mapped at the Raman lines and thereby will pave the way of a detection mechanism of high sensitivity.

HL 15.7 Tue 11:00 POT 51

Weak Localization and Transport Gap in Graphene Antidot Lattices — •Jonathan Eroms and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We have performed transport experiments in antidot lattices in single layer graphene. After mechanical exfoliation from natural graphite, suitable single layer flakes were patterned into antidot lattices using electron beam lithography and plasma etching. The lattice periods varied between 90 nm and 400 nm.

When the lattice period is reduced, the quantum Hall effect gradually disappears owing to the geometrical condition that a cyclotron orbit has to fit through the constrictions between the antidots. Samples with narrow channels between the antidots can be regarded as a network of graphene nanoribbons and correspondingly show a transport gap of a few mV at low temperatures.

In the magnetotransport curves we observe a pronounced weak localization effect. The strong visibility is due to intervalley scattering at the antidot edges. By a careful examination of the temperature and geometry dependence we conclude that our short-period antidot lattices are best described as an array of phase-coherent cavities.

HL 15.8 Tue 11:15 POT 51

Adsorbates on graphene: Impurity states and electron scattering — •Tim Wehling[1], Mikhail Katsnelson[2], and Alexander Lichtenstein[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstrasse 9, 20355 Hamburg — [2]Institute for Molecules and Materials, Radboud University of Nijmegen, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

Sources of electron scattering in graphene are being controversially debated to date. Midgap states and / or charged impurites are considered as possible factors determining graphene's electronic transport properties. We present ab-initio studies of impurites on graphene and elucidate the role of the SiO_2 substrate. We show that water and ethanol adsorbates strongly affect the coupling of graphene's electrons to impurity bands in the substrate. Covalently and ionically bond impurities on free standing graphene are considered and characteristic desorption energies are discussed. Covalently bond impurities are shown to cause midgap states which are strongly coupled to the graphene bands.

15 min. break

HL 15.9 Tue 11:45 POT 51

Graphene on various substrates — •Ulrich Stöberl, Ursula Wurstbauer, Werner Wegscheider, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

So far nearly all transport experiments on graphene have been carried out using silicon dioxide (SiO_2) as a substrate. Therefore it is interesting to study electrical transport in graphene on substrates other than SiO_2. To clarify the influence of the substrate on visibility, morphology and transport properties of graphene and few layer graphene (FLG), we study graphene on molecular beam epitaxy (MBE) grown (001)-GaAs-, manganese p-doped (001) GaAs- and InGaAs-substrates. We combine scanning electron microscopy (SEM) and atomic force microscopy (AFM) to detect, pattern, and study the morphology of the graphitic layers on different substrate materials. The MBE grown substrates can be tailored in terms of morphology, polarity as well as doping and are all equipped with back-gate electrodes. From morphology and flexibility measurements we learned that graphene is quite flexible and follows continuous textures. Thin layers of carbon have the capacity to follow the morphology of the substrate from the nm- to the μm range. Low-temperature magnetotransport measurements of graphene on these substrates reveal normal electric field dependence via back gate voltages as known from reports of transport on suspended graphene or layers on SiO_2. In further studies, the influence of the substrate on position and sharpness of the Dirac-Point, intrinsic carrier density and mobility will be investigated.

HL 15.10 Tue 12:00 POT 51

Raman Spectroscopy of Graphene and Few Layer Graphene in Different Dielectric Environments — •Philipp Klar, Robert Panknin, Cinzia Casiraghi, and Stephanie Reich — Fachbereich Physik, Freie Universität, Berlin, Germany

Graphene is the two-dimensional prototype for carbon allotropes. Recently, graphene has attracted a lot of interest because it shows ballistic transport at room temperature along with chemical and mechanical stability [1]. Raman spectroscopy is a powerful tool to identify graphene and to probe its doping level [2-4]. It has been shown that charged-impurities can strongly affect the electronic properties of graphene, in particular they can limit its mobility [5]. Here we use Raman spectroscopy in order to investigate the effect of different dielectric environments and substrates on the electronic structure of graphene and few layer graphene. Graphene and graphene layers have been obtained by micro mechanical cleavage of graphite and placed on different substrates (silicon covered with 300 nm silicon oxide, glass and calcium fluoride) and in different media with high dielectric constant.

[1] A.K. Geim et al., Nat. Mater. **6**, 183 (2007)
[2] A.C. Ferrari et al., PRL **97**, 187401 (2006)

[3] S. Pisana et al., Nat. Mater. **6**, 198 (2007)
[4] C. Casiraghi et al., APL **91**, 233108 (2007)
[5] J.H. Chen et al., Nat. Phys. **4**, 377 (2008)

HL 15.11 Tue 12:15 POT 51

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

During the past decades, graphite-related materials of nanoscale, such as nanotubes, have been subject to scientific research. Their remarkable optical and electronical properties make them promising for use in future nanotechnology. Recently, another type of nanoscale materials, narrow strips of graphene (single layer graphite), have been fabricated and investigated regarding their electronical and transport properties. Those graphene nanoribbons correspond to "unrolled" carbon nanotubes, i.e. the model system used in zone-folding calculations of carbon nanotube properties. We use DFT calculations to obtain the bandstructures and phonon dispersions of nanoribbons of various shapes and widths. Group theory was applied to classify the resulting phonon modes. We show that most of the phonon modes can be interpreted as "overtones" of a few "fundamental modes" and that these overtones can be understood from zone folding the phonon dispersions of graphene. Shape and size dependences are found. Similarities between nanoribbons and carbon nanotubes will be discussed.

HL 15.12 Tue 12:30 POT 51

Bound states and magnetic field-induced valley splitting in gate-tunable graphene quantum dots — •Patrik Recher[1,2], Johan Nilsson[1], Guido Burkard[3], and Björn Trauzettel[2] — [1]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands — [2]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [3]Department of Physics, University of Konstanz, 78457 Konstanz, Germany

The magnetic field dependence of energy levels in gapped single- and bilayer graphene quantum dots (QDs) defined by electrostatic gates is studied analytically in terms of the Dirac equation. Due to the absence of sharp edges in these types of QDs, the valley degree of freedom is a good quantum number. We show that its degeneracy is efficiently and controllably broken by a magnetic field applied perpendicular to the graphene plane. This opens up a feasible route to create well-defined and well controlled spin- and valley-qubits in graphene QDs. We also point out the similarities and differences in the spectrum between single- and bilayer graphene quantum dots. Striking in the case of bilayer graphene is the anomalous bulk Landau level (LL) that crosses the gap which results in crossings of QD states with this bulk LL at large magnetic fields in stark contrast to the single-layer case where this LL is absent. We discuss the applicability of such QDs to control and measure the valley isospin and their potential use for hosting and controlling spin qubits.

HL 15.13 Tue 12:45 POT 51

Graphene-based nanoelectronics — •Soeren Neubeck, Frank Freitag, L. A. Ponomarenko, Rui Yang, A. K. Geim, and K. S. Novoselov — Department of Physics, University of Manchester, Manchester M13 9PL, UK

Graphene, a monolayer of Carbon atoms arranged in a honeycomb-lattice, holds strong promise for microelectronic applications in the post-Silicon age. Still, a current technological problem is, that graphene remains conducting even in the limit of virtually zero carrier concentration.

Recent theoretical and experimental work has shown, that it is possible to introduce an energy gap in graphene by confining its geometrical dimensions.

Here, we use an atomic force microscope (AFM) to manipulate graphene films on a nanoscopic length scale. By means of local anodic oxidation with an AFM-tip we are able to structure isolating trenches into single-layer graphene flakes, down to a trench size of less than 30nm in width. Using this technique, we demonstrate the fabrication of a single-layer graphene quantum dot. The device consists of a nanometre-sized graphene island, that is coupled to source and drain electrodes via two narrow constrictions. Low-temperature transport measurements of this device reveal Coulomb blockade, and Coulomb diamonds, characteristic of quantum dots, have been measured. A charging energy of the dot of 10meV could be extracted, which corresponds to the geometric dimensions of the dot structure formed.

HL 16: III-V semiconductors II

Time: Tuesday 9:30–12:00 Location: POT 151

HL 16.1 Tue 9:30 POT 151

Temperaturverhalten des In(Cd)-Defekt-Komplexes in AlN — •Jens Niederhausen[1], Reiner Vianden[1] und Joao Guilherme Martins Correia[2] — [1]HISKP, Universität Bonn — [2]ISOLDE Collaboration, CERN

Implantiert man ^{111}In in eine AlN-Schicht auf Saphir-Substrat und heilt dieses bei 1273 K aus, erwartet man den substitionellen Einbau der Sonde auf einem ungestörten Al-Gitterplatz. Mit der Methode der gestörten Winkelkorrelation (PAC) lässt sich jedoch noch eine weitere Situation nachweisen: ungefähr die Hälfte der Sonden befinden sich in einer Umgebung die einem In-Defekt-Komplex zuzuordnen ist. Diese Konfiguration konnte auch bei bulk-Proben nachgewiesen werden.

Zur Untersuchung seiner Dynamik wurden detaillierte Messungen über ausgewählte Temperaturbereiche mit Proben unterschiedlicher Schichtdicke durchgeführt. Es zeigte sich, dass die Dämpfung des Defektanteils in einem Bereich um 500 K minimal ist, wobei bei größerer Dicke das Plateau breiter ist. Bei Temperaturen bis zu einem Minimum von 4 K wurde keine Abnahme der Dämpfung festgestellt.

Bei Implantationen mit ^{111m}Cd unter ähnlichen Bedingungen konnte die substitionelle Konfiguration (mit deutlich höherem Anteil) ebenfalls beobachtet werden. Dies zeigt, dass sich ein großer Teil der In- und Cd-Atome in gleicher Weise in das Wirtsgitter integrieren, was den Weg für Beta-Gamma-Messungen frei macht, mit Hilfe derer sich das Vorzeichen des EFG bestimmen lässt. Dies ist für theoretische Rechnungen wichtig. Der Cd-Defekt-Komplex ist weniger ausgeprägt als der In-Defekt-Komplex, muss jedoch noch genauer vermessen werden.

HL 16.2 Tue 9:45 POT 151

Temperature and Time Resolved Measurements of Nitride-based Quantumwell Structures on Modified GaN Substrates — •Miran Alic[1], Christian Nenstiel[1], Ronny Kirste[1], Markus R.Wagner[1], Axel Hoffmann[1], Tadek Suski[2], Martin Albrecht[3], and Tobias Schulz[3] — [1]Technische Universität zu Berlin Institut für Festkörperphysik — [2]Institute of High Pressure Physics "Unipress" Warsaw — [3]Leibniz-Institut für Kristallzüchtung Berlin

Over the last few years InGaN-based semiconductors attracted much attention, especially in the domain of light emitting device applications. We report on temperature-dependent time-integrated and time-resolved photoluminescence studies of InGaN/GaN multi quantum wells (MQWs) grown by hydride vapor phase epitaxy. MQW structures composed of 3 InGaN QWs were grown on a GaN substrate with an intended variation of the misorientation angle with respect to the c-axis, as well as a different degree of indium content. The samples exhibit a broad peak around a central wavelength of 2.92eV (5K). Temperature resolved PL measurements for this peak display a redshift without a characteristic "S-shape" behavior in the range of 0 - 300K. A "S-shape" would indicate an energy transfer mechanism from lower energy levels to higher energy states through the energy barrier. However, the absence of this behavior suggests the barrier to be higher than 27meV. Time resolved measurements at different energies between 2.88eV and 3.02eV revealed a constantly decreasing carrier lifetime. We assume that this behavior is attributed to deep localized quantum dot states.

HL 16.3 Tue 10:00 POT 151

Stain dependent optical properties of AlN measured by means of VUV-spectroscopic Ellipsometry — •Christoph Werner[1], Marcus Röppischer[1], Christoph Cobet[1], Carsten

Buchheim[2], Rüdiger Goldhahn[2], Frank Brunner[3], and Nobert Esser[1] — [1]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin — [2]TU - Ilmenau, Institut für Physik, Weimarer Straße 32 (Faradaybau), 98693 Ilmenau — [3]Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin

The growth of hexagonal group-III nitrides on foreign substrates causes in-plane strain due to the different thermal expansion coefficients of substrate and layer. Optical properties of semiconductors are strongly influenced by internal strain and electric fields. These effects were investigated in the dielectric function of aluminium nitride samples grown on different substrates (sapphire and silicon carbide) in the photon energy range from 4 to 9.5eV. The region around the fundamental band gap at 6 eV is of particular interest for the strain analysis. On the base of excitonic transitions, we have studied the crystal field and strain dependent ordering of the valence bands and oscillator strength at the Γ-point. Further more, various strain contribution in the temperature related shift of excitonic transitions are also been observed. Our measurements will be discussed in comparison to calculations within the kp-theory, XRD measurements and former published data.

HL 16.4 Tue 10:15 POT 151

High Excitation Photoluminescence studies on epitaxially grown AlN layers — •Robert Anton Richard Leute[1], Martin Feneberg[1], Klaus Thonke[1], Rolf Sauer[1], Sarad Bahadur Thapa[2], Ferdinand Scholz[2], Yoshitaka Taniyasu[3], and Makoto Kasu[3] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm, Germany — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm, Germany — [3]NTT Basic Research Laboratories, NTT Corporation, 3-1 Morinosato-Wakiyama, Atsugi, 243-0198, Japan

Nominally undoped high quality AlN layers are investigated by lowtemperature photoluminescence (PL) spectroscopy, using the focused beam of an ArF Excimer Laser (193 nm) for excitation. For samples grown by MOVPE on different substrates, namely sapphire and SiC, different types of spectra are found. Comparison with low excitation photoluminescence and cathodoluminescence shows new contributions increasing with superlinear response to the excitation intensity. The observed contributions are discussed in terms of radiative decay of biexcitons, exciton-exciton scattering (P band), and electron hole plasma.

HL 16.5 Tue 10:30 POT 151

Optical characterisation of AlGaN/GaN MQW — •Christian Nenstiel[1], Ronny Kirste[1], Viola Küller[2], Frank Brunner[2], Arne Knauer[2], Markus Weyers[2], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH) in Berlin, Germany

The direct transition energy of the ternary semiconductor AlGaN system can be adjusted between 6.2 eV (AlN) and 3.4 eV (GaN). The preferences of AlGaN/GaN multiple quantum wells (MQW) are the large bandgap, large longitudinal phonon energy, good carrier confinement and ultra fast carrier and intersubband relaxation. These properties make AlGaN/GaN and AlGaN/AlN MQWs a possible material for optoelectronic devices like ultra violet light emitting diodes, laser diodes or photodetectors. AlGaN MQWs were grown on [0001]-oriented sapphire substrates (c-plane) by metal organic vapour phase epitaxy at high temperatures around 1500°C. In this contribution we analyse $Al_{28}Ga_{72}N$:nid and $Al_{28}Ga_{72}N$:Si samples with super lattice structures consisting of 10 - 80 layers with 1 - 11nm thickness. The samples were investigated by Raman spectroscopy and temperature-dependent photoluminescence. The Raman spectra show a shift of the strain-sensitive E_2 (high) mode, which can be attributed to the doping of the sample. The temperature-dependent photoluminescence spectra demonstrate different exciton energies and defect luminescences of the samples. Thereby the strength of the defect luminescence depends on the structure and doping of the samples.

15 min. break

HL 16.6 Tue 11:00 POT 151

Electrical conductivity in InN nanowires — •Florian Werner[1], Friederich Limbach[2], Michael Carsten[1], Christian Denker[1], Joerg Malindretos[1], and Angela Rizzi[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich GmbH, Germany

Electrical conductance through InN nanowires strongly depends on their geometry and on the carrier distribution inside them. By measuring wires of different radii and lengths in a four-point probe geometry, quadratic contributions from the bulk and linear contributions from the surface can be distinguished. The linear contribution is attributed to a high density electron accumulation layer which had previously been confirmed by Raman and photoluminescence spectroscopy. The electron accumulation layer is demonstrated to dominate the conductance through wires with less than 55 nm in diameter, although the influence of the bulk conductance cannot be neglected even for small wires. Evidence of a thin surface layer of indium oxide is provided by X-ray core level photoemission spectroscopy. Therefore the electron accumulation layer is expected to form at the InN/In_2O_3 interface. The surface oxide forms a tunneling barrier between the contacts and the electron accumulation layer and therefore has a strong impact on the contact resistance.

HL 16.7 Tue 11:15 POT 151

Optimization of AlN-based seeding and superlattice buffer layers to grow high-quality AlxGa1-xN with Al content up to x=0.66 on Si (111) substrates — •P. Saengkaew, A. Dadgar, J. Blaesing, B. Bastek, F. Bertram, T. Hempel, P. Veit, J. Christen, and A. Krost — AHE/IEP/FNW,Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg

AlxGa1-xN is one of the most attractive materials to develop UV optoelectronic devices due to its direct wide-bandgap energy from 3.4 to 6.2 eV. Here we present MOVPE-grown high-quality AlxGa1-xN layers with Al content up to x=0.66 on Si (111) substrates. With optimized AlN-based seeding and superlattice buffer, crack-free layers with smooth surface and low defect density were obtained. Initially, the impact of the AlN seeding layer was investigated by varying growth parameters as growth temperature, time, pressure and V/III ratio. To optimize high- and low-temperature AlN-based superlattices, the growth temperature, growth time, and number of SL periods were varied. These optimized AlN seeding and SL layers are efficient in reducing the dislocation density and in-plane strain. By HR-XRD, the crystalline quality of AlxGa1-xN was characterized. The finite thickness fringes of AlxGa1-xN have been observed in theta/2theta-scans of the (0002) reflections showing their excellent crystalline quality and abrupt smooth surface. AFM and FE-SEM measurements were used to observe the surface morphology and TEM measurements to determine the dislocation behaviour. The optical properties were investigated by CL measurements.

HL 16.8 Tue 11:30 POT 151

Pulsed Growth of AlN by MOVPE — •Hanno Kröncke, Stephan Figge, and Detlef Hommel — Institute for Solid State Physics (IFP), University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen

The growth of AlN is of interest because of it's special features like high thermal conductivity and large bandgap. These provide applications like high power- or opto-electronic devices in the UV. However the production of high quality AlN templates is challenging because of the low diffusivity of Al, which inhibits lateral overgrowth and demands high growth temperatures over $1300\,°C$ to decrease the defect density. A second approach is the pulsed or flow modulation MOVPE growth [1], where an alternating supply of the precursors TMA and NH_3 increases the surface mobility of the atoms. This allows for growing AlN even at temperatures of $800\,°C$ [2].

In our study we grew thick AlN layers on c-plane sapphire in a closed coupled showerhead MOVPE at temperatures of $1000\,°C$. We investigated the influence of nitridation, different seed layers and length of precursor pulses on the surface roughness, cracking and crystal quality by AFM, SEM and XRD. Especially a nitridation and low temperature AlN buffer lead to a rough surface, so that we developed a process starting with pure TMA supply. By this method we achieved more than $1\,\mu m$ thick AlN layers with an RMS roughness below 1 nm, which show no cracks and high crystal quality.

[1] M. Asif Kahn, Appl. Phys Lett. **61** (1992), 2539
[2] Jung-Seung Yang, Jap. J. App. Phys. **46**, 38, (2007), L927

HL 16.9 Tue 11:45 POT 151

Pseudosymmetrische (11-20)-Reflexe bei a-planarem GaN auf r-planarem Saphir — •Matthias Wieneke, Jürgen Bläsing, Armin Dadgar und Alois Krost — Otto-von-Guericke-Universität

Magdeburg, Postfach 4120, 39016 Magdeburg

Unter der Variation von Wachstumsbedingungen, z.B. des V-III-Verhältnisses oder der Wachstumstemperatur wurden unterschiedliche Serien von a-planaren GaN-Schichten mittels metallorganischer Gasphasenepitaxie auf r-planarem Saphir gewachsen. Weiterhin wurde der Einfluss von Zwischenschichten, wie z.B. die Dicke oder die vertikale Position von SiN_x-Nanomasken auf die Mikrostruktur der GaN-Schicht analysiert. Die Untersuchung der mikrostrukturellen Eigenschaften der gewachsenen Schichten erfolgte mittels hochauflösender Röntgenbeugung am symmetrischen (11-20)- und den in der Wachstumsebene liegenden (10-10)- und (0002)-Reflexen. Dabei zeigte diese und die Abhängigkeit von einigen Wachstumsparametern eine eindeutige Anisotropie in Bezug auf die m- und c-Richtung in der Wachstumsebene. So wiesen die ω-Scans des symmetrischen (11-20)-Reflexes eine deutliche Abhängigkeit von der Einfallsrichtung der Röntgenstrahlung bezüglich des Azimutwinkels auf. Genauere Untersuchungen mittels (11-20)-Polfiguren ergaben für einige Wachtumsbedingungen zwei annähernd symmetrische Texturkomponenten, die um wenige Grad zu einander und zur Oberflächennormalen verkippt sind. Der Einfluss beider Komponenten auf die Messungen unter Standardeinstellungen und Annahme eines symmetrischen Reflexes wird diskutiert.

HL 17: Quantum wires: Optical and transport properties

Time: Tuesday 10:00–13:00 Location: BEY 154

HL 17.1 Tue 10:00 BEY 154

Growth and Optical Properties of GaN Nanodisks in GaN/AlGaN Nanowires — •Florian Furtmayr[1], Christoph Stark[1], Martin Stutzmann[1], Sònia Conesa-Boj[2], Francesca Peiro[2], Jordi Arbiol[2], Joan Ramon Morante[2], and Martin Eickhoff[1,3] — [1]Walter Schottky Institut, Technische Universität München, 85748 Garching — [2]EME/CeRMAE/IN2UB, Dept. d'Electronica, Universitat de Barcelona, E-08028 Barcelona, Spain — [3]I. Physikalisches Institut, Justus-Liebig-Universität, 35392 Giessen

We report on the self-assembled growth of GaN/AlGaN and GaN/AlN nanowires with embedded GaN nanodisks (NDs) by plasma assisted molecular beam epitaxy (PAMBE) on Si(111). GaN multi quantum wells with different thicknesses were formed between barriers of AlN or $Al_xGa_{x-1}N$ in different compositions. The samples were analyzed by high resolution transmission electron microscopy (HRTEM) and photoluminescence (PL). The PL emission energy of the NDs at 3.53 eV to 3.70 eV can be controlled by the variation of the Al-content in the barrier. Its intensity exceeds that of the GaN base of the NW (3.40 eV - 3.47 eV) by about a factor of ten. The FWHM increases with the Al-content and varies between 21 meV and 70 meV at 4K. Due to the presence of polarization fields, the emission energies show a red shift, which increases with increasing well-thickness. HRTEM analysis reveals well defined flat GaN NDs with sharp interfaces. Whereas the radial growth rate of the GaN region is almost zero, it is 11% of the axial growth for the AlN region, leading to the formation of an AlN shell around the NW.

HL 17.2 Tue 10:15 BEY 154

Optical Studies on Single GaN Nanowires — •Carsten Pfüller, Oliver Brandt, Caroline Chèze, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik Berlin, Germany

The self-organized formation of GaN nanowires (NWs) offers the unique possibility to fabricate strain- and defect-free GaN crystals on foreign substrates like Si. Here, we present a detailed investigation of the photoluminescence (PL) of GaN NWs grown directly on Si(111) by plasma-assisted molecular beam epitaxy.

The temperature and power-dependent PL spectra of the NW ensemble are compared with those of a reference layer grown by hydride vapor phase epitaxy. The spectral position of the dominant donor-bound exciton emission at 3.472 eV demonstrates the NWs to be free of strain. The evolution of the PL intensity with temperature or excitation intensity for the NWs is clearly different from that of the reference layer, indicating the participation of different nonradiative recombination channels possibly related to the free surface.

For a more detailed understanding, we have examined the PL of individual NWs which have been dispersed on a Si(111) substrate. The spectra of single NWs vary widely from wire to wire in intensity, peak energy and peak width. The frequently observed peak broadening compared to the ensemble reveals that individual NWs may be severely affected by strain induced by the interaction with the underlying substrate.

HL 17.3 Tue 10:30 BEY 154

Laser oscillation thresholds for ZnO nanowires — Mariano A. Zimmler[1], Jiming Bao[1], Kristen A. Sunter[1], Federico Capasso[1], Sven Müller[2], and •Carsten Ronning[3] — [1]School of Engineering and Applied Science, Harvard University — [2]II. Institute of Physics, University of Göttingen — [3]Institute of Solid State Physics, University of Jena

In our work, we will present direct evidence of the transition from ASE to laser action in optically pumped ZnO nanowires at room temperature. The optical power evolves from a superlinear to a linear regime as the pump power exceeds threshold, concomitant with a transition to directional emission along the nanowire and the emergence of well defined cavity Fabry-Perot modes around a wavelength of 385 nm. The laser oscillation threshold is found to be strongly dependent on the nanowire diameter, with no laser oscillation observed for diameters and lengths smaller than ˜150 nm and ˜3 microns, respectively. Furthermore, we will present an alternative *head on* detection geometry for measuring the output power of a single nanowire laser, which provides a useful benchmark for the future development of these nanoscale devices.

HL 17.4 Tue 10:45 BEY 154

Edge-disorder-induced conduction gap in bilayer graphene nanoribbons — •Hengyi Xu[1], Thomas Heinzel[1], and Igor Zozoulenko[2] — [1]Heinrich-Heine Universität, Düsseldorf, Germany — [2]Department of Science and Technology, Linköping University, Sweden

Graphene bilayers are interesting because they show some anomalous properties compared with single layers. We study the energy spectra of the Bernal-type bilayers with zigzag and armchair edges within the tight-binding model. Furthermore, a recursive Green's function (RGF) method for bilayer graphene nanoribbons (GNRs), which provides an efficient way to account for the effects due to the bilayer leads, is developed based on our implementation in the monolayer case. By means of the newly-developed RGF technique, the magnetoelectronic properties are examined. An important work in graphene engineering is to tune the electronic properties of GNRs by introducing an energy gap. There has been many attempts to induce an energy gap in monolayer graphene by various ways, in particular, it is shown that a modest edge disorder is sufficient to induce the conduction energy gap in the otherwise metallic graphene nanoribbons. We further study the electronic transport behaviors of bilayer GNRs with edge imperfections and discuss the possibilities of opening energy gaps by the edge disorder in bilayers. The conductance of realistic edge-disordered bilayer GNRs is calculated numerically and dependency of the gap width on the strength of the disorder is investigated systematically.

15 min. break

HL 17.5 Tue 11:15 BEY 154

Modelling Quantum Transport Through Nano-Structures by Finite Elements: Getting the Boundaries Right — •Stephan Kramer, Oliver Bendix, Kai Bröking, Ragnar Fleischmann, and Theo Geisel — Max-Planck-Institut für Dynamik und Selbstorganisation, 37073 Göttingen

For simulating the electronic transport through a ballistic semiconductor device quantum mechanically, one has to solve the stationary Schrödinger equation in a complex geometry with intricate boundary conditions. We are especially interested in the transmission properties of scattering states, e.g. as in [1]. For their computation we employ higher order finite element methods which make it possible to properly incorporate curvilinear boundaries and spatial adaptivity.

Scattering experiments in semiconductor devices can be described by

a finite domain containing scatterers and leads of semi-infinite length providing a source for incoming plane waves and a sink for outgoing scattered waves. As FEMs are capable only of describing problems on a finite domain, the leads must be cut off after some finite distance. Because of this, their infinite extent has to be modelled by suitable boundary conditions. For semi-infinite leads, these are provided by the *Sommerfeld radiation condition*.

We apply our approach to electron transport in the presence of static magnetic fields and show how to set up the correct boundary conditions for different complex geometries.

[1] Nature Physics 3, 464 - 468 (2007)

HL 17.6 Tue 11:30 BEY 154

Evanescent channels and scattering in cylindrical nanowire heterostructures — •Paul Nicolae Racec[1,2], Elena Roxana Racec[3,4], and Hagen Neidhardt[1] — [1]Weierstraß-Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39 10117 Berlin, Germany — [2]National Institute of Materials Physics, PO Box MG-7,077125 Bucharest Magurele, Romania — [3]Institut für Physik, Technische Universität Cottbus, Postfach 101344, 03013 Cottbus, Germany — [4]Faculty of Physics, University of Bucharest, PO Box MG-11,077125 Bucharest Magurele, Romania

We investigate the scattering phenomena produced by a general finite range non-separable potential in a multi-channel two-probe cylindrical nanowire heterostructure. The multi-channel current scattering matrix is efficiently computed using the R-matrix formalism extended for cylindrical coordinates. Considering the contribution of the evanescent channels to the scattering matrix, we were able to put in evidence the specific dips in the tunneling probability in the case of an attractive scattering potential. The cylindrical symmetry cancels the "selection rules"known for Cartesian coordinates. Detailed maps of the localization probability density sustain the physical interpretation of the resonances. We present numerical results for a quantum dot embedded into the nano-cylinder and a double barrier along the nano-cylinder.

HL 17.7 Tue 11:45 BEY 154

Magnetic barriers in quantum wires — •Mihai Cerchez[1], Hengyi Xu[1], Alexey Tarasov[1], Thomas Heinzel[1], Stefan Hugger[2], Igor Zozoulenko[3], Dirk Reuter[4], and Andreas Wieck[4] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Fraunhofer Institut für Angewandte Festkörperphysik, Freiburg, Germany — [3]Linköping University, Norrköping, Sweden — [4]Ruhr-Universität Bochum, Bochum, Germany

A strongly localized, spatially varying magnetic field (magnetic barrier, MB) is created by the stray field at the edge of a magnetised ferromagnetic material aligned across a quantum wire (QWR). The quantum wire is produced by local anodic oxidation of a GaAs/AlGaAs heterostructure with a two-dimensional electron gas below the surface. We find pronounced and reproducible conductance fluctuations of the QWR as a function of the MB height tuned by the field applied, for various values of the electronic wire width tuned by the in-plane gates. The conductance fluctuations are strongly temperature dependent but visible up to 10 K. The findings differ both from what is expected from larger size samples and from homogenous magnetic fields. Our analysis supported by simulations using the recursive Green's functions technique shows that the observed effects are caused by the coherent part of the electron wave function which, by scattering in the impurity potential landscape creates an interference pattern depending on the position of the scatterers and the height of the MB. The MB acts like a repulsive scatterer which can be tuned to form a resonator inside the QWR.

15 min. break

HL 17.8 Tue 12:15 BEY 154

Phase-coherent transport in InN nanowires: Analysis by four-terminal measurements — •Robert Frielinghaus[1,2], Sergio Estévez Hernández[1,2], Raffaella Calarco[1,2], Stefan Trellenkamp[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology

Bottom-up assembled nanowires receive an increasing interest as possible candidates for future semiconductor nanoscale devices. Especially InN nanowires are interesting due to their surface accumulation layer which inhibits Schottky barriers [1]. Yet, contact resistances prove to be spread in a wide range as can be shown in multi-terminal measurements.

At low temperatures phase-coherence leads to universal conductance fluctuations in the magnetoconductance. While they are fully symmetric in a two-terminal setup this feature is gradually lost when turning to three- or four-terminal measurements. Using the latter configuration the temperature dependence of the electron phase-coherence in the nanowire itself can be determined, i.e. without any contact resistance contribution.

[1] Th. Richter et al.: Nano Letters **8**, 2834 (2008)

HL 17.9 Tue 12:30 BEY 154

Non-local Aharonov-Bohm conductance oscillations in an asymmetric ballistic quantum ring — •S. S. Buchholz[1], S. F. Fischer[1], U. Kunze[1], D. Reuter[2], and A. D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

We investigate ballistic transport and quantum interference in a nanoscale quantum wire loop fabricated as a GaAs/AlGaAs field-effect heterostructure [1]. Our device consists of two equally wide electron waveguides, a bent and a straight one, which orthogonally intersect twice forming an asymmetric ring like structure. Four-terminal measurements of current and voltage characteristics as a function of top gate voltages show negative remote bend resistance as a clear signature of ballistic transport. In perpendicular magnetic fields phase-coherent transport leads to Aharonov-Bohm (AB) conductance oscillations which show equal amplitudes in the local and the non-local measurement at a temperature of 1.5 K and above. We attribute this novel observation to the symmetry of the orthogonal cross junctions connecting the four quantum wire leads with the asymmetric quantum wire ring. [1] S.S. Buchholz, S.F. Fischer, U. Kunze, D. Reuter, A.D. Wieck, arXiv:0811.3150 (2008).

HL 17.10 Tue 12:45 BEY 154

Classical ballistic transport in a triangular shaped cavity — •Martin Richter and Roland Ketzmerick — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Recent magneto-resistance measurements on semiconductor heterostructures with a triangular shaped gate revealed an unexpected splitting of a commensurability peak [D. Maryenko et al., unpublished]. We explain this splitting in the context of classical ballistic transport. The importance of the phase-space structure, width of the openings, and softness of the potential is stressed.

HL 18: Impurities/amorphous semiconductors

Time: Tuesday 12:00–13:00 Location: POT 151

HL 18.1 Tue 12:00 POT 151

Pulsed electrically detected magnetic resonance study of spin relaxation and recombination in thin-film silicon solar cells — •Matthias Fehr[1], Jan Behrends[1], Alexander Schnegg[1], Klaus Lips[1], Bernd Rech[1], Oleksandr Astakhov[2], and Friedhelm Finger[2] — [1]Helmholtz-Zentrum Berlin, Silizium Photovoltaik, 12489 Berlin, Germany — [2]Forschungszentrum Jülich, IEF-5 Photovoltaik, 52425 Jülich, Germany

We have investigated the influence of paramagnetic states on electronic transport processes in thin-film pin solar cells with pulsed Electrically Detected Magnetic Resonance (pEDMR) at X-Band frequency and low temperature (10 K). The solar cells consist of an intrinsic microcrystalline absorber layer and amorphous or microcrystalline n/p contacting layers. In addition to the identification of the participating paramagnetic centres by their g-factors, pEDMR can be used to study the dynamics of the electronic processes in detail. We present measurements of modified EPR pulse sequences in order to identify the

dominating relaxation mechanisms within correlated solid-state spin-pairs. By this technique a monitoring of the spin and charge motion is possible. In the outlook we present measurements of the electron spin echo envelope and critically discuss modulations in terms of dipolar coupling within the spin-pairs or hyperfine couplings to surrounding nuclei.

HL 18.2 Tue 12:15 POT 151

First-principles calculations on self-diffusion in indium oxide — •Péter Ágoston[1], Paul Erhart[2], Andreas Klein[1], and Karsten Albe[1] — [1]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23 64287 Darmstadt — [2]Lawrence Livermore National Lab, California, USA

Indium oxide/ITO (indium tin oxide) is one of the most commonly used TCO materials (transparent conducting oxide). Although it is well known that point defects govern the materials' functional properties, so far very little is known about their thermodynamic and kinetic properties. Defect concentrations sensitively depend on temperature, oxygen processing gas composition (oxygen partial pressure) and impurity level like the commonly used tin substitutional doping. Thus, different deposition techniques and temperature processing steps directly affect the defect equilibria and consequently the materials properties, which makes a more detailed understanding highly desirable. Therefore, we have conducted extensive calculations based on density functional theory in order to calculate the formation and migration energies of the dominant intrinsic point defects. Additionally, we have derived the entropy contributions to defect formation and migration in a rigorous way. Using this input data we are able to calculate the Fermi energy in the material as a function of temperature, oxygen partial pressure and doping. The defect concentrations at the calculated Fermi energy are then used to predict the diffusivity at different environmental conditions.

HL 18.3 Tue 12:30 POT 151

Structural modification of swift heavy ion irradiated amorphous Ge layers — •Werner Wesch[1], Claudia S. Schnohr[2], Patrick Kluth[2], Zohair S. Hussain[2], Leandro L. Araujo[2], R. Giulian[2], David J. Sprouster[2], Aydan P. Byrne[2], and Mark C. Ridgway[2] — [1]Institute of Solid State Physics, Friedrich Schiller University Jena — [2]Department of Electronic Materials Engineering, Australian National University, Canberra

To study the effect of high electronic energy deposition on amorphous Ge layers, crystalline Ge wafers were amorphised to a thickness of 3.2μm by multiple Ge ion implantation at 80 K. A Au grid was then evaporated on the sample surface which was partly masked during the irradiation. The samples were then irradiated with various fluences of 185 MeV Au ions at room temperature and an angle of incidence of 45° with respect to the surface normal. The irradiated samples were analysed by optical microscopy, surface profilometry and scanning electron microscopy (SEM). Subsequent to irradiation, a change in sample surface colour from light brown to black with increasing ion fluence was readily apparent. The change of colour was accompanied with swelling of the amorphous layer, the latter also increasing with ion fluence. The swelling was a consequence of void formation within the amorphous layer, which transformed into a sponge-like porous structure at higher ion fluences. Additionally, as in a-Si, a surface shift in the irradiated region along the projection of the ion beam to the sample surface increasing with the ion fluence was observed demonstrating liquid polymorphism is common to these two semiconductors.

HL 18.4 Tue 12:45 POT 151

Ab-initio calculations of hyperfine parameters for various Si-dangling bond models — •Gernot Pfanner, Christoph Freysoldt, and Jörg Neugebauer — Max-Planck Institute for Iron Research, Computational Materials Design, Max-Planck-Strasse 1, D-40237 Duesseldorf

Thin-film silicon solar cells are considered as low-cost successors of bulk crystalline Si solar cells. However, at the moment, their efficiency is severely limited by light-induced defects. The nature of the so-called 'Staebler-Wronski' effect, i.e. light-induced metastable changes in the properties of hydrogenated amorphous silicon, is not yet understood and remains challenging. Electron-paramagnetic resonance (EPR) is a key technique to improve our knowledge about the local atomic structure and, consequently, about the processes causing the long-term drop in the conversion rate and thus in the device performance. However, the interpretation of the EPR spectrum requires theoretical insights in the influence of the microscopic structure on the hyperfine parameters, which we provide by first-principle calculations. For this purpose, we employ density-functional theory and a pseudopotential approach, in which the all-electron wave function is reconstructed from a combination of free-atom and pseudo-wavefunctions. Within this approach, we consider various dangling-bond models and study the sensitivity of the hyperfine parameters to structural features in the vicinity of the defect. A comparison with available experimental data allows us to identify realistic dangling bond models.

HL 19: Theory of electronic structure

Time: Tuesday 12:30–13:00 Location: BEY 81

HL 19.1 Tue 12:30 BEY 81

Phonons in strongly correlated materials from Hubbard-corrected density-functional-perturbation theory — Andrea Floris[1,2], Matteo Cococcioni[3], •Eberhard K. U. Gross[1,2], and Stefano de Gironcoli[4] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany — [2]ETSF, European Theoretical Spectroscopy Facility — [3]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis MN 55455B — [4]Scuola Internazionale Superiore di Studi Avanzati (SISSA), I-34014 Trieste, Italy and INFM DEMOCRITOS National Simulation Center, I-34014 Trieste, Italy

In this contribution, the density functional perturbation theory is extended to compute the vibrational frequencies of strongly correlated systems whose ground state electronic properties are well reproduced within the DFT+U approach. The formalism, extended to both norm-conserving and Vanderbilt ultrasoft pseudo-potentials, allows to compute phonon frequencies with a computational cost that is independent from the q-vector, thus permitting the efficient exploration of the entire Brillouin zone. The main features of the implementation [1] , as the correction to the perturbed self-consistent potential and to the dynamical matrix due to the inclusion of the Hubbard U term, will be discussed along with several applications.

1. QUANTUM ESPRESSO code: http://www.quantum-espresso.org/

HL 19.2 Tue 12:45 BEY 81

Pseudospin Resonance in two Coaxial Tubes — •Benedikt Scharf[1], Jaroslav Fabian[2], and Alex Matos-Abiague[3] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Deutschland — [2]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Deutschland — [3]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Deutschland

In a 2DEG confined to two coaxial tubes the 'tube degree of freedom' can be described in terms of pseudospin-1/2 dynamics. The presence of tunneling between the two tubes leads to a collective oscillation known as pseudospin resonance. We employ perturbation theory to examine the dependence of the dispersion of this mode on a coaxial magnetic field for the case of small intertube distances. Coulomb interactions lead to a shift in the resonance frequency. The presence of the coaxial magnetic field gives rise to pronounced peaks in the shift of the resonance frequency. For large magnetic fields this shift vanishes due to the effects of Zeeman splitting.

HL 20: Invited Talk Yakovlev

Time: Tuesday 14:00–14:45 Location: HSZ 01

Invited Talk HL 20.1 Tue 14:00 HSZ 01

Electron spin coherence in singly charged quantum dots — •Dmitri R. Yakovlev — Experimentelle Physik 2, Technische Universität Dortmund, Germany

We present experimental and theoretical study on electron spin coherence in ensemble of n-type doped InGaAs/GaAs quantum dots containing one electron per dot. A pump-probe time-resolved Faraday rotation technique is exploited. Long-lived spin precession of resident electrons in external magnetic fields is observed with the dephasing time of spin ensemble exceeding 6 ns. Rabi oscillations of the Faraday rotation amplitude are detected confirming the suggested model of generation electron spin coherence via excitation of coherent superposition of the trion state and the resident electron. We show that the ensemble dephasing can be overcome by using a periodic train of light pulses to synchronize the phases of the precessing spins. This modelocking leads to constructive interference of contributions to Faraday rotation, and presents potential applications based on robust quantum coherency within an ensemble of dots. Under these experimental conditions spins of the dots nuclei are aligned in a way that all dots in the ensemble contribute to the coherent signal with a potential to focus the electron Larmor frequencies in the ensemble to a single mode. This optical technique allows to measure the spin coherence time of a single quantum dot of 3 microseconds. This work is done in collaboration with A. Greilich, I. A. Yugova, S. Spatzek, M. Bayer, A. Shabaev, Al. L. Efros, S. E. Economou, T. L. Reinecke, D. Reuter and A. D. Wieck.

HL 21: Devices

Time: Tuesday 14:00–16:00 Location: BEY 81

HL 21.1 Tue 14:00 BEY 81

High-Performance Tunnel Field Effect Transistor (TFET) using ultra-high-k gate dielectrics — •Martin Schlosser, Helmut Lochner, Martin Sauter, Thomas Zilbauer, Torsten Sulima, and Ignaz Eisele — Institute of Physics, Nano and Micro Systems, University of the German Federal Armed Forces Munich, 85577 Neubiberg, Germany

Continuous downscaling of field effect transistors is about to reach physical limits and calls for new device concepts. The Tunnel FET (TFET), based on a gated pin-diode, is a promising candidate for future CMOS technology due to its superior properties like small subthreshold slope, fabrication without sophisticated technology and good temperature stability. However, increasing the on-current remains challenging. We propose to use thick ultra-high-k materials as gate dielectrics in order to induce a higher electric field at the tunnelling junction due to the well-known fringing field effect. While worsening the device characteristics of a conventional MOSFET, it turns out that this effect significantly enhances the device performance of TFET devices. The reason is that the off-current is given by a pin-diode leakage current, while the on-current increases exponentially with the electric field. On-currents fulfilling the actual ITRS roadmap and slopes down to 20 mV/dec are observed in simulations of the device by using a generic dielectric with k = 200 and d = 102 nm. As aggressive downscaling of EOT is not needed, the usability for high-frequency applications is very good due to the low gate capacitance.

HL 21.2 Tue 14:15 BEY 81

Separation and Analysis of different leakage mechanisms in modern MOSFETs — •Guntrade Roll[1], Matthias Goldbach[2], Andre Wachowiak[2], Juergen Holz[2], and Lothar Frey[3] — [1]Namlab Gmbh, D-01187 Dresden — [2]Qimonda, D-01099 Dresden — [3]Fraunhofer IISB, D-91058 Erlangen

CMOS device development via gate length reduction is driven by the requirement for performance enhancement under power consumption control. Gate length scaling is enabled by reducing gate oxide thickness, parasitic capacitances as well as source/drain junction depth. These actions typically lead to increasing device leakage currents.
I will present detailed investigations of leakage currents and mechanisms on industry fabricated PFET devices with channel length smaller 100nm. The influence of the gate induced drain leakage (GIDL), drain induced barrier lowering (DIBL), p+/n-junction- and gate leakage on the total device current loss is studied with temperature dependent current-voltage- and capacitance-voltage-measurements. Two types of sample systems have been investigated:
- PFETs with ultra shallow source/drain (carbon co-implantation)
- PFETs with high-k gate dielectric and metal gate
The analysis reveals the relative magnitude of the different leakage current contributions, the DIBL effect and GIDL control the leakage for increasing drain bias. The underlying mechanisms (direct tunneling, defect assisted etc.) are investigated.

HL 21.3 Tue 14:30 BEY 81

Vertical IMOS with n-doped deltas for high temperature applications — •Tina Kubot, Ulrich Abelein, Peter Iskra, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The demands for process control in high temperature (HT) environments like engines or exhaust systems grow e.g. due to stricter requirements in CO_2-emission. The low temperature tolerance of common silicon based devices becomes a great issue in the development of suitable sensors and readout electronics. Increased intrinsic charge carrier density and decreased pn-junction barrier height can reduce the device performance down to total failure of the devices.

With the IMOS we have introduced a device concept which has proven its suitability for HT-environments. After realizing p-delta planar doped barrier (PDB) FET structures with superior Drain-Source leakage currents and high On-Off-Ratios at 500 K we now present n-doped PDB-structures. We show investigations on the temperature dependent barrier properties of highly phosphorus doped deltas in p^+-i-$n^+\delta$-i-p^+-diode structures fabricated by molecular beam epitaxy. The deltas have a thickness of 3 nm and a doping level of $> 10^{19}$ cm^{-3}. Temperature dependent I-V-measurements were carried out from room temperature up to 500 K. For the measurements a semiconductor parameter analyzer with a heated chuck was used. The electrical characteristics of these test devices show a good barrier formation by the delta layer even at elevated temperatures.

HL 21.4 Tue 14:45 BEY 81

Characterization of of ZnO and MgZnO MSM Photodectecors — •Lucie Behnke, Zhang Zhipeng, Gisela Biene, Mathias Schmidt, Alexander Müller, Holger v. Wenckstern, Marius Grundmann, and Holger Hochmuth — Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnéstr. 5, Germany

There is a wide range of applications for small, fast and transparent photodetectors. For their fabrication ZnO is a promising material, because of its large, direct bandgap. We investigated interdigital metal-semiconconductor-metal structures of different Schottky contact metals on $Mg_xZn_{1-x}O$; the concentration of magnesium x varies from 0 to 0,21. The contacts were realized by reactiv DC sputtering, which results in high-quality Schottky contacts. The reproducibility was confirmed by current-voltage measurements of about 80 devices. The detectors were characterized by photocurrent, noise and light beam induced current measurements. Further, we found a correlation between the magnesium concentration and the leakage current. We discuss the quantum efficiency in dependence of x.

15 min. break

HL 21.5 Tue 15:15 BEY 81

Low operation voltage light emitting device based on ZnO nanoparticles — •Ekaterina Neshataeva[1], Tilmar Kümmell[1], André Ebbers[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik and CeNIDE, Universität Duisburg-Essen, 47057 Duisburg — [2]Evonik Degussa GmbH, Creavis, 45764 Marl, Germany

Semiconductor nanoparticles are very attractive candidates for future large-area light emitting devices that are both cost-effective and robust. In this contribution we demonstrate a ZnO nanoparticle light emitting device, which operates at low voltages without the need of any organic support layers. Tight nanoparticle layers were fabricated by a spin coating process using commercially available ZnO nanoparticles from the gas phase and fluorine-doped tin oxide glass as a substrate. After evaporation of a top electrode, a diode-like I-V characteristic was obtained. The device operation at room temperature starts at 4V and shows electroluminescence in the visible spectral range and a pronounced UV peak related to near-band gap emission of the ZnO. Thus, our findings open a path towards all-inorganic large-area particle based luminescent devices.

HL 21.6 Tue 15:30 BEY 81

E-Beam alignment markers for high overlay accuracy — •Jürgen Moers[1,2], Julian Gerharz[1,2], Stefan Trellenkamp[1,2], and Detlev Grützmacher[1,2] — [1]Institute for Bio- and Nanosystems, Research Center Jülich, D-52425 Jülich, Gemany — [2]JARA Jülich Aachen Research Alliance

In recent years the dimensions of semiconductor devices have been decreased to the deep sub-100nm range with an overlay requirement of 10nm and below. In research e-beam lithography is used to meet those requirements. The key issue for achieving the overly accuracy is the quality of the alignment markers. For this purpose square holes etched into the silicon substrate are used.

The e-beam tool triggers on the contrast transition between the marker and the surrounding area. The position of this transition is the marker edge. Its position is determined by averaging over several measurements of the contrast transition. The marker position is given by the center of the positions of the four marker edges.

While with new markers an intrinsic overlay of 10nm can be achieved, the quality of the markers deteriorate during processing. In this work the effect of layer deposition, epitaxial growth and etching steps on the overlay accuracy is investigated. It can be shown, that the standard deviation of the determined position of the marker edge increases, while the determined center of the marker is till found in good agreement with its designed position. Hence an overlay of 10 nm can still be achieved.

HL 21.7 Tue 15:45 BEY 81

First prototype of a novel memory device based on self-organized quantum dots — •Andreas Marent[1], Tobias Nowozin[1], Martin Geller[2], Johannes Gelze[1], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Fachbereich Physik und CeNIDE, Universität Duisburg-Essen , Lotharstrasse 1, 47048 Duisburg

We have developed a memory concept (QD-Flash) based on self-organized quantum dots (QDs) [1] with the potential to overcome the restrictions of nowadays most important semiconductor memory, the Flash-memory. The main disadvantage of the Flash-memory results from the use of Si/SiO_2 which leads to a fundamental trade-off between write time and storage time. In contrast, using III-V semiconductors in the QD-Flash, ultra fast write times ($<$ ns) in combination with a long storage time ($>>$ 10 years) can be realized.

We demonstrate a first prototype of the QD-Flash with full functionality using InAs-QDs in $Al_{0.9}Ga_{0.1}As$ as memory units. The performance of the prototype has been evaluated up to room temperature. Read out of the stored information was successfully realized by measuring the resistance of a two-dimenional hole gas formed in a $GaAs/Al_{0.9}Ga_{0.1}As$ quantum well embedded below the QD-layer.

[1] M. Geller, A. Marent, and D. Bimberg, Auf Halbleiter-Nanostrukturen basierender nicht-flüchtiger Speicher "A non-volatile memory based on semiconductor nanostructure", CPT patent application, submitted (2006).

HL 22: Focused Session: Semi- and nonpolar group III nitrides II

Time: Tuesday 14:00–16:30 Location: BEY 118

Topical Talk HL 22.1 Tue 14:00 BEY 118

Optical anisotropy of nitride semiconductors — •Rüdiger Goldhahn — Institut für Physik, Technische Universität Ilmenau

The ordinary and extraordinary dielectric functions (DF) describe the optical response of a semiconductor to an electromagnetic wave with electric field polarization perpendicular and parallel to the optic axis (c-axis), respectively. The spectral dependence is closely related to the valence band ordering at the center of the Brillouin zone as well as to the transition energies and transition probabilities in the vicinity of the high-energy van Hove singularities. We have applied ellipsometry in the photon energy range from 0.7 to 9.5 eV in order to determine the DFs of binary and ternary nitrides with wurtzite structure. Results for both polarization directions will be presented and discussed. The experimental results are compared to the results of theoretical calculations. Density functional theory in the local density approximation leads to independent-particle DFs which emphasize the observed optical anisotropy, but the peaks are found at higher energies with respect to the experimental data. If instead the electron-hole Hamiltonian (exciton effects) is employed for the calculations the overall agreement is strongly improved, i.e. the comparison of both calculated DFs yields the size of the peak shift for the high-energy CPs caused by the final state interaction.

Topical Talk HL 22.2 Tue 14:30 BEY 118

Growth on nonpolar and semipolar GaN: The substrate dilemma — •T. Wernicke[1], M. Weyers[1], and M. Kneissl[1,2] — [1]Ferdinand-Braun-Institute, Berlin, Germany — [2]Institute of Solid State Physics, TU Berlin, Germany

Growth of nonpolar and semipolar GaN is very promising for achieving green laser diodes (LDs). However, the choice of the substrate is a difficult one: Heteroepitaxial growth on sapphire, SiC, $LiAlO_2$ yields GaN films with a poor surface quality and high defect densities. On the other hand non- and semipolar bulk GaN substrates provide excellent crystal quality, but are so far only available in very small sizes. In this paper hetero- and homoepitaxial growth will be compared. For all heteroepitaxially grown semi- and nonpolar GaN layers threading dislocations (TD) and basal plane stacking faults (BSF) can be found. There are four possible mechanisms for the generation of BSF: Growth of the N-polar basal plane, formation during nucleation at substrate steps, formation at the coalescence front of differently stacked nucleation islands, and generation at planar defects occurring in m-plane GaN on $LiAlO_2$. BSF induce surface roughening and are associated with partial dislocations causing nonradiative recombination. Thus they affect the performance of devices. We will show that BSFs and TDs can be reduced by epitaxial lateral overgrowth resulting in several micrometer wide defect free areas. However, for LEDs larger defect-free areas are required. GaN layers grown on bulk GaN substrates exhibit a high crystal quality, but show in many cases long-range surface structures with a height of $\approx 1\,\mu m$.

Topical Talk HL 22.3 Tue 15:00 BEY 118

Microscopic Correlation of Structural, Electronical and Optical Properties of semi- and non-polar grown Group-III-Nitrides — •Frank Bertram — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

Although tremendous progress has been achieved in the growth of GaN, there are still many fundamental problems remaining: In particular reaching higher quantum efficiency and extending the spectral range towards shorter and longer wavelengths. One principal physical problem is the quantum confined Stark effect as a consequence of the strong internal electrical polarization fields in c-direction. The most common strategy to overcome the QCSE-problem is to avoid or minimize the polarization fields by growing the heterostructures in other directions, e.g. perpendicular to the GaN c axis by using a- or m-plane nitrides. Another approach to reduce the fields is growing in semi-polar directions. However, epitaxial growth on such planes is by far less developed than the growth on the commonly used c-plane. Morphological defects like dislocations and - in particular in non-c-axis grown material - stacking faults and spontaneous and piezo-electric polarization fields are the major problems in group-III-nitrides. In ternary and quaternary alloys as well as in their hetero-structures nano-scale fluctuations of stoichiometry and/or interfaces have strong impact on the radiative recombination in light emitters. We correlate the structural, elec-

tronical and optical properties of non- and semipolar epitaxial nitride structures on a micro- and nano-scale with the crystalline real structure using spatially/spectrally/time-resolved cathodoluminescence.

15 min. break

HL 22.4 Tue 15:45 BEY 118

Fabrication of high quality semipolar GaN on full 2 inch for green light emitters — •Thomas Wunderer[1], Frank Lipski[1], Stephan Schwaiger[1], Ferdinand Scholz[1], Michael Wiedenmann[2], Martin Feneberg[2], and Klaus Thonke[2] — [1]Institut für Optoelektronik, Universität Ulm, 89069 Ulm — [2]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

We present a fabrication method for semipolar GaN planes with high material quality and the possibility for large scale production. Inverse GaN pyramids with semipolar {1-101} and {11-22} planes are formed intentionally on a template masked with different hexagonally ordered patterns. Systematic studies of the 3D GaN growth parameters are performed. By varying the V/III ratio, the temperature, and the pressure during the MOVPE growth big differences in the structural shape of the structures and the homogeneity of their distribution could be observed. As figure of merit an InGaN single quantum well emitting in the blue to green spectral region is grown on the semipolar facets. Optical and scanning electron microscopy (SEM) investigations are combined with photoluminescence (PL) and spatially resolved cathodoluminescence (SEM-CL) measurements. Using the optimized growth conditions a complete LED structure is realized on the 3D surface. First results of electroluminescence measurements with emission in the green spectral region are presented.

HL 22.5 Tue 16:00 BEY 118

Characterization of photoluminescence (PL) emission from semipolar {1-101} InGaN quantum wells — •Hans-Jürgen Möstl[1], Clemens Vierheilig[1], Ulrich T. Schwarz[1], Thomas Wunderer[2], Stephan Schwaiger[2], Frank Lipski[2], and Ferdinand Scholz[2] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Institut für Optoelektronik, Ulm University, 89069 Ulm, Germany

The strained growth of InGaN quantum films on polar c-plane GaN induces a strong piezoelectric field in the quantum well structures, which leads to a reduction of the emission energy and a spatial separation of electrons and holes in the QW. In order to reduce this piezoelectric fields for future efficient LEDs and LDs, InGaN quantum films are grown on semi- or nonpolar GaN surfaces. In our work we characterize the PL-spectra of InGaN quantum wells grown on semipolar {1-101} FACELO-samples by highly spatial resolved confocal laser scanning microscopy. The emission intensity and energy and their correlation are investigated for varying sample geometries. Furthermore we study the PL-spectra of InGaN layers with a thickness of about 25 nm grown on the same semipolar planes, which show an increased intensity compared to c-plane layers.

HL 22.6 Tue 16:15 BEY 118

GaInN quantum wells with high indium concentrations on polar and nonpolar surfaces — •Holger Jönen[1], Torsten Langer[1], Daniel Dräger[1], Lars Hoffmann[1], Heiko Bremers[1], Uwe Rossow[1], Sebastian Metzner[2], Frank Bertram[2], Jürgen Christen[2], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig — [2]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

The strong decrease of the internal quantum efficiency (IQE) of GaN based light emitters towards the green spectral region is a well known problem. Beside a degrading material quality the stronger piezoelectric field with increasing indium content reduces the quantum efficiency. A promising way to solve this problem is to grow on non-polar surfaces such as the $(1\bar{1}00)$ of the wurtzite crystal structure. In this case there is no field in growth direction and therefore devices might be more efficient. However, growth conditions may significantly differ from those on conventional c-plane surfaces. In this contribution we discuss the indium incorporation in c-plane and m-plane GaInN quantum wells.

Our samples were grown by low pressure MOVPE and characterized by SEM, XRD, CL and PL measurements. The In content of GaInN layers increases with decreasing growth temperature and seems to be comparable for both surfaces under same growth conditions. However, for high In concentrations above 30% possible relaxation and a degradation of the quantum wells during high temperature growth steps become critical issues.

HL 23: Transport in high magnetic field/quantum-Hall-effect

Time: Tuesday 14:00–15:15 Location: BEY 154

HL 23.1 Tue 14:00 BEY 154

Landauer-Büttiker study of the anomalous Hall effect in a spin-orbit coupled two-degenerate electron gas — •maria silvia garelli and john schliemann — Institute for theoretical physics, Regensburg Universität, 93040 Regensburg

We study the anomalous Hall effect in a finite-size spin-orbit coupled two-degenerate electron gas with enclosed magnetic impurities. We focus on the investigation of the Charge Hall Conductance (CHC) at the bottom of the conduction band within the Landauer-Büttiker formalism. In the case of a uniform magnetization of the 2DEG, we find that for a fixed system size the CHC is characterized by a peak, whose position shifts with changing the magnetization coupling and the Rashba spin-orbit coupling. The investigation of the density of states (DOS) proves its accordance with the CHC.

HL 23.2 Tue 14:15 BEY 154

FQHE measurements on a GaAs/GaAlAs high mobility sample — •Lina Bockhorn[1], Annelene F. Dethlefsen[2], Frank Hohls[1], Werner Wegscheider[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Centre for Atom Optics and Ultrafast Spectroscopy, Faculty of Engineering and Industrial Science, Swinburne University of Technology — [3]Institut für Experimentelle und Angewandte Physik, Universität Regensburg

We study the fractional Quantum-Hall effect in high mobility two-dimensional electron systems (2DES). Hall geometries are created by photolithography on a GaAs/GaAlAs heterostructure containing a 2DES. The mobility and the density of electrons are manipulated by illuminating the samples with a LED and by using a topgate. For a given density of electrons we study the Shubnikov-de Haas-oscillations for different temperatures to extract the activation energies.

We observe a Hall plateau at filling factor 5/2 for a mobility of electrons with $4 \cdot 10^6$ cm^2/Vs. We can detect the Hall plateau at 5/2 for temperatures up to 270mK. For several other filling factors we observe an astonishing linear magnetic dependence of the activation energy for small magnetic fields and a cross-over to square root dependence for high magnetic fields.

HL 23.3 Tue 14:30 BEY 154

Signatures of neutral quantum Hall modes in transport through low-density constrictions — •Bernd Rosenow[1] and Bertrand I. Halperin[2] — [1]Max-Planck Insitut für Festkörperforschung, D-70569 Stuttgart, Germany — [2]Physics Department, Harvard University, Cambridge, MA 02138, USA

Constrictions in fractional quantum Hall (FQH) systems not only facilitate backscattering between counter-propagating edge modes, but also may reduce the constriction filling fraction ν_c with respect to the bulk filling fraction ν_b. If both ν_b and ν_c correspond to incompressible FQH states, at least part of the constriction region is surrounded by composite edges, whose low energy dynamics is characterized by a charge mode and one or several neutral modes. In the incoherent regime, decay of neutral modes describes the equilibration of composite FQH edges, while in the limit of coherent transport, the presence of neutral modes gives rise to universal conductance fluctuations. In addition, neutral modes renormalize the strength of scattering across the constriction, and thus can determine the relative strength of forward and backwards scattering.

HL 23.4 Tue 14:45 BEY 154

Electron interference and dephasing in electronic Mach-Zehnder interferometer — Leonid Litvin, •Andreas Helzel,

Hans-Peter Tranitz, Werner Wegscheider, and Christoph Strunk — Intitut für experimentelle und angewandte Physik, Universität Regensburg, D-93040 Regensburg, Deutschland

We study the visibility of Aharonov-Bohm interference in an electronic Mach-Zehnder interferometer (MZI) in the integer quantum Hall regime. The visibility is controlled by the filling factor ν and is observed only between $\nu \approx 2.0$ and 1.0, with an unexpected maximum near $\nu = 1.5$. Three energy scales extracted from the temperature and voltage dependences of the visibility change in a very similar way with the filling factor, indicating that the different aspects of the interference depend sensitively on the local structure of the compressible and incompressible strips forming the quantum Hall edge channels. The superposition of confining potentials, produced by gate of quantum point contact (QPC) and disorder potential from doping impurities, results in the formation of inadvertent quantum dot (QD) in one arm of interferometer. The phase of the QD transmission amplitude was directly observed in the MZI. This implies, that charge state of QD can be measured by detecting its transmission (reflection) phase with the interferometer, and may be used as more sensitive detectors for QD state, than the currently used QPCs.

HL 23.5 Tue 15:00 BEY 154

Optical manipulation of edge state transport in HgTe quantum wells — •Manuel Schmidt[1], Markus Kindermann[2], Alena Novik[3], and Björn Trauzettel[3] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332, USA — [3]Fakultät für Physik und Astronomie, University of Würzburg, 97074 Würzburg, Germany

We investigate the influence of electromagnetic radiation on edge state transport within an effective model for the band structure of a HgTe quantum well. This effective model describes the quantum well especially well near its mass inversion thickness [1], where it is sufficient to take the first pair of hole- and electron-like bands into account.

We show that, in an experimentally accessible regime, the motion of an electron which traverses one edge can be reversed. The mechanism behind this current direction inversion is the optical scattering of electrons in hole-like, counterclockwise moving states to electron-like, clockwise moving states.

[1] B. A. Bernevig, T. L. Huges, and S. Zhang, Science 314, 1757 (2006).

HL 24: Invited Talk Neumaier

Time: Tuesday 14:45–15:30 Location: HSZ 01

Invited Talk HL 24.1 Tue 14:45 HSZ 01

Phase coherent transport in (Ga,Mn)As — •D. Neumaier[1], K. Wagner[1], U. Wurstbauer[1,2], M. Reinwald[1], W. Wegscheider[1], and D. Weiss[1] — [1]Universität Regensburg — [2]Universität Hamburg

The low temperature conductance of mesoscopic samples is altered by quantum interference effects, caused by the electron's wave nature. Information on the relevant quantum mechanical transport properties is needed to understand charge transport in general and to design more sophisticated structures in particular. In this talk I will review our investigations on universal conductance fluctuations [1,2], Aharonov-Bohm oscillations [2] and weak localization [2,3] in the diluted magnetic semiconductor (Ga,Mn)As. Analyzing universal conductance fluctuations in (Ga,Mn)As nanowires results in a phase coherence length of $\approx$ 100 nm at 20 mK with a $1/\sqrt{T}$ temperature dependency. This agrees well with values extracted from the amplitude of periodic Aharonov-Bohm oscillations observed in (Ga,Mn)As nanorings. To investigate weak localization in (Ga,Mn)As, arrays of wires were fabricated to suppress universal conductance fluctuations by ensemble averaging. The magnetoconductance of the (Ga,Mn)As wire arrays displays a pronounced low temperature anomaly ascribed to weak localization. A comparison of phase coherent transport in (Ga,Mn)As with nonmagnetic materials and conventional ferromagnets will be given.

[1] K. Wagner *et al* PRL 97, 056803 (2006).
[2] D. Neumaier *et al.* NJP 10 055016 (2008).
[3] D. Neumaier *et al* PRL 99, 116803 (2007).

HL 25: C/diamond II

Time: Tuesday 16:00–16:30 Location: POT 51

HL 25.1 Tue 16:00 POT 51

Functionalizing graphene by embedded boron clusters — Alexander Quandt[1], Cem Özdogan[2], •Jens Kunstmann[3,4], and Holger Fehske[1] — [1]Institut für Physik der Universität Greifswald, Felix–Hausdorff-Str. 6, 17489 Greifswald, Germany — [2]Department of Computer Engineering, Çankaya University, Balgat, 06530 Ankara, Turkey — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany — [4]Institute for Materials Science, Dresden University of Technology, 01062 Dresden, Germany

We present results from an ab initio study of B_7 clusters implanted into graphene [1,2]. Our model system consists of an alternating chain of quasiplanar B_7 clusters. We show that graphene easily accepts these alternating B_7-C_6 chains and that the implanted boron components may dramatically modify the electronic properties. This suggests that our model system might serve as a blueprint for the controlled layout of graphene based nanodevices, where the semiconducting properties are supplemented by parts of the graphene matrix itself, and the basic metallic wiring is provided by alternating chains of implanted boron clusters. [1] A. Quandt, C. Özdoğan, J. Kunstmann, and H. Fehske, Nanotechnology **19**, 335707 (2008). [2] A. Quandt, C. Özdoğan, J. Kunstmann, and H. Fehske, phys. stat. solidi (b) **245**, 2077 (2008).

HL 25.2 Tue 16:15 POT 51

Theoretical studies of electronic transport and giant magnetoresistance in ferromagnetically contacted graphene nanoribbons — •Stefan Krompiewski — Institute of Molecular Physics, PAS, Poznan, Poland

Graphene – a monolayer of graphite – is believed to be even more promising for the emerging molecular electronics than carbon nanotubes. This contribution reports on a possible application potential of graphene nanoribbons also in magnetoelectronics (spintronics). The present methodology is based on the tight-binding model combined with the Green function recursive technique, within the ballistic transport regime. In contrast to hitherto existing theories, external magnetic contacts are here 3-dimensional and semi-infinite in the transport direction. The basic transport characteristics: conductance, shot noise and giant magnetoresistance (GMR) are studied for different aspect (width/length) ratios and the most common chiralities, i.e. zigzag and armchair ones. It turns out that typically the GMR effect at elevated gate voltages can exceed 10-20%, morover interestingly enough its value in armchair-edge ribbons is clearly higher than in those with zigzag edges.

HL 26: Focused Session: Novel nanowires electronic device concepts

Time: Wednesday 9:30–13:00 Location: HSZ 01

Topical Talk HL 26.1 Wed 9:30 HSZ 01

Nanoelectronics - Why 1D nanowires? — •Joerg Appenzeller — School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue University, West Lafayette, IN 47907, USA

While nano-materials have been explored extensively for the last fifteen years or so, the societal impact has been rather limited due to the lack of a substantial amount of nano-applications. This is in part a result of the time it takes to gain the necessary understanding of the material properties and underlying physics/chemistry, to a larger extend it is due to the fact that most studies do not cover materials and devices aspects with a clear application in mind simultaneously. For example, nano-materials frequently are discussed in the context of high density electronic applications. This seems to be a natural choice due to their intrinsic smallness. However, nano-materials have to offer unique electronic properties that enable new types of devices applications in order to be suitable for a future nano-electronics. One of the * if not THE - most pressing questions in the area of electronics is how to reduce power consumption. Here we discuss the impact of dimensionality and body thickness - the diameter in case of a nanowire - on the performance of nano-devices. We will elucidate on the impact of the wire diameter on the device on-state and off-state as well as the scaling of wire based transistors and the implications for low power device applications.

Topical Talk HL 26.2 Wed 10:00 HSZ 01

Doping limits in silicon nanowires — •Mikael Björk, Heinz Schmid, Joachim Knoch, Heike Riel, and Walter Riess — IBM Research GmbH, Ruschlikon, Switzerland

The operation of electronic devices relies heavily on the density of free charge carriers available in the semiconductor, a quantity that is usually well controlled by the addition of dopant atoms. The fabrication of ultimately scaled semiconductor devices will thus depend significantly on the ability to precisely control the location and number of active impurity atoms in the host semiconductor. As dimensions are scaled down the presence of interfaces and materials adjacent to the semiconductor become more important and can eventually completely determine the electronic properties of the device. Here we experimentally demonstrate the in-situ doping limits of silicon nanowires and that the free carrier density in nanoscale semiconductor wires is size dependent due to a reduction in the amount of ionized impurities. By measuring the electrical conduction of doped silicon nanowires as a function of wire radius, temperature and dielectric surrounding we present experimental proof of a deactivation of the doping atoms in the wires, which is due to a dielectric mismatch between the nanowire core and the surrounding.

15 min. break

Topical Talk HL 26.3 Wed 10:45 HSZ 01

Polarity control of silicon nanowire transistors by electrostatic coupling to the Schottky contacts — Walter Michael Weber[1,2], Lutz Geelhaar[4], Franz Kreupl[3], Henning Riechert[4], and •Paolo Lugli[2] — [1]Namlab gGmbH, Dresden, Germany — [2]TU - Munich, Institute for Nanoelectronics, Munich, Germany — [3]Qimonda AG, Neubiberg, Germany — [4]Paul Drude Institute, Berlin, Germany

One of the challenges for implementing nanoscale semiconductors in future electronics is the accurate adjustment of the charge carrier concentration. We present an innovative method of creating p- and n-type FETs by employing intrinsic Si nanowires (NW) as the active region. This method does not require doping, but takes advantage of the inherent NW geometry and simply relies on the electrostatic control of the bands near the source- and drain- (S/D) contacts. The FETs are built from longitudinal $NiSi_2$/Si/$NiSi_2$ NW-heterostructures. The intruded metallic $NiSi_2$ segments act as S/D -regions and introduce a Schottky barrier (SB) at their interface to the Si active region. Temperature activation measurements were used to reveal the relation between the applied electric fields and the charge carrier injection over the contacts. Accordingly, the transistor's conductance was electrostatically steered by switching between thermionic emission and thermal assisted tunneling. This effect was employed to provide additional functionality to the transistors. By independently coupling each Schottky contact through separate top gates the device polarity could be controlled. This simple method enables the possibility to conceive complementary logic circuits without the use of doping.

Topical Talk HL 26.4 Wed 11:15 HSZ 01

Antimonide-based nanowire devices — •Lars-Erik Wernersson — Lund University, Sweden

III/V nanowires are attractive for implementation in various transistor configurations. For instance, InAs nanowire FETs have shown high transconductance and good subthreshold characteristics at 50 nm Lg [1]. Capacitance studies of the III/V MOS structure confirmed the transistor operation and provided values for the interface state density [2]. Also heterostruture barriers have been introduced to the channel to shift Vt [3].

The introduction of Antimon-based materials into the channel enables new functionalities for the nanowire transistors. GaSb nanowires have demonstrated good p-type conduction [4], while InSb nanowires allow the introduction of a very high mobility material [5]. Besides, InSb has a very large g-factor.

In this talk, the performance for short-channel InAs nanowire transistors and MOS capacitors will be discussed. Furthermore, experimental data for growth and electrical performance of GaSb and InSb nanowires will be presented and discussed.

[1] Thelander, et al IEEE Electron Device Lett 29, 206 (2008) [2] Roddaro, et al, Appl. Phys. Lett. 92, 253509 (2008); [3] Lind, et al Nano Lett., 6 (9), 1842 (2006) [4] Jeppsson, et al Journal of Crystal Growth23, 5119 (2008) [5] Caroff et al, Small 4, 878 (2008)

15 min. break

Topical Talk HL 26.5 Wed 12:00 HSZ 01

Rf-characterization of III-V-Nanowire FET: Problems and Results — •Franz Tegude and Werner Prost — Univ. Duisburg-Essen

Nanowire fieldeffect transistors (NW-FET) are a straight forward continuation of downscaling in microelectronics. Further, because of their excellent transport properties, III-V-semiconductor materials have demonstrated record high frequency potential. This contribution addresses mainly, but not exclusively, InAs-n-channel MISFET prepared by a bottom-up approach employing the vapor-liquid-solid (VLS) epitaxial growth mode. Single NWs are processed yielding gate lengths in the micrometer and sub-micrometer range. Due to the nanometer scale two aspects become core problems with respect to FET device performance and characterisa-tion: parasitics, and mismatch to nearly exclusively used 50 Ohm rf measurement environment. Corner frequencies of about 15 GHz are presented, together with deembedding techniques to yield intrinsic and parasitic device parameters. In addition, rf characteristics are used for transport data evaluation, because standard methods like Hall characterisation is not immediately applicable to nanowire geometry.

Topical Talk HL 26.6 Wed 12:30 HSZ 01

Semiconductor nanowires as building blocks for quantum devices — •Thomas Schäpers[1], Sergio Estevez Hernandez[1], Gunnar Petersen[1], Robert Frielinghaus[1], Shima Alagha[1], Christian Blömers[1], Thomas Richter[1], Raffaella Calarco[1], Hans Lüth[1], Michel Marso[1], and Michael Indlekofer[2] — [1]Institute of Bio- and Nanosystems (IBN-1), JARA-Fundamentals of Future Information Technologies, Research Centre Jülich, 52425 Jülich, Germany — [2]Informationstechnologie and Elektrotechnik, Wiesbaden University of Applied Sciences, Am Brückweg 26, 65428 Rüsselsheim, Germany

Semiconductor nanowires are versatile building blocks for the design of future electronic devices. Among the many possible materials, InN is particularly interesting because of its low energy band gap and its high surface conductivity. At low temperatures electron interference effects often play an important role in the transport characteristics of nanostructures. We studied the electronic transport of InN nanowires grown by plasma-assisted molecular beam epitaxy. The wires had a diameter ranging from 40 nm to 130 nm and a length of approximately 1 μm. Information on the phase-coherent transport was gained from the measurement of universal conductance fluctuations. It was found that at low temperatures phase-coherence is maintained in the complete wire structure, which is an important prerequisite for quantum devices. For

nanowires comprising a very small diameter of approximately 40 nm pronounced flux-periodic oscillations in the magneto-conductance were observed. This effect is attributed to the formation of coherent circular quantum states on in the tube-like surface electron gas.

HL 27: GaN: preparation and characterization I

Time: Wednesday 9:30–13:00 Location: BEY 81

HL 27.1 Wed 9:30 BEY 81

SNOM measurements of GaInN/GaN and GaN/AlGaN light emittting quantum well structures — •Peter Clodius, Holger Jönen, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technische Universität Braunschweig, Institut für Angewandte Physik, Braunschweig

Today Group-III-Nitride based light emitting quantum well (QW) structures are used in a wide range of applications, from near green to blue and (ultra)violet LEDs and LDs. The high efficiency of the GaInN/GaN-QW structures in the blue and violet region is still a matter of discussion. Our explanation is based on the fact that, in high efficiency structures, nearly every dislocation in growth direction for c-plane surfaces, is decorated by a so called V-pit (hexagonal V-shaped structures with $(10\bar{1}1)$ sidewalls). On these sidewalls the growth rate of the QWs is reduced, compared to the growth on c-plane, which leads to thinner QWs with an increased bandgap, causing a potential which prevents charge carriers from reaching possible centers of non-radiative recombination at these defects. Recent SNOM-measurements showed a high energy emission from areas surrounding these pits even at room temperature. In this talk we will present the results of further experiments, trying to clarify the origin of this unusual emission. We will also present first measurements of GaN/AlGaN based QW structures emitting in the ultraviolet, investigating if V-pits play a role in these structures as well.

HL 27.2 Wed 9:45 BEY 81

Time-resolved measurements on blinking dots in InGaN/GaN quantum wells — •Anne Kuhnert[1], Clemens Vierheilig[1], Tobias Meyer[2], and Ulrich T. Schwarz[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany

In some InGaN/GaN quantum well samples the quantum well photoluminescence under cw laser excitation is not homogenously distributed, but shows dots with different emission wavelengths. The colors of the dots vary from red over green to blue. Some of these dots show a switching behavior between two intensity levels. The timescale of the blinking phenomenon is of the order of 10^{-2} s up to some seconds. At low excitation densities the time slices of on-state and off-state are mainly the same. With increasing excitation density the percentage of the off-state decreases and at high excitation intensities the dots stay permanently on. The photoluminescence of these samples is measured with a confocal microscope with high spatial resolution. The signal is detected time resolved by a photomultiplier tube.

HL 27.3 Wed 10:00 BEY 81

Korrelation von Raster-LBIC (Light Beam Induced Current), μ-EL und μ-PL-Spektroskopie an InGaN-MQW LEDs auf Silicon-On-Insulator (SOI)-Substrat — •T. Fey[1], L. Reissmann[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2], V.K.X. Lin[3], S.L. Teo[3] und S. Tripathy[3] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität, 39106 Magdeburg — [2]AZZURRO Semiconductors AG, Magdeburg — [3]Institute of Materials Research and Engineering, 3 Resarch Link, 117602 Singapore

Es wurden MOVPE-gewachsene InGaN-MQW LEDs auf SOI-Substrat mittels LBIC, μ-EL- und μ-PL-Spektroskopie untersucht. Der Messaufbau besteht aus einem optischen Mikroskop mit motorgetriebenem xy-Tisch und einem 500 mm Spektrometer mit N_2 gekühlter CCD Kamera. Die gesamte LED Oberfläche von 300x300 μm^2 wurde mit einer Schrittweite von 3 μm gerastert. Die Spektren zeigten klar Fabry-Perot-(FP)-Moden, welche Schichtdickeninterferenzen darstellen. Die PL-Peakwellenlänge ist im Vergleich zur EL-Peakwellenlänge für alle Ströme um ca. 35 nm blauverschoben. Außerdem zeigt sich eine Verschiebung der Peaks der FP-Interferenzen unter Strominjektion gegen über der optischen Anregung. Daraus lässt sich eine Veränderung des Brechungsindex aufgrund veränderter Ladungsträgerdichte ableiten. Die Intensitätsverteilungen der PL und EL unterscheiden sich deutlich. Jedoch kann eine eindeutige mikroskopische Korrelation zwischen LBIC und EL festgestellt werden. Das LBIC-Signal dient der Visualisierung lokaler Unterschiede der elektrischen Eigenschaften der LED sowie deren Einfluss auf die EL-Intensitätsverteilung

HL 27.4 Wed 10:15 BEY 81

Electro-optical properties of InGaN-based LED structures on the sub-μm length scale — •Clemens Vierheilig[1], Ulrich T. Schwarz[1], Nikolaus Gmeinwieser[2], Ansgar Laubsch[2], and Berthold Hahn[2] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany

The optical properties of InGaN-based quantum wells show strong fluctuations on different length scales. With pure optical measurements of the photoluminescence signal of the quantum wells it is not possible to separate effects of fluctuations of the quantum well width or indium content from local nonradiative recombination of the excited charge carriers. For this reason, we perform photoluminescence measurements with high spatial resolution (μPL) under external bias in combination with measurements of the laser beam induced photocurrent (LBIC). The strong fluctuations of the PL intensity on a length scale of several μm are also observed in the spectral position of the quantum well and the LBIC under reverse external bias. This indicates fluctuations of the quantum well width. An additional strong intensity fluctuation of the PL intensity on the sub-μm length scale is not observed in the LBIC signal. These short-range fluctuations are interpreted in terms of local nonradiative recombination.

15 min. break

HL 27.5 Wed 10:45 BEY 81

Structure and electronic properties of dislocations in GaN — •Philipp Ebert[1], Lena Ivanova[2], Svetlana Borisova[1], Holger Eisele[2], Ansger Laubsch[3], and Mario Dähne[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [3]OSRAM Opto-Semiconductors GmbH, 93055 Regensburg, Germany

Group-III nitrides developed rapidly toward the materials of choice for green to ultraviolet optoelectronics. Unfortunately, GaN substrates are still suffering from high dislocation densities, far above that of zincblende type III-V semiconductor substrates. This presence of high dislocation densities is detrimental for optoelectronics, because dislocations can act as recombination centers. Therefore, we investigated the type, spatial distribution, the projected line direction, and electronic properties of dislocations in n-type GaN by scanning tunneling microscopy. The dislocations were found to form localized bunches of entangled non-parallel dislocation lines. Within these bunches perfect dislocations with $a/3\left\{11\bar{2}0\right\}$ Burgers vectors were uncharged, while Shockley partials with $a/3\left\{11\bar{2}0\right\}$ Burgers vector and the related intrinsic type-2 stacking fault were negatively charged. The charges are traced to different charge transfer levels associated to the particular core structure. The observations suggest that the dissociation of dislocations may be responsible for the insertion of detrimental gap states in n-type GaN.
This work is supported by the DFG through SFB 787 and Eb 197/3-1.

HL 27.6 Wed 11:00 BEY 81

Sub micrometer photoluminescence fluctuations in green light emitting InGaN/GaN quantum wells — •Julia Danhof[1], Clemens Vierheilig[1], Ulrich Theodor Schwarz[1], Tobias Meyer[2], Matthias Peter[2], Berthold Hahn[2], Markus Maier[3], and Joachim Wagner[3] — [1]Institute for Experimental and Applied Physics, University of Regensburg, D-93040 — [2]Osram Opto Semiconductors GmbH, Leibnizstr. 4, D-95055 — [3]Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Tullastrasse 72, D-79108

For green light emitting InGaN/GaN multiple quantum well samples a correlation of surface morphology and photoluminescence measurements has been established by comparing atomic force microscopy images with PL maps. Of main interest here are threading dislocation. Three samples with nominally the same quantum well (QW) structures but different substrates and threading dislocation densities are compared. Emitted wavelengths lay between 510 nm and 520 nm. Green light emitting QWs usually show a meandering structure on micro photoluminescence maps. For the sample the lowest dislocation density pinhole scans were performed in order to address the issue of charge carrier diffusion length within the meandering structure.

HL 27.7 Wed 11:15 BEY 81

Screening Dynamics of the Spontaneous Polarisation Field in GaInN/GaN Quantum Well Structures — •Martina Finke, Daniel Fuhrmann, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institut für Angewandte Physik, Braunschweig

In GaN-based quantum well structures, the spontaneous and piezoelectric fields lead to the quantum confined Stark effect, which causes a decrease in the effective bandgap and a reduction of the oscillator strength and therefore the intensity of emitted light. The piezoelectric polarization was measured experimentally by various methods, but the spontaneous field as a bulk property is usually screened by charged species on the surface and was not accessible to direct experimental determination up to now. We use GaInN quantum wells as a sensitive probe for the magnitude and changes of the spontaneous field. The samples are investigated by cathodoluminescence and photoluminescence in an UHV environment. One the one hand the electron beam activates the spontaneous field by removal of charges at the surface. On the other hand, electron hole pairs generated in the bulk tend to screen the field. The complex dynamics are observed as a shift of spectral position and an intensity variation. By variation of electron beam penetration depth, cap thickness and doping level we study the different time dependent behaviour in screening and descreening of the spontaneous field.

HL 27.8 Wed 11:30 BEY 81

Spatially resolved X-ray diffraction measurements on AlInN/GaN distributed Bragg reflectors — •Christoph Berger, Pascal Moser, Jürgen Bläsing, Armin Dadgar, Thomas Hempel, and Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Deutschland

As a high-index-contrast and high-band gap material, which can be grown lattice-matched on GaN, AlInN is very promising for the fabrication of GaN-based optoelectronic devices. In vertical-cavity surface-emitting lasers (VCSELs) very high reflectivities are needed, which can be achieved by distributed Bragg reflectors (DBRs). For that purpose the layers need to have a quarter wave thickness and good crystalline quality. The DBRs were grown on GaN by metalorganic vapor phase epitaxy (MOVPE) on c-plane sapphire substrates and characterized by different X-ray diffraction (XRD) techniques, as symmetrical $\theta/2\theta$-scans, grazing-incidence in-plane diffraction (GIID) and reciprocal space mapping. Layer thicknesses and concentrations were determined and it could be shown, that the layers are grown fully strained on GaN. In $\theta/2\theta$-scans lots of satellite-peaks are observed, which implies a good periodicity and abrupt interfaces. However, spatially resolved XRD measurements revealed that the thickness ratio of the layers changes with the radial position on the wafer, which causes a shift of the corresponding optical stop band and a decrease of the maximum optical reflectivity.

15 min. break

HL 27.9 Wed 12:00 BEY 81

Radiative recombination in GaInN quantum wells investigated via time-resolved photoluminescence — •Torsten Langer, Holger Jönen, Carsten Netzel, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig

The optical properties of group-III-nitrides are strongly influenced by an interplay between radiative and nonradiative recombination processes. For our high internal efficiency c-plane GaInN/GaN quantum wells, the effective lifetime, determined by time-resolved photoluminescence(PL)-spectroscopy, is dominated by radiative recombination nearly up to room temperature. This is evidenced by an increase of the effective lifetime with increasing temperature, which is tantamount to a high internal quantum efficiency, proving the results from temperature and excitation power dependent PL-measurements (continuous wave excitation). While radiative lifetime increases almost linearly at higher temperatures, the nonradiative lifetime drops due to thermal activation of nonradiative processes. The influence of excitons is clearly visible too, when fitting the intensity transients with a model based on radiative excitonic and nonradiative recombination. In this model, the ratio between excitons and free carriers are described by the law of mass action. Furthermore, we observe higher effective lifetimes with increasing quantum well thickness, due to a decreased oscillator strength caused by piezoelectric fields. In m-plane GaInN quantum wells, the interplay between radiative and nonradiative recombination processes is present as well. Here we observe a higher oscillator strength and therefore a shorter effective lifetime.

HL 27.10 Wed 12:15 BEY 81

Wachstum von GaN auf hochindizierten Silizium-Substraten — •Roghaiyeh Ravash, Jürgen Bläsing, Matthias Wieneke, Armin Dadgar und Alois Krost — Institut für Experimentelle Physik (IEP), Magdeburg, Deutschland

Bei den meisten bisher realisierten Bauelementen, die auf GaN basieren, ist die Wachstumsorientierung parallel zur c-Achse. In solchen Schichten tritt Ladungsseparation aufgrund der internen spontanen- und verspannungsinduzierten piezoelektrischen Polarisation auf, was sich u. a. im Quantum Confined Stark Effekt (QCSE) äußert. Eine mögliche Lösung, die Polarisationsfelder und den QCSE zu kontrollieren, ist das Wachstum polarisationsreduzierter Schichten. Um nicht- bzw. semipolar orientiertes GaN mittels MOVPE zu wachsen, wird hier durch Änderung der Prozessparameter wie z.B. dem Druck, der Wachstumstemperatur, dem V-III Verhältnis, etc. nach geeigneter Silizium-Substratoberfläche, wie z. B. (511), (711) gesucht Die Oberflächen der gewachsenen Proben sind im Vergleich zu c-achsenorientierten GaN-Schichten auf Si(111)-Substraten, die meist als Referenz-Proben im selben Wachstumsversuch benutzt werden, sehr rau. Aufgrund der nahezu pulverartigen Verteilung der GaN-Kristallite treten eine Vielzahl von Intensitätsreflexen auf. Zur Bestimmung der Textur der Kristallite werden Polfigurmessungen durchgeführt. Für einige GaN Orientierungen wird bei bestimmten Si-Kristallorientierungen eine deutlich erhöhte Intensität beobachtet. Diese bevorzugten Orientierungen werden im Zusammenhang mit der bekannten Oberflächenstruktur der verschiedenen Si-Substrate diskutiert.

HL 27.11 Wed 12:30 BEY 81

Spectral behaviour of semipolar GaInN/GaN on $\{11\bar{2}2\}$ and $\{1\bar{1}01\}$ semipolar facets — •Michael Wiedenmann[1], Martin Feneberg[1], Rolf Sauer[1], Klaus Thonke[1], Thomas Wunderer[2], Stephan Schwaiger[2], Frank Lipski[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

We present cathodoluminescence measurements on GaInN/GaN single quantum wells grown on different semipolar facets. These semipolar facets were formed via selective epitaxy on a GaN template with hexagonally ordered mask patterns. The intentionally grown inverse pyramids possess $\{11\bar{2}2\}$ and $\{1\bar{1}01\}$ crystal planes. The optical properties of the quantum well on the different facets are investigated by spatially resolved cathodoluminescence spectroscopy. Strong shifts of the quantum well luminescence are found within individual facets, which are discussed in terms of concentration gradients and quantum well thickness changes.

HL 27.12 Wed 12:45 BEY 81

Mikroskopische Lumineszenzuntersuchungen an grünemittierenden InGaN/GaN MQWs auf semi-polaren $\{1\bar{1}01\}$ Facetten — •Sebastian Metzner[1], Frank Bertram[1], Jürgen Christen[1], Thomas Wunderer[2] und Ferdinand Scholz[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]Institut für Optoelektronik, Universität Ulm

Wir präsentieren hochortsaufgelöste Kathodolumineszenzmikroskopie (KL) von, für den grünen Spektralbereich optimierten, dreifach InGaN-MQWs, die selektiv auf $\{1\bar{1}01\}$ GaN-Facetten gewachsen wurden, welche mit MOVPE durch streifenförmige SiO_2-Maskierungen hergestellt wurden. Im auf Saphir gewachsenen GaN-Puffer dominiert die scharfe (FWHM $<$ 5 meV) (D^0,X) Lumineszenzlinie bei 355,8 nm, was einer biaxialen kompressiven Verspannung von 0,5 GPa entspricht. Die GaN-Prismen zeigen im Querschnitt einen schwachen, scharfen (D^0,X)-Peak, der im lateral überwachsenen QW-Bereich stark rotverschoben (357,7 nm) und verbreitert ist. Die ortsintegrale KL des InGaN-MQW

liegt im grünen Spektralbereich bei ca. 510 nm. Mikroskopisch ist ein QW-Lumineszenzverlauf zu identifizieren, der beginnend mit langwelliger KL (517 nm) in Maskennähe über eine kurzwellige KL (< 505 nm) auf 1/3 Facettenhöhe in Richtung Dachfirst zu längeren Wellenlängen (bis 512 nm) schiebt. Unmittelbar am First geht eine intensive, kurzwellige InGaN-Emission mit einer perfekten Morphologie einher. Im Gegensatz dazu korreliert eine schwache InGaN-Intensität bei 515 nm, begleitet von GaN-Defektlumineszenz bei 390 nm - 450 nm, mikroskopisch mit morphologischen Defekten unmittelbar am First.

HL 28: ZnO: preparation and characterization I

Time: Wednesday 9:30–13:00 Location: BEY 118

HL 28.1 Wed 9:30 BEY 118

Growth and optical properties of ZnO nanostructures grown on ZnO seed layers — •Yong Xie, Martin Feneberg, Anton Reiser, Ingo Tischer, Michael Wiedenmann, Reinhard Frey, Uwe Roeder, Rolf Sauer, and Klaus Thonke — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

Using a ZnO seed layer, we grow well-aligned ZnO nanopillars on different substrates including a-plane sapphire, c-plane GaN, and (100) silicon. We use Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) to characterize the morphology of the ZnO seed layers and of the ZnO nanopillars. Layers and nanopillars were also investigated by optical spectroscopy. For all kinds of substrates used, we find well-faceted nanopillars which are uniform along the whole length. The data indicate that they grow via the vapour-solid (VS) mechanism under well-controlled growth conditions. The photoluminescence of the ZnO nanopillars shows sharp near-band-edge luminescence and nearly no green or yellow band luminescence, indicating very low contamination.

HL 28.2 Wed 9:45 BEY 118

Growth and Characterization of ZnO/ZnMgO Quantum Wells — •Bernhard Laumer[1], Thomas A. Wassner[1], Jochen Bruckbauer[1], Martin Stutzmann[1], and Martin Eickhoff[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

$ZnO/Zn_{1-x}Mg_xO$ quantum wells (QWs) were grown on c-plane sapphire substrates by plasma assisted molecular beam epitaxy (PAMBE). In order to obtain smooth interfaces, growth was initiated by deposition of a thin MgO/ZnO double buffer and a thick ZnO intermediate layer. This was followed by the actual $Zn_{1-x}Mg_xO/ZnO/Zn_{1-x}Mg_xO$ QWs with Mg contents x up to 0.18. The ZnMgO barriers were found to grow pseudomorphically. The photoluminescence (PL) spectra taken at 4.2 K are dominated by an emission line that is blue-shifted with respect to the ZnO emission and that is attributed to localized excitons in the QWs. Increasing the Mg content x in the barrier results in a blue-shift of the QW emission, as expected from quantum confinement. Temperature-dependent PL measurements show that at higher temperatures the emission of free excitons prevails. Furthermore, an emission line (D) below that of ZnO with pronounced phonon replica appears, which red-shifts with increasing x.

HL 28.3 Wed 10:00 BEY 118

Growth of ZnO heterostructures in an ultra compact MBE system — •Marcel Ruth[1,2] and Cedrik Meier[2] — [1]University of Duisburg-Essen, Institute of Experimental Physics, Lotharstr. 1, 47048 Duisburg — [2]University of Paderborn, Group Nanophotonics and Nanomaterials, Warburger Str. 100, 33098 Paderborn

Due to its unique properties such as the large direct bandgap of 3.37eV and its high exciton binding energy, zinc oxide (ZnO) is a very promising semiconductor for optoelectronic and photonic applications even at room temperature. By adding cadmium (Cd) or magnesium (Mg) the bandgap can be tuned between 3.0eV and 4.0eV.

It has already been shown that plasma assisted molecular beam epitaxy (PA-MBE) is a very suitable technique for growing high-quality epilayers of ZnO. Especially for research issues small samples are often sufficient. By using ultra compact MBE-systems the running costs can be kept down. However, the special system geometry and the very compact design lead to high requirements on the system. It is not trivial that in such a system stoicometric and homogeneous growth conditions be achieved anyway. Furthermore, very high growth-rates can be obtained. By working in the zinc- (Zn) or oxygen-rich (O) regime completely different surface morphologies free of any metallic clusters are created.

We present a systematic study on the growth conditions in such a compact system. Especially, the determinaton of the flux will be discussed and the grown heterostructures will be characterised for their usability for nanophotonic devices.

HL 28.4 Wed 10:15 BEY 118

Growth of ZnO on Si by pulsed laser deposition under different oxygen partial pressures and temperatures — •Andreas Kraus, Helena Hilmer, Philipp Kühne, Stefan Schöche, Gerald Wagner, Christof Dietrich, Holger von Wenckstern, Matthias Brandt, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

ZnO thin films were grown on Si (111) substrates by pulsed-laser deposition at different oxygen partial pressures and temperatures, respectively. They were characterized by X-ray diffraction (XRD), I-V measurements, spectroscopic ellipsometry and for selected samples by transmission electron microscopy (TEM). XRD measurements show that by increasing the oxygen partial pressure, the crystalline quality first increases and then decreases. Further, the crystalline quality improves with increasing substrate temperature. Ellipsometry measurements show that the growth rate first increases with increasing the oxygen partial pressure and then decreases similar to the structural quality. The resistivity obtained by I-V characteristics indicates that the higher the temperature the lower is the resistivity. TEM images show a presence of a large number of grain boundaries which are due to the amorphous SiO_x layer on top of the Si substrate. These grain boundaries determine the electrical properties and consequently the I-V characteristics of the deposited ZnO layers.

15 min. break

HL 28.5 Wed 10:45 BEY 118

Growth of ZnO thin films on lattice matched GaN buffered sapphire substrates using pulsed laser interval deposition with in-situ RHEED — •Alexander Hirsch[1], Christian Wille[1], Frank Ludwig[1], Meinhard Schilling[1], Uwe Rossow[2], and Andreas Hangleiter[2] — [1]TU Braunschweig, Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, Hans-Sommer-Straße 66, D-38106 Braunschweig, Germany — [2]TU Braunschweig, Institut für Angewandte Physik, Mendelssohnstraße 2, D-38106 Braunschweig

Due to its wide and direct band gap ZnO is an interesting oxide semiconducting material. Nevertheless, p-type doping with long time stability remains difficult. One way to overcome the doping problem is to use n-type doped ZnO in combination with p-type doped GaN. Therefore, we have studied the pulsed laser deposition (PLD) growth of ZnO thin films on lattice matched GaN buffered Al_2O_3 substrates.

The target was prepared by standard ceramics synthesis. To achieve lattice matching to ZnO GaN was grown on top of the Al_2O_3-substrates using MOVPE. The ZnO thin films were grown using a PLD setup equipped with a high-pressure reflection high energy electron diffraction (RHEED) for in-situ investigation of the thin film quality. The structural investigation was supplemented by XRD and AFM.

The influence of the growth temperature and the effect of interval deposition on the thin film quality was analyzed. RHEED intensity oscillations have been observed. Best results are achieved using high temperatures and the technique of interval deposition. These conditions lead to high quality crystalline films with roughnesses < 1 nm.

HL 28.6 Wed 11:00 BEY 118

Design and characterization of ZnO-based MESFETs on glass

substrates — •Michael Lorenz, Heiko Frenzel, Holger Hochmuth, Gisela Biehne und Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Metal-semiconductor field-effect transistors (MESFETs) were fabricated by reactive dc-sputtering of Ag as Schottky-gate contact on ZnO thin films grown by pulsed-laser deposition (PLD) on glass substrates. For applications in transparent electronics, the use of cheap glass substrates is more beneficial than sapphire or other crystalline substrates. However, the non-epitaxial growth leads to more structural defects like dislocations, twist and tilt of grain boundaries, and higher surface roughness of the ZnO films. An insulating MgZnO buffer layer was introduced to decrease the influence of such defects on the Al-doped ZnO channel layer. X-ray diffraction, atomic force microscopy as well as Hall-measurements were performed on samples grown at different substrate temperatures between 440°C and 630°C and oxygen partial pressures ranging from 0.1 to 3×10^{-4} mbar. The channel mobilties are at about 1 cm^2/Vs and the on/off-ratio is 10^5. Normally-on and normally-off MESFETs were achieved by adjusting the Al-doping concentration between 0.01% and 0.001%.

HL 28.7 Wed 11:15 BEY 118

Direct Synthesis of Zinc Oxide Nanoseaurchins and Nanocups from Zn-Powder — •Yogendra Kumar Mishra[1], Seid Jebril[1], Rahul Singhal[2], Devesh Kumar Avasthi[2], and Rainer Adelung[1] — [1]Functional Nanomaterials, Institute of Materials Science, Faculty of Engineering, CAU Kiel — [2]Inter University Accelerator Centre, P. O. Box 10502, New Delhi-110067, India

ZnO, a II-VI semiconductor and a member of wurtzite structure family, has attracted enormous research interest due to it fascinating properties like high exciton binding energy, hydrophobic nature and biocompatibility [1]. In present work, we report the synthesis of ZnO nanourchins and nanocups by a vapour-liquid-solid (VLS) approach from Zn-powder in a tube furnace. The synthesis conditions like temperature and fractions were varied to investigate the fundamental phenomenon of growth. In some cases, formation of ZnO nanocups was observed however in most of the cases growth of long crystalline ZnO nanowhiskers were obtained, suggesting a growth kinetics that will be explained here. Au-ZnO nanocomposite was synthesized by atom beam co-sputtering and formation of ZnO nanorods with Au nanoparticles on the top after annealing at 600C was observed[2]. Scanning/transmission electron microscopies were used to observe the grown nanostructures. Experiments to utilize the structures as sensors as well as in biomedical engineering are in progress, first results are presented here.

[1] Z. L. Wang, Materials Today 26 (June 2004). [2] Y. K. Mishra et al., Appl. Phys. Lett. 92 (2008)43107.

HL 28.8 Wed 11:30 BEY 118

Homo- and heteroepitaxial growth of non-polar ZnO — Stefan Lautenschlaeger, •Sebastian Eisermann, Joachim Sann, Melanie Pinnisch, Andreas Laufer, and Bruno K. Meyer — 1st physics institute, JLU Gießen, Heinrich Buff Ring 16, 35392 Gießen

Polarization fields, parallel to the c-axis, strongly reduce the quantum efficiency in wurzite semiconductors. To eliminate these polarization fields epitaxial ZnO thin films have been grown on a-plane ZnO, r-plane sapphire and a-plane GaN templates. The grown epilayers have been investigated using low temperature Photoluminescence (PL), Atomic Force Microscopy (AFM), Secondary Ion Mass Spectrometry (SIMS), Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD) and Raman spectroscopy. We compare the hetero- and the homoepitaxially grown samples with respect to their morphological and optical quality.

15 min. break

HL 28.9 Wed 12:00 BEY 118

Identification of excitonic transitions in $Mg_xZn_{1-x}O$ thin films grown by pulsed laser deposition — •Christof Dietrich, Gabriele Benndorf, Jörg Lenzner, and Marius Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für Experimentelle Physik II, Leipzig, Germany

The incorporation of Mg-atoms into ZnO leads to an increase of the band-gap allowing a tuning between 3,4 eV and about 8 eV. Nevertheless the recombination mechanisms in MgZnO are not yet well understood because alloy broadening superimposes spectral information.

In order to obtain more information about the recombination mechanisms, MgZnO thin films with a low Mg-content (1 - 7 %) were grown on a-plane sapphire substrates by pulsed-laser deposition. Buffer layers containing about 40 % Mg were deposited prior to the thin films. The Mg-contents were determined by energy dispersive x-ray diffraction spectroscopy.
Photoluminescence measurements at 2 K showed two peaks with a separation of 15 meV in the excitonic regime which we attribute to the transitions of the free and the Al-donor bound excitons. Temperature dependent photoluminescence measurements from 5 K up to room temperature confirmed this and revealed a S-shape behaviour for the donor bound exciton only.

HL 28.10 Wed 12:15 BEY 118

Magneto-optical studies of bound exciton complexes in homoepitaxially grown polar ZnO Epilayers — •J.-H. Schulze[1], M. R. Wagner[1], C. Rauch[1], A. Hoffmann[1], J. Sann[2], S. Lautenschläger[2], B. K. Meyer[2], and A. Rodina[3] — [1]Technische Universität Berlin, Institut für Feskörperphysik, Herdenbergstraße 36, 10623 Berlin, Germany — [2]Justus Liebig Universität Giessen, I. Physics Insitute, Heinrich-Buff-Ring 16, 35592 Giessen, Germany — [3]A. F. Ioffe Physico-Technical Institute, 194021 St.-Petersburg, Russia

The optical properties of homoepitaxially grown ZnO are strongly influenced by the surface polarity of the substrate. This dependency is e.g. shown at the luminescence of complex bound excitons. Our investigations revealed excitonic recombination lines that could exclusively be observed from a sample grown on O-polar ZnO (PRB 77, 144108). In order to determine the complex properties of this excitons magneto-optical investigations are performed. The electron- and hole effective g-values of the involved complex are calculated from these measurements. To obtain information about the symmetry of the excitonic valence states angular resolved magneto-optical data is acquired. Temperature and power dependent PL measurements are done to get further insight into the explicit recombination behavior with respect to the fine structure splitting. In addition pico-second time resolved measurements reveal the recombination dynamics. These results are compared with the temperature and magnetic field dependent thermalization behavior. Possible defect models and energy level splittings are discussed and compared to theoretical models.

HL 28.11 Wed 12:30 BEY 118

Electrical properties of ZnMgO thin films grown by pulsed-laser deposition — •Kerstin Brachwitz, Holger von Wenckstern, Holger Hochmuth, Gisela Biehne, Christof Dietrich, Matthias Brandt, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Abteilung Halbleiterphysik

We present electrical investigations of $Mg_xZn_{1-x}O$-semiconductor alloys, grown by pulsed-laser deposition (PLD). The Mg-content in the samples ranged from 4% to 50%. We grew nominally undoped and intensionally Al-doped (0.5%) MgZnO thin films and investigated their structural and electrical properties in dependence on the Mg-content. Furthermore we monitored changes of the samples properties after annealing for 30 minutes at different temperatures (500°C, 700°C and 900°C) in 700 mbar oxygen. High quality Schottky contacts were realized by reactive dc-sputtering of Pd. We investigated their properties by current-voltage- (IV) and capacitance-voltage-measurements (CV). Further on, we used these Schottky diodes to investigate defect states using depletion layer spectroscopy. Additionally we characterized the samples by X-ray-diffraction (XRD), atomic force microscopy (AFM) and photoluminescence (PL). In conclusion we will show correlations between the structural and electronic properties for the as-grown and the annealed samples.

HL 28.12 Wed 12:45 BEY 118

Nitrogen incorporation in ZnO thin films grown by radio frequency (RF) sputtering — •Sebastian Eisermann, Stefan Lautenschlaeger, Andreas Laufer, Angelika Polity, and Bruno K. Meyer — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Bipolar conduction of electron and holes is mandatory for many electronic and opto-electronic applications of ZnO. Among the impurity atoms suited for acceptor formation nitrogen is the prime candidate. Controlling the incorporation without the formation of deep donors and acceptors and avoiding the deterioration of the materials quality is a main goal for homo- and heteroepitaxially grown ZnO films. We report on the sputter deposition of N-doped ZnO layers and will show by SIMS and Raman spectroscopy how the substrate type and

substrate temperature influence the nitrogen incorporation.

HL 29: Quantum dots: Optical properties II

Time: Wednesday 9:30–13:00 Location: BEY 154

HL 29.1 Wed 9:30 BEY 154

Multiparticle Calculations for Single GaN/AlN Quantum Dots - Results and Comparison — •Gerald Hönig, Momme Winkelnkemper, Andrei Schliwa, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany

Despite tremendous advances in single quantum dot (QD) spectroscopy of GaN/AlN QDs, many of their properties, especially the Coulomb-interactions in multiparticle-systems, are only poorly understood. In this theoretical work we investigate different calculation methods for such interactions based on 8-band-kp theory.

Configuration-interaction (CI) calculations for this QD-system fail due to an insufficient basis size, which is limited by the computational expense. Self-consistent calculations within the Hartree-approximation have been performed, neglecting exchange- and correlation-effects. Different approaches (e.g. local density based approximations) are used to include these effects, correcting the Hartree-energies of excitons, trions, biexcitons confined in QDs with different structural properties and giving more realistic results for recombination energies. We will report our results and compare the different methods.

HL 29.2 Wed 9:45 BEY 154

Demonstration of strong coupling via electro-optical tuning in high quality QD-micropillar systems — •Caroline Kistner, Tobias Heindel, Christian Schneider, Arash Rahimi-Iman, Stephan Reitzenstein, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg

The investigation of cavity quantum electrodynamics effects such as strong coupling in optically pumped QD-microcavity systems has become an active area of research in recent years. Up to now, most of the experiments employed a temperature change of the sample in order to tune a QD exciton line through resonance with the cavity mode. This limits the tuning speed to the range from kHz to MHz due to the thermal relaxation time of the structures. Recent progress in the fabrication of electrically contacted micropillar cavities enabled us to develop a reversible and fast electro-optical resonance tuning technique. Electro-optical tuning exploits the quantum confined Stark effect (QCSE) and paves the way for fast optical switches operating in the GHz range. Making use of the QCSE we tuned a QD emission line through resonance with a high quality (Q) cavity mode (Q=14,000) by applying a reverse bias to the p-i-n structure and observed of strong coupling associated with a vacuum Rabi-Splitting of 63 μeV.

HL 29.3 Wed 10:00 BEY 154

Phonon-assisted tunneling in two-electron quantum dot molecules — •Anna Grodecka[1], Paweł Machnikowski[2], and Jens Förstner[1] — [1]Computational Nanophotonics Group, Theoretical Physics, University Paderborn, Paderborn, Germany — [2]Institute of Physics, Wrocław University of Technology, Wrocław, Poland

Spin states of two-electron doped quantum dot molecules (QDMs) have been employed in many quantum logical gates proposals where tunneling processes play a crucial role. Therefore, their timescales and efficiency are of primary importance. In this work, phonon-assisted tunneling in a lateral two-electron QDM is studied theoretically [1]. The phonon and Coulomb interactions are simultaneously incorporated. We take into account interaction with acoustic phonons via deformation potential and piezoelectric coupling and show that the latter can be even the dominant contribution. The phonon-assisted tunneling rates calculated for GaAs QDMs reach values (up to 160/ns) many orders of magnitude higher than the other decoherence processes resulting from spin-orbit or hyperfine interaction, thus can play a dominant role in QDM-based quantum gates.

1. A. Grodecka, P. Machnikowski, and J. Förstner, Phys. Rev. B 78, 085302 (2008).

HL 29.4 Wed 10:15 BEY 154

The Influence of Fröhlich-Coupling on Rabi-Oscillations in Semiconductor Quantum Dots — •Kolja Schuh, Jan Seebeck, Paul Gartner, and Frank Jahnke — Institute for Theoretical Physics, University of Bremen, Germany

Rabi-oscillations can be used to switch occupations in a well-defined way and therefore are considered for application in optical switches. Particularly quantum dots have been regarded as possible candidates. The influence of dephasing due to electron-LA-phonon interaction in semiconductor quantum dots was shown in Ref. [1]. In addition to dephasing, this contribution focuses on the influence of scattering processes due to electron-LO-phonon-interaction.

We use a quantum-kinetic many-body theory, where carriers are described as polarons [2]. For quantum-dot states the effective coupling is enhanced, so that there are strong dephasing as well as fast carrier scattering processes even for semiconductors with weak polar coupling. We find that the particle scattering is of particular importance for the switching behaviour as the carrier distribution changes even in the absence of an optical pulse.

[1] J. Förstner et al., Phys. Rev. Lett. 91, 127401 (2003).
[2] J. Seebeck et al., Phys. Rev. B 71, 125327 (2005).

15 min. break

HL 29.5 Wed 10:45 BEY 154

Influence of phonon confinement on optical and current spectra in nanowire-based quantum dots — •Carsten Weber and Andreas Wacker — Mathematical Physics, Lund University, Box 118, 221 00 Lund, Sweden

Recent progress in the growth of nanowire heterostructures allows the study of quantum dots embedded in semiconductor nanowires. Here, we investigate the influence of the reduced dimensionality of the quantized phonon modes on the electron-phonon coupling and compare it to the interaction with bulk phonons. In the optical spectrum, this is reflected in the form of discrete side peaks of the excitonic transition and a zero-phonon line broadening, where both the deformation potential and the piezoelectric coupling are important for different types of phonon modes. In transport signals, discrete characteristics found in the current spectra through double dot systems may be explained by the one-dimensional density of states of the phonons. We present theoretical results of electron-phonon coupling in nanowire-based quantum dots in optical and current spectra.

HL 29.6 Wed 11:00 BEY 154

Time-resolved μ-photoluminesence investigations of group-III-nitride quantum dots — •Thomas Switaiski, Stefan Werner, Erik Stock, Momme Winkelnkemper, Axel Hoffmann, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin

Small fluctuations in size, shape and composition of self-organized quantum dots (QDs) strongly effect the decay times of localized excitonic transitions. Here, we present time and spatially resolved photoluminesence measurements of single InGaN/GaN QDs. The sample is excited with the second harmonic of a modelocked and tuneable Ti:Sapphire laser through a metallic shadow mask, which improves the lateral resolution and allowing spectroscopy of single QDs. Using eight-band $\boldsymbol{k} \cdot \boldsymbol{p}$ modelling, we show that the built-in piezo- and pyroelectric fields within the QDs cause a sensitive dependence of the radiative lifetimes of the exact QD geometry and composition. Moreover, the radiative lifetimes also depend strongly on the composition of the direct surrounding of the QDs.

HL 29.7 Wed 11:15 BEY 154

Resonant Raman and resonant photoluminescence spectroscopy on quantum-dot helium — •Tim Köppen[1], Dennis Franz[1], Andreas Schramm[2], Christian Heyn[1], Detlef Heitmann[1], and Tobias Kipp[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Optoelectronics Research Center, Tampere University of Technology, Finland

We investigate electronic excitations in InGaAs quantum dots containing two electrons, also called artificial quantum-dot helium, by resonant optical spectroscopy in magnetic fields. In order to match the quantum dot ground state transition energy to both the sensitivity range of our detector and the emission energy range of our laser we rapidly thermally annealed the samples. The occupation of the quantum dots with electrons can be precisely controlled and monitored by applying a voltage between a back contact and a gate of our sample and by measuring the capacitance. The quantum-dot helium is the most fundamental system to investigate many-particle effects induced by Coulomb interaction. We observe optical transitions in the quantum dots provoked by resonant Raman and resonant photoluminescence spectroscopy.

This project is supported by the Deutsche Forschungsgemeinschaft via SFB 508 "Quantenmaterialien".

HL 29.8 Wed 11:30 BEY 154

Low threshold lasing in electrically pumped high-Q quantum dot-micropillar cavities — •Tobias Heindel, Caroline Kistner, Arash Rahimi-Iman, Christian Schneider, Sven Höfling, Stephan Reitzenstein, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

High-Q semiconductor microcavities are very attractive structures for the study of low threshold lasing with quantum dot (QD) gain media. Exploiting cavity quantum electrodynamics (cQED) effects these structures are good candidates for a thresholdless laser as they feature a large fraction β of spontaneous emission coupled into the lasing mode. So far, most of the studies on microcavity lasers have focussed on lasing in optically pumped QD-microcavity systems. However, in light of an ultimate thresholdless microcavity laser, it is crucial to combine pronounced cQED effects with the possibility of electrically pumping the active medium.

We report on low threshold lasing in high-Q electrically pumped QD-micropillar cavities. Lasing action associated with threshold currents as low as 8 μA at 10 K is observed for micropillar lasers with quality factors exceeding 10.000. An optimized contact scheme allows us to observe lasing for pillar structures with diameters as small as 1.5 μm, containing on average less than 100 quantum dots as gain medium. Photon autocorrelation studies reveal pronounced photon bunching near threshold as a clear signature for the transition from spontaneous to stimulated emission.

15 min. break

HL 29.9 Wed 12:00 BEY 154

Electric field tunable polarization and enhanced single-photon emission from lateral quantum dot molecules embedded in a planar microcavity — •Marcus Witzany[1], Claus Hermannstädter[1], Matthias Heldmaier[1], Gareth J. Beirne[1,4], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Lijuan Wang[2], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmadring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Helmholtzstr. 20, 01069 Dresden — [4]now: Cavendish Laboratories, University of Cambridge, J.J. Thomson Ave., Cambridge, CB3 0HE, UK

The photoluminescence (PL) from single InGaAs quantum dot molecules (QDMs) embedded in a planar micro-cavity grown using a combination of metal-organic vapor phase and molecular beam epitaxy has been examined. We demonstrate that embedding the QDM in a planar micro-cavity increases the single-photon extraction efficiency by a factor of 30. The molecules consist of two quantum dots coupled along the [1-10] crystal direction via electron tunneling [PRL 96, 137401, 2006]. The QDM PL is found to be linearly polarized along [1-10] with different polarization anisotropy values between 0 - 40% depending on the QDM geometry and coupling. Applying an electric field along the coupling axis can enhance the linear polarization of the PL due to electron wave function elongation.

HL 29.10 Wed 12:15 BEY 154

Nanocrystal Quantum Dots as Emitters in DBR Microcavities — •Johannes Haase[1], Tobias Otto[2], Maik Langner[1], Dirk Dorfs[2], Hartmut Fröb[1], Alexander Eychmüller[2], and Karl Leo[1] — [1]TU Dresden, Institut für Angewandte Photophysik, George-Bähr-Str. 1, 01069 Dresden — [2]TU Dresden, Physikalische Chemie und Elektrochemie, Bergstr. 66b, 01062 Dresden

Semiconductor nanocrystal quantum dots (NQD) have the outstanding property to emit photons of a wavelength depending on their physical size as a result of the quantum confinement. They are therefore spectral tunable emitters and furthermore exhibit very high quantum yields. For organic microcavity lasers or organic photonic boxes they can be used as alternative emitters or secondary emitters being coupled to the emission of the organic molecules. In our experiments, we use colloidal synthesized CdSe(core)/CdS(shell) rods, where the absorption edge is more blue shifted, with respect to the emission line, than for particles without shell. We incorporate these particles into transparent, thermally stable matrices with a high concentration of the NQDs. By varying the film thickness and changing the refractive index of the material by the amount of NQDs in the matrix material, we can modify the resonance conditions of the cavity to match the peak emission of the NQDs. We present emission spectra from micro-photoluminescence measurements.

HL 29.11 Wed 12:30 BEY 154

All optical spin storage and readout in a single quantum dot — Dominik Heiss, Vase Jovanov, Florian Klotz, •Daniel Rudolph, Max Bichler, Martin S. Brandt, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

We propose an all optical spin readout method for single quantum dots (QDs) and demonstrate its feasibility. Our method involves using a voltage switchable QD spin memory structure that can be switched between two modes of operation: (i) charging, where optically generated holes are removed from the dot whilst electrons remain stored and (ii) readout, where optically generated carriers recombine to produce luminescence. The spin projection of a electron prepared using circularly polarized light during the charging phase of the measurement can be tested via a polarization conditional absorption of a second laser pulse tuned to the X- transition. This readout pulse converts the spin information of the resident electron into a charge occupancy (1e or 2e), which can then be repeatedly sampled during the readout phase of the measurement. The charging and discharging dynamics are probed using time dependent measurements to measure the tunneling escape time of the electron and hole. Furthermore, first measurements in magnetic fields (B=10 T) show indications of spin blockade during attempts to charge the dot with the second electron. This blockade can be lifted by delaying the 2e charging pulse by times longer than the electron spin relaxation time (T1˜40 us).

HL 29.12 Wed 12:45 BEY 154

Optical spin control in charged quantum dots with a single Mn atom — •Giselmar Hemmert[1], Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, WWU Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

In semiconductor quantum dots spins bear good prospects as basic elements for new quantum hardware such as quantum bits. In a single quantum dot containing a single Mn atom charged by an electron (hole) the excitation by laser light causes the formation of a trion complex, i.e. a positively or negatively charged exciton. The trion spin, like the carrier spin in the non-excited state, is coupled to the Mn spin via the exchange interaction. This coupling allows for the manipulation of the optically not directly accessible Mn spin via spin flip processes of either the electron (hole) or the trion and thus ultimately for the manipulation of the Mn spin by laser light. We consider a charged CdTe quantum dot doped with a single Mn atom and focus on electron and light hole processes as heavy holes do not induce spin flips. Starting from a well defined initial state we show that the six Mn spin states can be set by a series of ultrashort laser pulses. Thus besides the electron (hole)/trion spin also the Mn spin may be used as a basis for controlled operations in the field of spintronics.

HL 30: Si/Ge

Time: Wednesday 9:30–13:00 Location: POT 51

HL 30.1 Wed 9:30 POT 51

Comparison of the top-down and bottom-up approach to synthesise nanowire-based Si/Ge heterostructures — •Andreas Wolfsteller, Nadine Geyer, Trung-Kien Nguyen-Duc, Nikolai Zakharov, Manfred Reiche, Wilfried Erfurth, Ursel Doss, Horst Blumtritt, Peter Werner, and Ulrich Gösele — Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle (Saale), Germany

Si nanowires (NWs) and nanowire-based Si/Ge heterostructures are expected to be building blocks for future electronic and optical devices, e. g. new field-effect transistors or sensors. In principle two approaches can be applied to synthesise NWs: i) the 'top-down' approach and ii) the 'bottom-up' approach. The most common method for the latter is the vapour-liquid-solid (VLS) mechanism, which can also be applied to grow NWs by molecular beam epitaxy (MBE). However, the VLS mechanism prevents the synthesis of heterostructures with sharp interfaces and high Ge concentrations due to the general nature of the growth process via an eutectic. Furthermore, Au, which acts as the catalyst, can be incorporated into the crystal structure, possibly resulting in a significant loss of optical properties. In the 'top-down' approach the Si/Ge heterostructure is first grown by MBE as a multilayer leading to sharper interfaces and higher element concentrations with the drawback of the generation of misfit-dislocations. The NWs (40 nm diameter) are then produced by electron beam lithography and reactive ion etching. The morphology, structure and chemical composition of both kind of NWs was analyzed by TEM, SEM, and EDX.

HL 30.2 Wed 9:45 POT 51

Interplay between Si dangling bond states and P doping in freestanding Si nanocrystals — •Andre R. Stegner[1], Rui N. Pereira[1,2], Jinming Lu[1], Hartmut Wiggers[3], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]University of Aveiro, 3810-193 Aveiro, Portugal — [3]Universität Duisburg-Essen, Institut für Verbrennung und Gasdynamik, Lotharstrasse 1, 47048 Duisburg

Electron paramagnetic resonance (EPR) and secondary ion mass spectroscopy (SIMS) have been used to investigate the phosphorus doping of freestanding silicon nanocrystals (Si-NCs) with mean diameters selected between 4 nm and 45 nm which were produced by microwave-induced decomposition of silane and phosphine in a low-pressure plasma reactor. SIMS results do not indicate a size dependence of the P incorporation efficiency. However, it is found that approx. 95% of the P segregates to the Si-NC surface region during growth, which is oxidized after exposure to air. The concentration of electrically active, paramagnetic P detected by EPR further falls below this SIMS concentration by about one order of magnitude for Si-NCs with diameters larger than 15 nm. Charge compensation by Si dangling bonds, which are investigated using room temperature EPR and which can be passivated by H, is shown to be the reason for this deviation and can quantitatively be described by a statistical model. For smaller Si-NCs, a further strong drop of the concentration of paramagnetic donors is observed, which cannot be explained by the compensation model alone.

HL 30.3 Wed 10:00 POT 51

Fabrication of Silicon Nanostructures by Laser Interference Lithography and Metal-Induced Etching — •Johannes de Boor, Nadine Geyer, Dirk Hagen, Volker Schmidt, and Ulrich Gösele — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Nanostructured silicon is the foundation of nowadays electronics. Trying to meet the demand for increasing device densities, much scientific and industrial effort has been spent on the fabrication of silicon nanostructures by various approaches.

We present a simple, fast, and cost-effective method to produce virtually defect- free and strictly periodic arrays of silicon nanowires and other nanostructures.

In a first step photoresist patterns with square symmetry are created by laser interference lithography. The applied frequency doubled argon-ion laser has a wavelength of 244 nm and the period of these patterns can be varied continuously between 130 nm and 1000 nm. In a second step a noble metal film is deposited onto the exposed silicon parts and the photoresist is removed. In a HF/H_2O_2 solution the silicon in contact with the metal film is dissolved in a redox reaction, i.e. the metal film sinks into the substrate. As result an array of single crystalline nanowires with narrow size distribution is formed, the diameter of the wires can be chosen between several hundred and 80 nm. By varying illumination times and angles other structures like nanofins can be formed as well, all periodic over several cm^2.

HL 30.4 Wed 10:15 POT 51

Electronic and transport properties of semiconducting nanoparticles — •Andreas Gondorf[1], Martin Geller[1], Daniel Tadych[1], Axel Lorke[1], Cedrik Meier[2], and Hartmut Wiggers[3] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen, Duisburg — [2]Department of Physics, University of Paderborn — [3]Combustion and Gas Dynamics, University of Duisburg-Essen

We investigate the charge carrier concentration and mobility in Ge and Si nanoparticle pellets. These transport properties are crucial for future Si or Ge based optoelectronic devices, as they determine the conductivity, for instance, in printable electronics. We use current-voltage (I-V) and Hall-measurements and find a very weak but measurable Hall-effect in compressed powder pellets. In pellets based on Si nanoparticles a very low charge carrier concentration of about 10^{12} cm^{-3} is measured at 250°C while Ge nanoparticles show at 25°C two order of magnitude higher concentration of about $4 \cdot 10^{14}$ cm^{-3}. These numbers are comparable to the intrinsic charge carrier concentration in the corresponding bulk materials. Ge nanoparticles have a very small mobility of 0,1 cm^2/Vs at 25°C which is comparable to the mobility of organic semiconductors. Surprisingly for Si nanoparticles we find mobilities of up to 100 cm^2/Vs at 250°C which is not understood yet. Furthermore we show a simulation of I-V characteristics of semiconducting nanoparticles embedded in a dielectric matrix. The model includes the size dependent band gap and capacitance and the size distribution of the particles. The simulation is in good agreement with experimental results [C. H. Cho et al. Appl. Phys. Lett. **89** 013116 (2006)].

HL 30.5 Wed 10:30 POT 51

Doping of vertical silicon nanowires by ion implantation — •Pratyush Das Kanungo[1], Reinhard Kögler[2], Nikolai Zakharov[1], Kien Ngyuen-Duc[1], Peter Werner[1], and Ulrich Gösele[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [2]Forschungszentrum Dresden - Rossendorf, FWIM, 01314 Dresden, Germany

Ion implantation is one of the key processing steps in fabricating planar silicon devices and circuits in the ultra large scale integration (ULSI) technology. With ion implanatation one can selectively dope specific areas on a planar silicon device defined by lithographic masks and confine the vertical penetration depth of the dopant atoms into the bulk of silicon at that region. However, this process has so far not been fully exploited in nanoelectronics, especially in doping silicon nanowires (Si NWs). Si NWs which are promising candidates for future nanoelectronics have mostly been doped in situ. We demonstrate that ion implantation can also effectively dope vertical Si NWs both n and p-type. We implanted boron as p-type dopant, and separately phosphorus and arsenic as n-type dopants on the Si NWs grown by molecular beam epitaxy. We demonstrate homogeneous doping [1] along the length of the NWs, as well as formation of an axial p-n junction inside the NWs and performed detailed structural and electrical characterizations of individual NWs. For the p-n junction formation a combined approach of in situ p-doping [2] and ex situ n-doping was used. Our results show significant differences between n and p-doping which conform to theory.

HL 30.6 Wed 10:45 POT 51

Polycrystalline silicon layers for large area electronics prepared by aluminum-induced layer exchange — •Christian Jaeger, Tobias Antesberger, Michael Algasinger, and Martin Stutzmann — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

Polycrystalline silicon thin films on low cost substrates are attractive for large area electronics. Besides laser-annealing, metal-induced

methods for crystallization of amorphous silicon are of general interest for this purpose. In particular, the aluminum-induced layer exchange (ALILE) process is a promising approach to obtain large-grained high quality polycrystalline Si films at low process temperatures. In a typical ALILE process, an Al/amorphous Si layer stack, separated by a thin oxide film, is annealed at temperatures below the eutectic temperature (570°C) of the Al-Si system, leading to a layer exchange and the crystallization of the a-Si. Due to the high solid solubility of Al in Si, the resulting layers are p-doped with hole carrier concentrations of about $10^{19}\mathrm{cm}^{-3}$.

In this work, a hydrogen plasma is used to passivate the Al acceptors, thereby reducing the hole carrier concentrations in the crystallized poly-Si films. Field-effect structures in bottom-gate configuration made from hydrogenated ALILE films are prepared and characterized. The influence of different gate insulators like thermally grown SiO_2, HfO_2, and Ta_2O_5 will be shown. Furthermore, the dependence of field effect mobilities, threshold voltages, and interface state densities on the device properties will be presented.

HL 30.7 Wed 11:00 POT 51

Electrical transport in undoped laser-crystallized polycrystalline silicon-germanium thin films — •Lars-Peter Scheller[1], Moshe Weizman[1], N. H. Nickel[1], and Baojie Yan[2] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Ovonic Corporation, 1100 West Maple Road Troy, MI 48084, USA

Due to its enhanced optical absorption in the IR and visible spectral range polycrystalline silicon-germanium (poly-SiGe) is a promising absorber material for future thin film and tandem solar cells.
In this study we report on the electrical transport properties of intentionally undoped laser-crystallized poly-$Si_{1-x}Ge_x$ thin films ($0 \leq x \leq 1$) on quartz. Temperature dependent Hall and conductivity measurements reveal a strong dependence of the main transport mechanism on both, the alloy composition and the crystallization procedure. At low temperatures most of the intentionally undoped films show an unexpected high p-type conductivity with a characteristic temperature dependence of either variable range hopping (VRH) or metallic like transport. Moreover, a post hydrogen treatment of the laser-crystallized samples causes a strong decrease of the conductivity. In some cases this reduction is accompanied by a change in the dominating low temperature transport mechanism from either metallic to hopping or hopping to activated behavior. This effect will be explained with an intrinsic transport path along grain boundaries caused by Ge dangling bonds.

15 min. break

HL 30.8 Wed 11:30 POT 51

Strained delta SiGe Layer for increasing ON current of Tunnel Field Effect Transistors (TFET) — •Helmut Lochner, Peter Iskra, Dorota Kulaga-Egger, Martin Schlosser, Thomas Zilbauer, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

To meet the high demands of process and information technology the semiconductor industry gets into problems in the development of new devices. Continuous downscaling leads to increasing importance of quantum mechanical effects, such as the band to band tunnelling mechanism which has to be avoided or reduced in standard CMOS technology. Instead of avoiding the Tunnel Field Effect Transistors (TFET) uses this tunnel current as an advantage, but the ON current cannot fulfil the International Technology Roadmap for Semiconductors. We attempt to adjust this demerit for example by band gap engineering. We fabricated vertical TFETs in silicon with different silicon-germanium delta layers grown epitaxially in a Centura Cluster Tool by means of LPCVD. The device structure is a common p-i-n diode with gated intrinsic layer. To distinguish the influences of strained silicon-germanium we varied the strain in the interface layers between the intrinsic channel and source or drain respectively by different germanium concentrations. The experimental I-V characteristics show the advantages of these SiGe delta layers. The subthreshold slope increases clearly and the ON current considerably. The theoretical border will be shown in simulations.

HL 30.9 Wed 11:45 POT 51

Electronic structure and effective masses in strained silicon — •Mohammed Bouhassoune[1,2] and Arno Schindlmayr[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Department Physik, Universität Paderborn, 33095 Paderborn, Germany

Metal-oxide-semiconductor field-effect transistors (MOSFETs) based on strained silicon hold considerable interest for modern microelectronics, because they are compatible with existing manufacturing technology and promise higher carrier mobility and faster switching times. Here we quantitatively examine the effect of strain on the electronic structure of silicon, combining density-functional theory within the local-density approximation and the GW approximation for the electronic self-energy. Quasiparticle band structures, deformation potentials and effective masses are obtained for tetragonal, orthorhombic and trigonal distortions of the unit cell, corresponding to biaxial strain in the (100), (110) and (111) planes with full relaxation, respectively. The tetragonal and orthorhombic distortions lift the sixfold degeneracy of the conduction-band minimum. Furthermore, strain in any direction causes the band structure to warp, and an energy split between light and heavy holes occurs at the top of the valence band. The inclusion of proper self-energy corrections within the GW approximation in our work not only yields band gaps in much better agreement with experimental measurements, but also predicts slightly larger electron effective masses. Even for small strain values, these changes in the electronic structure significantly affect the mobility of the charge carriers.

HL 30.10 Wed 12:00 POT 51

Phosphorus doping by chemical vapour deposition for vertical p-MOSFETs — •Peter Iskra, Dorota Kulaga-Egger, Thomas Zilbauer, Helmut Lochner, Torsten Sulima, and Ignaz Eisele — Universität der Bundeswehr München, Institut für Physik, Werner-Heisenberg- Weg 39, 85577 Neubiberg

The major advantage of a vertical MOSFET concept is the capability of defining the channel length by the thickness of the deposited layer. This allows an inexpensive fabrication of short channel devices. The deposition of the epitaxy stacks can be realized by LP-CVD (low pressure chemical vapour deposition). But, while the CVD process for p-type doping provides sharp doping profiles, the n-type doping suffers from surface segregation. This leads to an inhomogeneous doping profile and to redistribution of dopands from an underlaying doped layer into subsequent layers. A suppression of this effect can be achieved by optimizing the deposition parameters, the use of additional precursors or an ex situ wafer cleaning process.

Epitaxial pnp-structures were grown using a commercial LPCVD system. Dichlorosilane, phosphine and diborane were used as silicon and dopand sources. The n-type process was investigated with respect to growth temperature and dopand precursor flow. Additionally n-doped SiGe layers ware deposited for studying the influence on the phosphorus surface segregation. The germanium content was adjusted by germane flow. Furthermore, an ex situ oxidation cleaning process was investigated. All samples were characterised by secondary ion mass spectrometry (SIMS).

HL 30.11 Wed 12:15 POT 51

Optical spin injection and two-color interference effects in Ge — •Julien Rioux[1,2] and John E. Sipe[1] — [1]Department of Physics and Institute for Optical Sciences, University of Toronto, Canada — [2]Department of Physics, University of Konstanz, Germany

We discuss spin population and currents in bulk germanium injected by one- and two-photon absorption. For monochromatic circularly-polarized light, we calculate the spectral dependence of the spin polarization of photoexcited carriers. In the case of two-color irradiation, currents are generated and coherently controlled by interference of one- and two-photon transitions. In particular, we look at the contribution of the holes to these all-optical effects. Calculations are performed with a full-zone $\mathbf{k} \cdot \mathbf{p}$ band structure.

HL 30.12 Wed 12:30 POT 51

Vanadium:Silicon - an ion-beam generated diluted magnetic semiconductor? — •Sibylle Gemming, Mike B. Thieme, and Kay Potzger — Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, D-01314 Dresden, Germany

The generation of dilute magnetic semiconductors (DMS) by ion-beam implantation of magnetic centres into semiconducting materials has experienced renewed interest since the generation of magnetic thin films from the Cobalt-doped wide-gap semiconductor TiO2. Since the magnitude of the magnetic moment in such films is strongly varying

and since the implementation in a standard, Silicon-based semiconductor device is challenging, we have concentrated on the binary and fully integrable system Vanadium:Silicon. At higher doping concentrations, Vanadium and Silicon form several binary compounds; the most well characterised structures have the compositions V:Si= 3:1, 5:3, 6:5, 1:2, and bear the potential to exhibit magnetism. At higher dilution, Vanadium may form point defects in the crystalline Silicon host matrix. Here, we investigate different combinations of substitutional and interstitial vanadium atoms in a silicon crystal matrix.

HL 30.13 Wed 12:45 POT 51

Properties of Vacancies in Germanium Probed by Fast Diffusing Transition Metals — Ludmila Lerner and •Nicolaas Stolwijk — Universität Münster, Institut für Materialphysik, 48149 Münster

The equilibrium concentration and diffusivity of vacancies (V) in Ge were assessed as a function of temperature from a detailed analysis of the diffusion behaviour of Co and Fe in electronic-grade Ge wafers. Surprisingly, it was found that the resulting equilibrium concentrations C_V^{eq} exceed the published experimental data by one order of magnitude. Accordingly, the diffusivities D_V fall below existing estimates by roughly a factor of ten in order to reproduce the well-established Ge self-diffusivity via the vacancy mechanism. In addition, the enthalpy of vacancy formation appears to be much smaller than the values calculated by ab initio theoretical methods.

Diffusion experiments were performed with the radiotracers ^{57}Co and ^{59}Fe over the temperature range 600-900 °C. The sensitivity of Co and Fe diffusion for the vacancy properties of the Ge host lattice relies on the observation that these impurities migrate via the dissociative mechanism involving V-mediated interstitial-substitutional exchange. In particular, Co was found to be an interesting probe atom as it crosses the borderline - upon increase of temperature - between a V-controlled mode of diffusion and a Co-interstitial-controlled one. Also the fact that the solubility of substitutional Co proved to be similar in magnitude to C_V^{eq} constitutes a crucial feature in the evaluation of the V-related data.

HL 31: Walter Schottky Prize

Time: Wednesday 13:00–13:45 Location: HSZ 01

Prize Talk HL 31.1 Wed 13:00 HSZ 01

Optomechanics — •Florian Marquardt — Department of Physics, Center for NanoScience, and Arnold Sommerfeld Center for Theoretical Physics, Ludwig Maximilians Universität München, Theresienstrasse 37, 80333 München — Träger des Walter-Schottky-Preises

In this talk I will review recent progress in understanding the physics of the interaction between radiation and mechanical motion. The paradigmatic system in this field of 'optomechanics' consists of an optical cavity with a movable mirror attached to a cantilever. I will discuss how the coupled dynamics of the light field inside the cavity and the cantilever motion gives rise to a series of interesting effects. On the level of classical dynamics, I will present the theory of nonlinear oscillations and the corresponding attractor diagram. Furthermore, it is possible to cool the cantilever by irradiating the cavity with a red-detuned laser beam. I will present the quantum theory of optomechanical cooling and discuss the prospects for reaching the ground state of the cantilever's center-of-mass motion. This could open the door to the observation of quantum jumps between Fock states of a macroscopic object, and I will illustrate this by presenting a setup where a quantum-non-demolition measurement of the cantilever's phonon number could be achieved. Finally, I comment on the opportunities opened up by various recent developments in this field, such as the connection with cold atom physics.

HL 32: Focused Session: Quantum optomechanics

Time: Wednesday 14:00–15:30 Location: HSZ 01

Topical Talk HL 32.1 Wed 14:00 HSZ 01

Cavity Optomechanics using Optical Microresonators — •Tobias Kippenberg[1,2], Albert Schliesser[2], Remi Riviere[2], and Olivier Arcizet[2] — [1]Ecole Polytechnique Federale de Lausanne (EPFL) — [2]Max Planck Institut fuer Quantentoptik (MPQ)

In this talk I will describe the advances the Max Planck Institute of Quantum Optics has made in the field of cavity optomechanics. Using on chip micro-cavities that combine both optical and mechanical degrees of freedom in one and the same device(2), we have been able to show that the radiation pressure back-action of photons can be used to passively cool3 the mechanical oscillator, akin to Doppler Cooling of Atoms. Furthermore, we have been able to demonstrate for the first time resolved sideband cooling(4) by using optical microresonators whose mechanical oscillator frequency exceeds the cavity decay rate. This technique is well known in Atomic Physics to provide ground state cooling. Moreover the ability to monitor the motion of the oscillator with a quantum limited sensitivity attometer will be discussed and a description of our quest to ever lower phonon occupancies using cryogenic exchange gas cooling to 1.6 K will be described, which has allowed to reach a final occupancy of only 68 +/- 20 phonons. (1) Kippenberg, T. J. & Vahala, K. J. Science 321, 1172 (2008). (2)Kippenberg, T. J., Rokhsari, H., Carmon, T., Scherer, A. & Vahala, K. J. Physical Review Letters 95, 033901 (2005). (3) Schliesser, A., Del'Haye, P., Nooshi, N., Vahala, K. J. & Kippenberg, T. J. Physical Review Letters 97, 243905 (2006). (4) Schliesser, A., Riviere, R., Anetsberger, G., Arcizet, O. & Kippenberg, T. J. Nature Physics 2008 (2008).

Topical Talk HL 32.2 Wed 14:30 HSZ 01

Experimental quantum optical control of micromechanical resonators — •Markus Aspelmeyer — Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Vienna, Austria

Experiments on massive mechanical resonators are now approaching the quantum regime. This opens up not only a spectrum of new applications but it also promises access to a previously inaccessible parameter range for macroscopic quantum experiments.

Quantum optics provides a rich toolbox to prepare and detect quantum states of mechanical systems, in particular by combining nano- and micromechanical resonators with high-finesse cavities. I will review our recent experiments in Vienna on laser cooling micromechanical systems towards the quantum ground state by using radiation pressure. I will also discuss the prospects and experimental challenges of generating optomechanical entanglement, which is at the heart of Schrödinger's cat paradox and which is also essential for future quantum hybrid architectures.

Topical Talk HL 32.3 Wed 15:00 HSZ 01

Optomechanical correlations between light and mirrors — •Antoine Heidmann, Pierre-Francois Cohadon, and Tristan Briant — Laboratoire Kastler Brossel, Paris, France

Recent progress in high-finesse optical cavities and mechanical resonators allows one to reach a new regime in which the dynamical properties of an optomechanical system are governed by the radiation pressure exerted by light on mirrors. This optomechanical coupling leads to quantum limits in ultra-sensitive interferometric measurements such as gravitational-wave detectors, but also to very efficient laser-cooling mechanisms. This may help to reach the quantum fundamental state of a macroscopic mechanical resonator, by cooling a micromirror down to a temperature unreachable by other conventional techniques.

To experimentally study this optomechanical coupling, we monitor in a very high-finesse cavity the displacements of moving mirrors, either coated on a cm-size silica substrate or on a silicon micro-resonator. We have recently observed the optomechanical correlations induced by radiation pressure between a tiny classical intensity noise of a light beam

and the resulting mirror displacements. This scheme can be extended down to the quantum level and has applications both in high-sensitivity measurements and in quantum optics.

HL 33: Quantum wires: preparation and characterization

Time: Wednesday 14:00–17:15 Location: BEY 81

HL 33.1 Wed 14:00 BEY 81

Electrical characterization of InAs/GaAs (110) nanostructures by Conductive Atomic Force Microscopy — •Igor Beinik[1], Christian Teichert[1], Laura Díez-Merino[2], and Paloma Tejedor[2] — [1]Institute of Physics, Montanuniversität Leoben, Franz Josef Straße 18, 8700 Leoben, Austria — [2]Instituto de Ciencia de Materiales de Madrid, CSIC, C/Sor Juana Inés de la Cruz 3, 28049-Madrid, Spain

Self-assembled InAs quantum dots and wires have been studied over many years and still they are of great interest for application in nanoelectronics, high-speed spintronic devices, etc. Samples for our investigation were grown by molecular beam epitaxy on misoriented (110) GaAs substrates. Conductive Atomic Force Microscopy (C-AFM) technique was used to study the surface topography and conductivity simultaneously. Comparison of the corresponding cross-section profiles indicated that InAs nucleation takes place on the [1-10]-oriented step bunches, forming 3 nm-high and up to 70 nm-wide wires of variable length. On the other hand, [1-12]-type steps very rarely appeared to be decorated by InAs, also in agreement with previous TEM studies[1]. The presented results prove that C-AFM technique might be successfully applied as a tool for investigation of electrical properties in III-V quantum dots and wires on the nanometer scale. This work is supported by FWF Project # P19636, ÖAD project # ES 17/2007, TEC2007-66955 and HU2006-0022. [1] X.M. Zhang, D.W. Pashley, I. Kamiya, J.H. Neave, B.A. Joyce, J. Cryst. Growth 147 (1995) 234.

HL 33.2 Wed 14:15 BEY 81

Nucleation of Au-induced GaAs Nanowires on Si(111) and GaAs(111)B — •Steffen Breuer, Maria Wagler, Lutz Geelhaar, Achim Trampert, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

Vertical nanowires (NWs) offer a novel path towards monolithic integration of III-V semiconductors such as GaAs on Si. We studied nucleation and growth of GaAs NWs by the Au-induced vapor-liquid-solid (VLS) mechanism in a molecular beam epitaxy (MBE) chamber on Si(111) and compared it to the homoepitaxial case on GaAs(111)B. NWs grown for 30 min on each substrate are straight and have very similar shapes, lengths and densities, as found by scanning electron microscopy (SEM). We conclude from reflection high-energy electron diffraction (RHEED) patterns that on both substrates the NWs have Wurtzite (WZ) crystal structure and are epitaxially aligned to the respective substrate. A series of experiments with growth times between 5 s and 300 s was performed on each substrate. At this early stage, there are significantly more NWs on GaAs(111)B than on Si(111). Apparently, on Si(111) NW formation is delayed. Instead, the early surface is predominantly covered by three-dimensional GaAs islands that have Zincblende (ZB) crystal structure and a high density of twinning defects, as found by RHEED. We conclude that on Si(111) most Au droplets are inactive initially until the whole surface is covered by coalesced GaAs islands. We speculatively explain this by a model that assumes different interface energies for liquid Au on the two types of substrate.

HL 33.3 Wed 14:30 BEY 81

Ga-assisted growth of GaAs nanowires by molecular beam epitaxy — •Sonja Heiderich[1,2], Mihail Ion Lepsa[1], and Detlev Grützmnacher[1] — [1]Institute of Bio- and Nanosystems (IBN-1) and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich — [2]Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

An important aim of many research activities is the integration of III-V semiconductor nanowires in the established and cheaper silicon technology to get novel electronic and optoelectronic devices. Until now, III-V semiconductor nanowires have been typically synthesized using Au nanoparticles (catalyst) as a seed and the vapor-liquid-solid (VLS) or vapor-solid-solid (VSS) mechanisms. However, the Au can diffuse into the wire during the growth and affect the electronic transport properties. Therefore the growth of nanowires using the group III element as a seed represent the ideal option. In this report, we present data about the Ga-assisted growth of GaAs nanowires by molecular beam epitaxy (MBE). The nanowires have been grown on (100) or (111) GaAs substrates covered with a thin hydrogen silsesquioxan (HSQ) film. A study varying the growth conditions has been realized. From the analysis of the nanowire diameter and length (growth rate) in different growth conditions, we propose a phenomenological growth model. The model take into account that the growth proceeds via VLS mechanism from Ga droplets which develop at the beginning and are situated over preexisting pinholes in HSQ.

HL 33.4 Wed 14:45 BEY 81

Fabrication of longitudinal silicon nanowire heterostructures for implementation in field effect transistors — •Andre Heinzig and Walter M. Weber — Namlab GmbH, D-01187 Dresden

Continuous down scaling of field effect transistors will eventually lead to fabrication and performance related difficulties. In this respect, Schottky contact nanowire FETs are an interesting alternative for post-CMOS applications. Longitudinal metal-semiconductor-metal heterostructures are particularly interesting, since homogeneous and well defined Schottky junctions can be created. These are necessary to ensure a reliable device performance. A process for synthesizing such heterostructures has been developed by the silicidation of silicon nanowires with nickel. In particular, radial and longitudinal silicidation schemes have been established by applying self-aligned techniques. Both methods will be assessed to provide a customized metallic segment length with sharp interfaces in the nanometer scale. Finally, the fabrication of nanowire FETs based on nanowire heterostructures will be shown.

15 min. break

HL 33.5 Wed 15:15 BEY 81

Local droplet etching of nanoholes and semiconductor quantum rings — •Christian Heyn, Andrea Stemmann, and Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Local droplet etching (LDE) is a very interesting technique which allows the patterning of semiconductor surfaces without any lithographic steps. In particular, the fabrication of deep nanoholes [1,2] and the generation of semiconductor quantum rings [2] has been demonstrated. The LDE technique is related to the droplet epitaxy, where at first liquid Ga droplets are formed on crystalline surfaces in a Volmer-Weber-like growth mode which in a subsequent step are crystallized under As pressure. As a main difference, during LDE, significantly higher temperatures are used at which nanoholes at the interface between the liquid droplets and the surface are formed by local etching. Furthermore, distinct walls surrounding the nanohole openings are crystallized from droplet material [2] and act as semiconductor quantum rings with tunable size and composition. This presentation gives an overview on the LDE technique and the influence of the process parameters on nanohole and wall structural properties.

[1] Zh. M. Wang, B. L. Liang, K. A. Sablon, and G. J. Salamo, Appl. Phys. Lett. 90, 113120 (2007).

[2] A. Stemmann, Ch. Heyn, T. Köppen, T. Kipp, and W. Hansen, Appl. Phys. Lett. 93, 123108 (2008).

HL 33.6 Wed 15:30 BEY 81

In-situ study of catalyst-induced GaN nanowire nucleation — •Caroline Chèze[1,2], Lutz Geelhaar[1,2], Achim Trampert[1], Oliver Brandt[1], and Henning Riechert[1,2] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin — [2]Formerly at Qimonda, 81730 Munich, Germany

We investigated in situ the nucleation of Ni-seeded GaN nanowires (NWs) grown on C-plane sapphire by molecular beam epitaxy (MBE).

The crystal structure was probed by reflection high-energy electron diffraction (RHEED), and simultaneously the incorporated amount of Ga was monitored by line-of-sight quadrupole mass spectrometry (QMS). Additionally, some samples were investigated by transmission electron microscopy (TEM). During growth three different RHEED patterns appear subsequently, and each of them is accompanied by a change in the Ga incorporation behavior. We explained these three different nucleation phases as follows: first an accumulation of Ga into Ni seeds, then a drastic change in the orientation of the seed structure probably corresponding to a phase change induced by Ga incorporation, and finally growth of GaN below the seeds. The comparison of the QMS profiles for the first phase with and without Ni showed that Ga incorporation into the Ni seeds is not the growth limiting step. Moreover the tilt of the seed crystal structure in the second phase suggests a bulk diffusion process of Ga into the Ni seeds. Last the observation of a clear RHEED pattern during the whole nucleation is a strong evidence for the vapor-solid-solid mechanism (VSS).

HL 33.7 Wed 15:45 BEY 81

Catalyst free selective area MBE growth of InN nanocolumns on Si — •Boris Landgraf, Christian Denker, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut, Georg-August Universität Göttingen, 37077 Göttingen, Germany

Nowadays InN nanocolumns (NCs) are studied for many possible applications, e.g. as single devices - nanowire transistors - as well as ensembles in solar cells. A size and position controlled growth of nanocolumns is highly desirable. It allows a detailed study and optimization of the growth mechanism and is mandatory for the growth of axial and radial heterostructures. To maintain the high purity of MBE grown nanocolumns a catalyst free approach is preferable.

The selective area MBE growth of InN NCs has been investigated by using various masking materials. Electron beam lithography is applied to pattern the material masks with different layouts in order to determine the diffusion length of the indium on the respective materials. Subsequently nanocolumns were grown on the patterned substrates. It will be shown that the size and position of the InN nanocolumns can be controlled by the use of appropriate mask patterns and materials.

HL 33.8 Wed 16:00 BEY 81

GaN and InN nanowires: Si and Mg doping — Toma Stoica[1], Eli Sutter[2], Ralph Meijers[1], Ratan Debnath[1], Kulandaivel Jeganathan[1,3], Thomas Richter[1], Michel Marso[1,4], Hans Lüth[1], and •Raffaella Calarco[1] — [1]Institute of Semiconductor Nanoelectronics (IBN-1), Research Centre Jülich GmbH, D-52425 Jülich, Germany, and JARA- Fundamentals of Future Information Technology — [2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973 — [3]Department of Physics, Bharathidasan University, Trichirappalli - 620 025, India — [4]University of Luxembourg, Faculty of Sciences, Technology and Communication - 6, rue Richard Coudenhove-Kalergi, L-1359 Luxembourg

Doping is essential for the realization of optoelectronic devices and represents a complex task if related to nanowires. We have studied GaN and InN nanowires (NWs) doped by Si and Mg obtained by catalyst-free MBE on Si(111) in N-rich conditions. Increasing the Si amount the morphology as well as the density of the wires changes. Successful n-doping of GaN nanowires has been shown by electrical and optoelectrical measurements. Due to the sensitivity of the electrical transport to the wire diameter (size dependent surface barrier), it was possible to determine the doping level of single nanowire. A small amount of Mg increases the tendency of the wires to coalesce. For InN nanowires doped with Si a reduced NWs density is observed as compared to the undoped counterpart. The Mg doping does not change the morphology of the NWs as compared to the undoped however some staking faults at the tip could be observed.

15 min. break

HL 33.9 Wed 16:30 BEY 81

In-situ RHEED study on the morphology of MBE-grown GaN nanowires — •Matthias Knelangen, Achim Trampert, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

GaN nanowires are defect-free, quasi 1-dimensional nanocrystals. Although the fabrication of nanowires is well established, there is still a lack of understanding of the initial nucleation and the catalyst-free self-organized growth mechanism. In this work, we will present an in-situ RHEED study of the nucleation process of GaN nanowires growth on Si (111) substrates.

If GaN growth is initiated directly on Si, the RHEED pattern turns faint and blurry, characteristic for the formation of an amorphous Si_xN_y layer. After GaN nucleation, the RHEED spots are broadened, indicating a tilt of the wires with respect to the substrate. The superposition of two different azimuthal RHEED patterns and the independence to substrate rotation demonstrate the loss of in-plane orientation.

When growing on a smooth AlN buffer, the RHEED shows a clear transition from the AlN reflection pattern to a GaN transmission pattern. The two characteristic azimuths do correspond, showing the epitaxial alignment between AlN and GaN. HRTEM images show that the AlN layer relaxes by formation of misfit dislocations. The GaN/AlN interface is defect-free, so there is no plastic relaxation in the nanowires. Additional ex-situ TEM and XRD experiments will complement this RHEED study to investigate the overall strain of GaN and AlN.

HL 33.10 Wed 16:45 BEY 81

Local electrical analysis of a single semiconductor nanowire by Kelvin probe force microscopy — •Sasa Vinaji[1], André Lochthofen[1], Wolfgang Mertin[1], Ingo Regolin[2], Christoph Gutsche[2], Kai Blekker[2], Werner Prost[2], Franz Josef Tegude[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik & CeNIDE, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg, Germany — [2]Halbleitertechnologie & CeNIDE, Universität Duisburg-Essen, Lotharstr. 55, 47048 Duisburg, Germany

Semiconductor nanowires open a wide range of innovative electronic and optoelectronic applications. For future device design a detailed knowledge of the local electrical potential is essential. This can be easily accessed by non-contact Kelvin Probe Force Microscopy (KPFM) without damaging the fragile nanowire.

Single GaAs nanowires grown by metal-organic vapour phase epitaxy have been investigated with KPFM. In order to prove the efficiency of p-type doping by ion implantation of Zn [1], the local voltage drop across a biased nanowire was measured quantitatively. From the resistance of the nanowire found, an effective carrier concentration of 6*10ˆ17 cmˆ-3 could be estimated. Alternatively, a GaAs nanowire was doped during growth with Si and C for n- and p-type doping, respectively. We could localize the doping transition inside the nanowire via KPFM measurements and found a depletion zone of about 350 nm.

[1] D. Stichtenoth, K. Wegener, C. Gutsche, I. Regolin, F. J. Tegude, W. Prost, M. Seibt and C. Ronning, Appl. Phys. Lett. 92, 163107 (2008)

HL 33.11 Wed 17:00 BEY 81

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

GaAs nanowires were grown on top of <100> GaAs substrates, mainly adopting the epitaxial relation and thus growing with an angle of about 35° off the substrate surface. These perfectly straight nanowires were irradiated with different kinds of energetic ions. Depending on ion species, energy, and fluence, we observed that the nanowires bended down towards the surface or up. The intensity of the bending increased with ion fluence. In the case of upwards bending, alignment of the nanowires along the incident ion beam direction could be achieved. The experiments have been simulated to obtain vacancy and interstitial distributions using a special version of TRIM, which accounts for the geometry of the nanowires. The simulated distributions indicate vacancy and interstitial formation within the implantation cascade as the key mechanism for bending.

HL 34: Spin controlled transport II

Time: Wednesday 14:00–17:00 Location: BEY 118

HL 34.1 Wed 14:00 BEY 118

Spin relaxation and spin orbit coupling in graphene — •Sergej Konschuh, Christian Ertler, Martin Gmitra, and Jaroslav Fabian — Universität Regensburg

We have used ab-initio full potential LAPW technique to calculate the intrinsic spin orbit coupling (SOC) parameter and the Rashba spin splitting in graphene. The Rashba SOC arises only in the presence of an external electric field or ripples and causes spin relaxation via the Dyakonov-Perel mechanism. We calculate the spin relaxation time by performing Monte Carlo simulations, in which the spatial randomness of the electric field is taken into account. We compaire our results tp the experiment on spin injunction in graphene. [N.Tombos et al. Nature 448 (2007)]

HL 34.2 Wed 14:15 BEY 118

Ballistic Intrinsic Spin-Hall Effect in HgTe Nanostructures — •Christoph Brüne[1], Andreas Roth[1], Elena G. Novik[1], Markus König[1], Ewelina Hankiewicz[2], Hartmut Buhmann[1], and Laurens W. Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany — [2]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

Due to their unique band structure and the high spin orbit coupling strength, HgTe/HgCdTe quantum wells provide a good system for the observation of spin dependend transport phenomena. In this work we used nano-scale H-shaped structures built on HgTe/HgCdTe quantum wells to detect the intrinsic spin-Hall effect (ISHE) in a non-local electrical measurement. The strength of the spin orbit coupling was controlled by a top gate, which also made a transition from n- to p-conductance possible. The observed non-local resistance signal in the p-regime is in the order of kΩ. In contrast in the n-regime the signal is at least an order of magnitude lower. These observations are in agreement with bandstructure considerations and are confirmed by detailed Landauer-Büttiker-Keldysh formalism calculations.

HL 34.3 Wed 14:30 BEY 118

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

Several all-semiconductor three-terminal devices have been proposed which utilize the intrinsic spin-Hall effect to generate two oppositely spin-polarized currents [1,2]. There are two main obstacles in the experimental realization of these devices: the limitation of electronic transport to only the lowest subband, and the detection of the spin polarization. We present numerical simulations and experimental results of a two-stage cascade of Y-shaped spin-filters based on a two-dimensional electron gas in an InAs heterostructure [3]. The two-stage design allows an all-electrical detection of the spin polarization by using the first filter as a polarizer and the second as an analyzer. The regime of transport in the lowest subband is reached by constricting each part of the device with a quantum-point contact. Experiments and simulations show a high degree of spin polarization for the spin-filter cascade. The influence of magnetic fields is also studied. [1] A. Kiselev and K. Kim, J. Appl. Phys. 94, 4001 (2000) [2] J.I. Ohe et al., Phys. Rev. B 72, 041308(R) (2005) [3] A. Cummings et al., J. App. Phys. 104, 066106 (2008)

HL 34.4 Wed 14:45 BEY 118

Non-local edge state transport in the quantum spin Hall state — •Andreas Roth, Nina Eikenberg, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany

In 2007 the quantum spin Hall insulator state was discovered in HgTe quantum well structures as a new state of matter. In contrast to conventional electronic devices where currents flow through the bulk satisfying the classical Ohm's law, in the quantum spin Hall insulator electric currents are confined to flow only along the edges of the sample. In order to verify the concept of edge channel transport we investigate the non-locality in multiterminal devices. The agreement with Landauer-Büttiker calculations confirm the edge channel character of quantum spin Hall states.

15 min. break

HL 34.5 Wed 15:15 BEY 118

High bandwidth detection of electrically detected magnetic resonance — •Hans Huebl, Robert P. Starrett, Laurens H. Willems van Beveren, Dane R. McCamey, and Andrew J. Fergusson — Centre for Quantum Computer Technology, University of New South Wales, Sydney, Australia

Several proposals discuss the realization of quantum computation with the help of the spin degree of freedom in semiconductors. Electrically detected magnetic resonance (EDMR) provides a well established tool to investigate spin states in semiconductors which was recently extended to investigate the spin dynamics of phosphorus donors in silicon. Typically, the detection bandwidth of EDMR is limited by the characteristic RC time constant of the setup. In this contribution we show that by embedding the sample in a LRC resonant circuit, a so-called tank circuit, it is possible to overcome this limitations. Here, we investigate a silicon MOSFET where the microwave magnetic field to induce the spin transitions is generated on chip by a shorted coplanar stripline[1]. We monitor the spin dependent change in resistance with a current amplifier and simultaneously perform rf-refectometry off the tank circuit. A spin resonance signature was observed in both cases. Investigating the detection bandwidth by using frequency modulation of the microwaves indicates that the spin signature observed is detected up to $f_{mod} = 1$ MHz limited here by the electronic setup used. This shows that this method has the expected high bandwidth opening the view to faster phenomena in EDMR. [1] Willems van Beveren et al., APL **93**, 072102 (2008)

HL 34.6 Wed 15:30 BEY 118

Resonant circular photogalvanic effect in GaN/AlGaN heterojunctions — •B. Wittmann[1], L. Golub[2], S. Danilov[1], J. Karch[1], C. Reitmaier[1], D. Kvon[3], N. Vinh[4], A. van der Meer[4], B. Murdin[5], and S. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia — [4]FOM Institute for Plasma Physics "Rijnhuizen", Nieuwegein, The Netherlands — [5]University of Surrey, Guildford, UK

The resonant circular photogalvanic effect is observed in wurtzite (0001)-oriented GaN/AlGaN heterojunction excited by infrared radiation. The current is induced by angular momentum transfer of photons to the photoexcited electrons at resonant intersubband optical transitions. The signal reverses upon the reversal of the radiation helicity or, at fixed helicity, when the propagation direction of the photons is reversed. Making use of the tunability of the free-electron laser FELIX, we measured the spectral behaviour of the photocurrent in the vicinity of the inter-subband resonance. We observed that the variation of the photon energy results in the change of sign of the photocurrent[1]. This proves that the dominant contribution to the total current is from the asymmetry in momentum distribution of carriers excited in optical transitions. We analyze spin-dependent as well as spin-independent mechanisms giving rise to a resonant photocurrent and demonstrate that, in spite of the weak spin-orbit interaction, the resonant CPGE in GaN is mostly caused by the spin-dependent mechanism.

[1] B. Wittmann, S.D. Ganichev et al., PRB **78**, 205435 (2008)

HL 34.7 Wed 15:45 BEY 118

Theory of spin-Hall effect in HgTe — •Ewelina Hankiewicz[1], Hartmut Buhmann[2], Laurens W. Molenkamp[2], Werner Hanke[1], and Jairo Sinova[3] — [1]Institut für Theoretische Physik, Universität Würzburg, 97074 Würzburg ,Germany — [2]Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany — [3]Department of Physics, Texas A&M University, College Station, USA

We study theoretically a ballistic transport in HgTe H-shaped nanostructures using Landauer-Büttiker formalism. We model inverted HgTe nanostructures using realistic parameters describing properly the spin-orbit splittings and effective mass in these structures. The idea of the transport measurements is as follows. When an electric current

flows in one of the legs of the H-bar structure, a transverse spin current due to the intrinsic spin-Hall effect is induced in the connecting part. Subsequently, this spin current produces, due to the inverse spin-Hall effect, a voltage difference in the opposite leg of the H-bar structure which can be measured by a voltmeter. We predict that the spin-Hall effect in H-shaped HgTe/HgCdTe inverted band structure quantum wells can be significant (on the order of a few % of the excitation voltage (microvolts)) if the size of the structure is below a ballistic length.

15 min. break

HL 34.8 Wed 16:15 BEY 118

Spin-dependent electron-impurity scattering in two-dimensional electron systems — •Andras Palyi — Department of Physics, University of Konstanz, 78457 Konstanz, Germany

We present a theoretical study of elastic spin-dependent electron scattering caused by a charged impurity in the vicinity of a two-dimensional electron gas. We find that the symmetry properties of the spin-dependent differential scattering cross section are different for an impurity located in the plane of the electron gas and for one at a finite distance from the plane. We show that in the latter case asymmetric ('skew') scattering can arise if the polarization of the incident electron has a finite projection on the plane spanned by the normal vector of the two-dimensional electron gas and the initial propagation direction. In specially prepared samples this scattering mechanism may give rise to a Hall-like effect in the presence of an in-plane magnetic field.

HL 34.9 Wed 16:30 BEY 118

Spin currents in diluted magnetic semiconductors — •P. Olbrich[1], S.D. Ganichev[1], S.A. Tarasenko[2], V.V. Bel'kov[2], W. Eder[1], D.R. Yakovlev[2,3], V. Kolkovsky[4], W. Zaleszczyk[4], C. Karczewski[4], T. Wojtowicz[4], and D. Weiss[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia — [3]Experimental Physics 2, TU Dortmund ,Dortmund, Germany — [4]Institute of Physics,Warsaw, Poland

We report on the observation of spin currents resulting in the zero-bias spin separation [1] in unbiased diluted magnetic semiconductor structures. We demonstrate that an absorption of THz radiation in (001)-grown (Cd,Mn)Te/(Cd,Mg)Te QWs with Mn^{2+} magnetic ions leads to a pure spin current. The effect is investigated in a magnetic field converting the spin separation into a net electric current. We demonstrate that the polarization of the magnetic ion system enhances drastically the conversion due to the spin-dependent scattering by localized Mn^{2+} ions and the giant Zeeman splitting [2]. Both effects disturb the balance of the oppositely directed spin-polarized flows yielding an electric current. In weak magnetic fields for a degenerated electron gas the scattering mechanism dominates the current conversion. We show that the spin-dependent exchange scattering of electrons by magnetic impurities plays an important role in the current generation providing a handle to manipulate the spin-polarized currents.

[1] S.D. Ganichev *et al.*, *Nature Physics* (London) **2**, 609 (2006)
[2] S.D. Ganichev *et al.*, *arXiv:cond-mat/0811.4327*(2008)

HL 34.10 Wed 16:45 BEY 118

Spatial Imaging of Spins Optically Excited by Linearly Polarized Light — •Stefan Göbbels[1,2], Paul Schlammes[1,2], Christian Rodenbücher[1,2], Markus Hagedorn[1,2], Klaus Schmalbuch[1,2], Gernot Güntherodt[1,2], Thomas Schäpers[3,2], Mikhail Lepsa[3,2], and Bernd Beschoten[1,2] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Jülich-Aachen Research Alliance, JARA - Fundamentals of Future Information Technology — [3]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich

Optical orientation is a well established technique to optically excite electron spins in semiconductors. In conventional all-optical pump-probe experiments a circularly polarized pump beam is used to generate spin-polarized electrons by transferring angular momentum from the photons to the electrons. – We present a new method for optical spin orientation using a linearly polarized pump beam. The polarization mechanism is studied by all-optical time-resolved Faraday microscopy in InGaAs films. Spatial imaging of the spin polarization after optical orientation with linearly polarized light shows a superposition of two spin components. An out-of-plane spin component is found, which depends on the polarization direction of the pump beam. We develop a model ascribing the polarization mechanism of these out-of-plane spins to the internal Dresselhaus field. Furthermore, we observe an in-plane spin component with spins aligned antiparallel when propagating in opposite directions away from the laser spot.

This work has been supported by DFG through FOR 912.

HL 35: Semiconductor Laser

Time: Wednesday 14:00–17:45 Location: BEY 154

HL 35.1 Wed 14:00 BEY 154

Crystal length dependency of the generation of the second harmonic with non-diffraction limited radiation — •Mirko Uebernickel, Gunnar Blume, Christian Fiebig, Katrin Paschke, Bernd Eppich, Reiner Güther, and Götz Erbert — Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Deutschland

The direct second harmonic generation (SHG) of high power, infrared semiconductor diode lasers is a possible candidate for the replacement of established visible laser systems, like Argon-Ion lasers or frequency doubled solid-state lasers. To achieve high optical output power in the visible wavelength range the length of nonlinear crystal needs to be considered. The SHG power scales linear with the length of the crystal in single path configuration for a Gaussian beam.

We determine the crystal length dependency for non-diffraction limited radiation of diode lasers in experiment and theory. Different semiconductor lasers with increasing beam propagation factor (second order moments) from 1.1 to 3 were used to examine the SHG power of four periodically poled MgO doped lithium niobate crystals with lengths of 10, 18, 22 and 50mm. It was found that the SHG power is indeed linearly dependent on the crystal length, but only if the focusing conditions are adjusted to the non-diffraction limited radiation. Theoretical calculations based on a Gauss-Shell model could verify these experimental results. The model can thus be used to predict optimised focussing conditions for SHG with non-diffraction limited beams.

HL 35.2 Wed 14:15 BEY 154

Metallorganische Gasphasenepitaxie von AlInN/GaN Bragg-Spiegeln — •Pascal Moser, Armin Dadgar, Christoph Berger, Jürgen Bläsing, Thomas Hempel und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Hochreflektierende gitterangepasste AlInN/GaN Bragg-Spiegel (DBR) für den Einsatz in Nitrid-basierten Lasern mit Vertikalresonator (VCSEL) werden präsentiert.

Die Spiegel wurden auf 2-Zoll c-achsenorientiertem Saphirsubstrat in einem AIXTRON 200/4 RF-S Reaktor gewachsen. Auf einer AlN-Nukleationsschicht wurden ca. 1500 nm GaN und anschließend 40 AlInN/GaN λ/4-Doppelschichten abgeschieden. Die jeweils 47.1 nm dicken AlInN-Schichten wurden bei 780°C unter einem Druck von 70 mbar und die 43.2 nm dicken GaN-Schichten bei 1145°C unter einem Druck von 200 mbar gewachsen. Ammoniak bei den AlInN- und Wasserstoff bei den GaN-Schichten fungierten als Trägergase. Die Rissfreiheit der Proben konnte mit Hilfe der Nomarski-Mikroskopie verifiziert werden, während zur Bestimmung der kristallinen Qualität Röntgenbeugung verwendet wurde. Darüber hinaus kam die Röntgenbeugung zur Bestimmung der Schichtdicken zum Einsatz, welche mit den aus Feldemission-Rasterelektronenmikroskopieaufnahmen ermittelten Werten verglichen wurden. Anhand von Reflektionsspektren konnten nicht nur eine hohe Reflektivität, sondern auch die ermittelten Schichtdicken durch angepasste Simulation nachgewiesen werden.

HL 35.3 Wed 14:30 BEY 154

Lasing of the direct bandgap material Ga(NAsP) pseudomophically grown on Si(001)-substrate — •Sven Liebich[1], Bernardette Kunert[2], Igor Németh[1], Steffen Zinnkann[1], An-

dreas Beyer[1], Rafael Fritz[1], Christoph Lange[1], Niko S. Köster[1], Daniel J. Franzbach[1], Sangam Chatterjee[1], Wolfgang W. Rühle[1], Nils C. Gerhardt[3], Nektarious Koukourakis[3], Martin Hofmann[3], Kerstin Volz[1], and Wolfgang Stolz[1] — [1]Material Sciences Center and Faculty of Physics, Philipps-University Marburg — [2]NAsPIII/V GmbH Marburg — [3]Photonics and Terahertz Technology, Ruhr-University Bochum

Photonic devices based on standard techniques used in complementary metal-oxide-semiconductor (CMOS) technology are of high interest to realize photonic integrated circuits. Silicon (Si) is the standard material but it is unsuitable for laser applications due to its indirect electronic bandgap. Therefore different strategies are pursued to realize an efficient Si-based light source i.e. the doping of crystalline Si with Erbium atoms or the use of Si nanocrystals. Our approach is the monolithic integration of the novel Ga(NAsP) laser material which can be grown nearly lattice-matched on Si. Through incorporation of Arsenic (As) and Nitrogen (N) the electronic structure can be designed in such a way that on one side the bandgap becomes direct. On the other side the lattice constant can be tuned to that of Si. Multi-quantum well structures containing the new material Ga(NAsP) were realized and results from optical pumping experiments revealed clear lasing action at low temperatures.

HL 35.4 Wed 14:45 BEY 154

Power limiting effects in 2.X μm emitting GaSb-based Diode-Lasers — •Markus Müller, Marcell Rattunde, Johannes Schmitz, Gudrun Kaufel, and Joachim Wagner — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, D-79108 Freiburg, Germany

Semiconductor lasers emitting around 2 μm are of interest for a range of applications including material processing, medical diagnostics and therapy or trace gas sensing. (AlGaIn)(AsSb)-based quantum well lasers are well suited for the 1.8-2.4 μm wavelength range as they exhibit excellent lasing characteristics.

Under CW operation the output power of GaSb-based diode lasers is limited by thermal rollover due to self-heating of the active region. To suppress this thermal effect in order to explore the high-power characteristics we analyzed these lasers under pulsed mode operation using 20 ns to 2 μs long current pulses. This way we reached optical pulse power above 16 W from a single-emitter when driven with current pulses up to 100 A. Simultaneously, we performed time-resolved measurements of the lasing spectra (3 ns time frame) in order to deduce remaining self-heating effects from the shift of the lasing spectrum.

The results obtained clearly demonstrate that the high current high power performance of GaSb-based 2.X μm diode lasers is limited by self-heating effects even under short pulse operation. In contrast to GaAs-based devices emitting around 1 μm, no catastrophic optical mirror damage (COMD) is observed even at the highest power densities at the facet of 16 MW/cm^2.

HL 35.5 Wed 15:00 BEY 154

Electrically pumped organic Microcavity-GaN-Hybrid System — •Robert Brückner, Maik Langner, Daniel Kasemann, Hartmut Fröb, Vadim Lyssenko, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany

We investigate a monolithic hybrid system as a step towards a small-scale electrically pumped organic solid state laser. A hybrid inorganic-organic emitting system is realized by depositing a high finesse Microcavity (MC) (21 layer DBR of TiO_2 and SiO_2, $\frac{\lambda}{2}$-layer of ALQ_3:DCM) directly on the surface of a UV-LED-Chip (CREE-XL7090). The monolithic system is characterized by negligible losses of the excitation light since no optics are involved. We obtain a high transmission from the GaN-Chip (GaN, n=2,5) to the first mirror layer (TiO_2, n=2,1). An additional DBR on the top of the MC reflects the excitation wavelength of the UV-LED (400nm), and hence the intensity of the pump light in the cavity increases. The LED is driven in pulsed mode operation (pulse duration 20ns @ 2kHz, maximum pulse current 80A) to measure the optical properties of the VCSEL device. We present first results of this hybrid system including emission at the cavity wavelength and Input-Output-characteristics.

15 min. break

HL 35.6 Wed 15:30 BEY 154

Time-resolved lasing-characteristics of external-cavity quantum-cascade (EC-QC) lasers emitting around 7.4 μm — •Borislav Hinkov, Frank Fuchs, Wolfgang Bronner, Klaus Köhler, and Joachim Wagner — Fraunhofer Institute for Applied Solid State Physics (IAF), Tullastraße 72, D-79108 Freiburg, Germany

Quantum-cascade (QC) lasers are semiconductor light sources covering the infrared spectral range from around 3 μm to 15 μm. For use in e.g. molecular fingerprint absorption spectroscopy the spectral tuning range of QC lasers can be extended significantly using external-cavity (EC) setups.

We investigated the temporal evolution of the lasing spectrum of an EC-QC laser emitting around 7.4 μm on a ns time-scale, applying 100 ns long pulses. Immediately after turn-on of the current pulse multiple-mode lasing starts at the gain maximum of the QC laser controlled by the cavity formed by the chip facets. After a time delay of about 10 ns the QC laser begins to couple to the external cavity as seen from a change in lasing wavelength to that defined by the external grating as wavelength selective element, reaching steady-state operation after 24 ns. The characteristic time constant for the change from internal cavity modes to external cavity operation is derived to 15 ns, comparable to the photon lifetime in the external cavity of 4.5 ns.

The dynamics of this coupling process is not only of fundamental interest but also important for practical applications because most EC-QC lasers are operated in short-pulsed mode.

HL 35.7 Wed 15:45 BEY 154

The Role of Decoupled Electron and Hole Dynamics in the Turn-on Behavior of Semiconductor Quantum-Dot Lasers — •Kathy Lüdge, Ermin Malić, and Eckehard Schöll — Institut für Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Quantum dot (QD) injection lasers are promising candidates for high-speed data transmission applications. However, so far their performance is hindered by low cuttoff frequencies. We show that mixed e-h Auger scattering events lead to separate dynamics for holes and electrons in the device. This decoupling is essential to explain the strong damping of the relaxation oscillations of the laser in excellent agreement with the experiment. For the numerical simulations we combine a microscopic approach for calculating the non-radiative scattering times and a rate equation model for simulating the complex dynamic turn-on behavior.

HL 35.8 Wed 16:00 BEY 154

GaAs-based high power tapered amplifiers in an external cavity setup for frequency doubling — •Christian Schilling, Ralf Ostendorf, Gudrun Kaufel, Rudolf Moritz, Hans-Joachim Wagner, and Oliver Ambacher — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, 79108 Freiburg, Germany

A range of future applications, especially laser TV, calls for robust and compact green laser sources. One promising approach is the conversion of infrared laser radiation generated by semiconductor laser diodes into green light by frequency doubling. Since the conversion efficiency of this nonlinear optical process depends superlinearly on the incident pump power density, the initial laser source has to provide a high output power combined with a good beam quality and a narrow line width. Frequency stabilized tapered amplifiers in an external cavity setup can meet these demands.

Thus, we have fabricated diode lasers based on the GaInAs/AlGaAs material system consisting of an index-guided ridge wave guide section and a gain-guided tapered section. The centre wavelength is around 1064 nm. A beam propagation factor of $M^2 < 2$ is measured at a maximum output power of 3.5 W. Wavelength tuning in the range from 1030 nm to 1070 nm is achieved by the use of an external diffraction grating in Littrow configuration with both laser facets anti-reflection coated. A split contact design enables us to separately adjust the currents in the ridge- and the taper section, thus allowing for a rapid modulation of the optical output power.

HL 35.9 Wed 16:15 BEY 154

Single mode emitting GaInAsSb/GaSb quantum well lasers operating in continuous wave mode at 3.02 μm — •Thomas Lehnhardt, Michael Hümmer, Karl Rössner, Mirjam Müller, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, Germany

Mid-infrared lasers have attracted significant attention for highly sensitive tunable diode laser spectroscopy of gases. We report here on room temperature continuous wave single mode GaSb based quantum

well (QW) lasers emitting at record long wavelength of 3 μm.

To obtain this long wavelength several challenges stemming from the GaInAsSb/GaSb material system have to be addressed. High In-contents are needed to realize narrow band gaps for long wavelength operation. In addition, quantization effects have to be reduced to avoid severe blue shifts. Therefore, thick QWs (17 nm) have to be grown, which necessitates higher As-contents in the GaInAsSb QWs. Too high As-contents however cause type-II band alignments. Thus, a compromise has to be found to keep a sufficient confinement for holes to avoid thermal emission from the QWs. With a commonly used band structure model, we estimate for our structures a valence band offset (VBO) in the range of only 20 meV. Nevertheless, we demonstrate with this approach state-of-the art single mode emitting distributed feedback lasers emitting 3 mW output power at room temperature, being ample for gas sensing applications.

15 min. break

HL 35.10 Wed 16:45 BEY 154

Optically pumped GaSb-based semiconductor disk lasers emitting in the 2.0 - 2.8 μm wavelength range — •Rüdiger Moser, Benno Rösener, Marcel Rattunde, Christian Manz, Klaus Köhler, and Joachim Wagner — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, D-79108 Freiburg, Germany

Semiconductor disk lasers, also known as vertical-external-cavity surface-emitting laser (VECSEL), combine the wavelength versatility and efficiency of diode lasers with the capability of a high output power to be emitted in a nearly diffraction-limited circular beam inherent to solid-state lasers. In the wavelength range between 2 - 3 μm there is a considerable demand for compact high brightness lasers, serving e.g. medical application, material processing or long-range chemical sensing (LIDAR).
In this presentation we report on the development of high-power GaSb-based VECSELs emitting in the 2.0 - 2.8 μm range. By way of barrier pumping with fiber-coupled diode lasers at 980 nm, a maximum cw output power of e.g. 2.8 W at 2.0 μm was obtained at 20 °C heat sink temperature in multi mode operation with a typical spectral width in the range of 10 nm. The optical power conversion efficiency was 18.6 %, corresponding to a quantum efficiency of 37 %. Single longitudinal mode operation was achieved by using an intracavity birefringent quartz plate. By rotating this plate, a tuning range of 118 nm was achieved. Further, results on longer wavelength VECSEL emitting at around 2.8 μm will be presented.

HL 35.11 Wed 17:00 BEY 154

Single Mode Quantum Dot Tapered Lasers — •Pia Weinmann[1], Bjoern Lekitsch[1], Christian Zimmermann[2], Emil-Mihai Pavelescu[3], Johann-Peter Reithmaier[3], Martin Kamp[1], and Alfred Forchel[1] — [1]Technische Physik, Am Hubland, 97074 Würzburg — [2]nanoplus GmbH, Oberer Kirschberg 4, 97218 Gerbrunn — [3]INA, Universtität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

A high output power combined with a good beam quality has made tapered lasers promising devices for applications in telecommunication, healthcare or i.e. as pump source for fibre lasers. For several applications, such as frequency doubling or pumping narrow absorption lines, a stable and spectrally narrow emission is required. We present quantum dot (QD) based tapered lasers in the 920nm and 1060nm wavelength range that fulfill these requirements. Compared to quantum well material, the shift of the emission wavelength with temperature is reduced by a factor of more than two since the decrease of the bandgap with increasing temperature can be partially balanced by the blueshift of the QD peak gain due to the increasing losses. Further stabilization of the wavelength can be achieved by including a wavelength selective distributed Bragg reflector (DBR) in the laser cavity. We have combined gain and index guided tapered lasers with etched DBR gratings, this approach allows an overgrowth free fabrication. The emission spectrum of the devices shows a very narrow spectral linewidth in combination with sidemode suppression ratios of over 40 dB. The shift of the emission wavelength with temperature is only 0.07nm/K. Output powers up to 2W are achieved with good beam quality.

HL 35.12 Wed 17:15 BEY 154

Towards green lasing: polar and nonpolar — •Alexander Daniel Dräger[1], Holger Jönen[1], Uwe Rossow[1], Heiko Bremers[1], David Schenk[2], Pierre Demolon[2], Jean-Yves Duboz[2], Brian Corbett[3], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig, Germany — [2]CRHEA-CNRS , Valbonne, France — [3]Tyndall National Institute, Cork, Ireland

While GaInN based violet-blue laser diodes are by now commercially available in large quantities and reach high output powers and long lifetimes, a green laser based on the same material system is not yet achieved. The aim of our work is to realize a green emitting laser. Therefore we investigated laser structures grown on SiC, sapphire and GaN substrates using the variable stripe length technique for gain measurement. Here we focus on two major problems that arise for laser diodes emitting in the green spectral range: the increase of the indium composition in the quantum well to 35% and above and the decrease of the optical confinement due to the decreased refractive index contrast between AlGaN and GaN. We present laser stuctures with high indium containing QW as well as with enhanced optical confinement.

Furthermore we grew and investigated structures on nonpolar substrates such as m-plane SiC. We compare the results of these measurements with those on similar structures grown on polar substrates and show the necessary changes to the structure for the growth on nonpolar substrates.

HL 35.13 Wed 17:30 BEY 154

Spin-relaxation measurements in VCSEL-structures at room temperature — •Hendrik Jähme[1], Mingyuan Li[1], Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], A. Kroner[2], and R. Michalzik[2] — [1]Ruhr-Universität Bochum, Lehrstuhl für Photonik und Terahertztechnologie — [2]Institut für Optoelektronik, Universität Ulm

We investigate the dynamic behaviour of optically induced electron spin-relaxation in a vertical-cavity surface-emitting laser (VCSEL). As the VCSEL emits perpendicularly to the active layer, it satisfies the Faraday-geometry required for the optical selection rules. A spin-amplification has been observed in such structures [1] raising interest in the utilisation of such devices for practical spintronic applications. We use a GaAs/AlGaAs-multi-quantum-well-laser and excite a spin-polarisation of electrons by pulsed optical pumping with circularly polarised light. Additionally the structure is pumped electrically to tune the rate of polarised carriers allowing an estimation of the spin-amplification [2]. A Stokes-polarimeter and a streak-camera are used to determine the degree of light polarisation and its dynamics.

An influence of the excitation on the emitted polarisation is observed. The dynamic measurements show relaxation-processes which are faster than the carrier-recombination dynamics. In this context we see a clear temporal separation between the pulses of right and left circularly polarised light on a low ps-timescale.

We thank the DFG for support within the SFB491

[1] S. Hövel et al, Spin controlled optically pumped vertical cavity surface emitting laser. Electronic Letters 41 (2005), No. 5

[2] S. Hövel et al, Optical spin manipulation of electrically pumped vertical-cavity surface-emitting lasers. APL 92, 041118 (2008)

HL 36: ZnO: preparation and characterization II

Time: Wednesday 14:00–16:15 Location: POT 51

HL 36.1 Wed 14:00 POT 51

Ultrafast exciton dynamics of highly excited ZnO — •Jan-Peter Richters[1], Tina Shih[2], Jürgen Gutowski[1], and Tobias Voss[1] — [1]Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen — [2]School of Engineering and Applied Sciences and Department of Physics, Harvard University, Cambridge, MA, USA

Large band-gap semiconductors like ZnO are currently of great interest as light emitting material and lasing media in the blue-UV spectral range. In order to make use of these materials it is mandatory to

understand the charge carrier dynamics and excitonic effects at high excitation densities.

We present results of pump-probe reflectance spectroscopy of c-plane and m-plane ZnO bulk material with a temporal resolution of $\Delta t < 200$ fs. The sample is excited using a frequency tripled (266 nm) Ti:Sapphire laser. The white light probe pulse (300 nm $< \lambda_{probe} <$ 600 nm) is generated by converting the Ti:Sapphire pulse with a CaF_2 crystal. We analyze the results of the reflectivity measurements by use of an exciton polariton model, from which we can obtain damping, shift, and broadening of the exciton resonances. For excitation densities near to the damage threshold of ZnO, the resonance is completely bleached on a time scale of several tens of ps. Our results indicate that lasing in ZnO observed under high excitation densities using fs-lasers is most probably not an excitonic process, but needs to be described in the frame of a strongly Coulomb correlated electron-hole plasma.

HL 36.2 Wed 14:15 POT 51

Properties of reactively sputtered Ag, Au, Pd, and Pt Schottky contacts on n-type ZnO — •Alexander Lajn[1], Holger von Wenckstern[1], Gisela Biehne[1], Holger Hochmuth[1], Michael Lorenz[1], Marius Grundmann[1], Sandra Künzel[2], Christian Vogt[2], and Reinhard Denecke[2] — [1]Universität Leipzig, Abteilung Halbleiterphysik, Institut für ExperimentellePhysik II — [2]Universität Leipzig, Physikalische Chemie der Oberflächen, Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie

The contact properties of reactively sputtered Ag, Au, Pd, and Pt Schottky contacts on nominally undoped n-ZnO thin films prepared by pulsed-laser deposition on a-plane sapphire substrates are compared. Without any surface preparation rectifying contacts were reproducibly realized by dc sputtering in an Ar/O_2 atmosphere. The degree of oxidation of the contact metals was investigated by X-ray photoelectron spectroscopy (XPS). Furthermore current-voltage (IV), capacitance-voltage (CV) and capacitance-frequency (Cf) measurements were employed. Ideality factors and barrier heights determined from IV measurements between 20 K and 300 K depend strongly on temperature indicating lateral fluctuations of the barrier potential. Considering a Gaussian distribution of barrier heights permits to describe the temperature dependence of the ideality factor and the barrier for $T > 200$ K. Assuming thermionic emission being the only current transport process and taking the Gaussian distribution of barrier heights into account we were able to model the entire IV characteristic (forward and reverse current for $U = \pm 2$ V) at 300 K.

HL 36.3 Wed 14:30 POT 51

Properties of hydrogen doped ZnO thin films prepared by RF magnetron sputtering — •Achim Kronenberger, Marc K. Dietrich, Steve Petznick, Andreas Laufer, Angelika Polity, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

In the 1950s E. Mollwo [1] observed the effect that hydrogen diffused into ZnO single crystals strongly decreases their resistivity. About 50 years later the forming of shallow donor levels due to hydrogen incorporation in ZnO was described theoretically by C. G. Van de Walle [2] and experimentally proved by several groups [3,4]. In our work hydrogen doped thin films have been prepared by radio frequency magnetron sputtering at different substrate temperatures using hydrogen and oxygen as reactive gases. The incorporation of hydrogen was quantified by secondary ion mass spectrometry and its influences on the structural, electrical and optical film properties have been investigated. By varying the deposition parameters we were able to adjust the electrical properties between semiconductor like and degenerated (highly conductive) behaviour for films deposited at room temperature.

[1]E. Mollwo, Z. Phys. 138 (1954) 478. [2]C. G. Van de Walle, Phys. Rev. Lett. 85 (2000) 1012. [3]D. M. Hofmann, A. Hofstaetter, F. Leiter, H. J. Zhou, F. Henecker, B. K. Meyer, S. B. Orlinskii, J. Schmidt, P. G. Baranov, Phys. Rev. Lett. 88 (2002) 045504. [4]S. F. J. Cox, E. A. Davis, S. P. Cottrell, P. J. C. King, J. S. Lord, J. M. Gil, H. V. Alberto, R. C. Vila*o, J. Piroto Duarte, N. Ayres de Campos, A. Weidinger, R. L. Lichti, and S. J. C. Irvine, Phys. Rev. Lett. 86 (2000) 2601.

HL 36.4 Wed 14:45 POT 51

Excitonic Recombination in MgZnO thin films — •Alexander Müller, Marko Stölzel, Gabriele Benndorf, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We present time-resolved photoluminescence (TRPL) measurements on MgZnO thin films. The samples have been grown by pulsed laser deposition on a-plane sapphire. We used time-correlated single photon counting to investigate the luminescence decay. The measured transients have been fitted using the convolution of a model decay function with the device function.

Due to random fluctuations of the local potential, the photoluminescence (PL) emission of MgZnO shows a large mixed crystal broadening. In contrast to pure ZnO, for Mg contents of more than 3 % in the thin films it is not possible to spectrally resolve the luminescence bands using standard PL. Therefore, the origin of the luminescence is not well known.

In this contribution, we present the spectral and temperature dependence of the TRPL transients. For low temperatures, we observe a blue shift of the spectral luminescence maximum over time. This can be explained by a slow process at higher emission energies.

The transients could be fitted using a sum of two model decay functions. The time-integrated intensities of the model decays show different spectral maxima. We attribute these to the emission of donor-bound and free excitons.

15 min. break

HL 36.5 Wed 15:15 POT 51

Strukturuntersuchungen an polykristallinem $In_2O_3(ZnO)_m$ und $InGaO_3(ZnO)_m$ — •Patrick Kessler[1], Reiner Vianden[1], Wentao Yu[2] und Werner Mader[2] — [1]HISKP, Universität Bonn — [2]Institut für anorganische Chemie, Universität Bonn

Transparente und leitende Oxid-Filme (TCO) sind Gegenstand aktueller Forschung, da sie als transparente Elektroden in optoelektronischen Anwendungen wie zum Beispiel Flachbildschirmen genutzt werden können. Weit verbreitet sind In_2O_3:Sn-Filme, die wegen der geringen Verfügbarkeit von In, sehr teuer geworden sind. Als Alternative werden In_2O_3-ZnO Systeme mit hoher ZnO Konzentration diskutiert, welche die gleichen optischen und elektrischen Eigenschaften aufweisen. Die genaue atomare Struktur dieser Filme ist noch nicht abschließend geklärt.

Untersucht wird deshalb $In_2O_3(ZnO)_m$ und $InGaO_3(ZnO)_m$ mit der Methode der gestörten γ - γ Winkelkorrelation (PAC). Dazu wird ^{111}In als Sondenatomen durch Diffusion in gepresstes Pulver eingebracht und bei 1300°C gesintert. Mit der PAC kann nun die direkte Sondenumgebung studiert werden.

Indium in $In_2O_3(ZnO)_m$ befindet sich ab einer bestimmten Konzentration (m>6) auf basalen Ebenen und sich dazwischen bildenden Zick-Zack Strukturen (ZZ), wie Messungen und theoretische Rechnungen zeigen. Bei $InGaO_3(ZnO)_m$ wird das Gallium bevorzugt auf diesen ZZ Plätzen eingebaut und verdrängt dort das Indium. Dies kann nun mit der PAC durch Vergleich der Sondenumgebungen in $In_2O_3(ZnO)_m$ und $InGaO_3(ZnO)_m$ überprüft werden.

HL 36.6 Wed 15:30 POT 51

Deep levels in nitrogen implanted ZnO — •Matthias Schmidt[1], Martin Ellguth[1], Florian Schmidt[1], Thomas Lüder[1], Rainer Pickenhain[1], Marius Grundmann[1], Gerhard Brauer[2], and Wolfgang Skorupa[2] — [1]Universität Leipzig, Institut für Experimentelle Physik II, 04103 Leipzig, Germany — [2]Forschungszentrum Dresden – Rossendorf e.V., Dresden, Germany

We investigated deep levels in a nitrogen implanted, PLD grown ZnO thin film. Subsequent to the ion implantation the sample has been thermally annealed. In preparation of capacitance spectroscopy measurements a Schottky contact made from evaporated palladium was deposited on the sample. From capacitance – voltage measurements the spacial dependence of the net doping concentration was obtained. Deep level transient spectroscopy was employed for the characterisation of deep levels with binding energies $E_c - E_d < 700$ meV below the conduction band edge. The prominent deep level E3 and a deeper one with $E_c - E_d \approx 590$ meV were detected. The presence of further defects was proven by photo – capacitance and photo – current measurements. A strong increase of the capacitance as well as on the current was observed for excitation with energies approx. 200 meV below the bandgap. This behaviour hints to the existence of a trap close to the valence band edge.

HL 36.7 Wed 15:45 POT 51

Nitrogen doping of ZnO — •Michael Hofmann[1], Melanie Pinnisch[1], Andreas Laufer[1], Sebastian Zöller[1], Sebastian Eisermann[1], Stefan Lautenschläger[1], Bruno K. Meyer[1], Gor-

don Callison[2], Markus R. Wagner[2], and Axel Hoffmann[2] — [1]Ist physics insitute, Justus Liebig University Gießen — [2]institute for semiconductor physics, Hardenbergstraße, Berlin

The controlled incorporation of acceptors into the ZnO matrix is still a not well understood obstacle for the fabrication of bipolar ZnO devices. We investigated the incorporation of nitrogen using low groth temperatures, different nitrogen percursors and polar or non polar ZnO surfaces. To characterize our thin films we used Raman spectroscopy, low temperature photoluminescence and secondary ion mass spectrometry measurements. It turned out that certain conditions, especially substrate polarity and temperature, favour the nitrogen incorporation.

HL 36.8 Wed 16:00 POT 51

On Cu diffusion in ZnO — •F. Herklotz, E.V. Lavrov, and J. Weber — Technische Universität Dresden, 01062 Dresden, Germany

Copper in ZnO is of special interest since recent theoretical and experimental studies found ferromagnetic behavior of ZnO:Cu at room temperature. In addition, Cu is a deep acceptor in ZnO and one of the causes of the green emission band.

Experimental studies of Cu diffusion in bulk ZnO single crystals were carried out in the temperature range 1030 to 1180 °C. Concentration profiles of substitutional Cu were determined via IR absorption at 5817 cm^{-1}. Our findings reveal that the diffusion coefficient of Cu is $7.6 \times 10^7 \exp(-4.56\ \mathrm{eV}/k_BT)\ \mathrm{cm^2 s^{-1}}$. This is about a factor of 25 higher than reported in the earlier studies, which probed the total Cu concentration. The discrepancy is explained by the formation of Cu complexes, which occurs at high concentrations. Diffusion mechanisms are discussed.

HL 37: ZnO: devices

Time: Wednesday 16:15–18:00 Location: POT 51

HL 37.1 Wed 16:15 POT 51

Optical characterization of zinc oxide microwire lasers — •Christian Czekalla, Chris Sturm, Rüdiger Schmidt-Grund, Jesus Zuniga Perez, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

We report the optical characterization including photoluminescence (PL) spectroscopy and optical pumping of hexagonally shaped zinc oxide (ZnO) microwires. The structures were grown by a simple carbothermal evaporation process. Under high excitation conditions, whispering gallery mode lasing can be observed [1]. The observed lasing peaks can be calculated very precisely from a simple plane wave model [2]. The lasing modes exhibit a full width at half maximum (FWHM) of down to 0.6 meV, limited solely by radiation loss in good agreement with the theory of hexagonal cavities [3]. This leads to quality factors of about 4000.

In order to tune the emitted photon energy of the microwire lasers, MgZnO/ZnO core shell heterostructures have been grown around the microwires by pulsed laser deposition. The PL results clearly indicate the growth of MgZnO barriers and ZnO quantum wells. Additionally, high excitation spectroscopy results will be shown.

[1] C. Czekalla et al., *Appl. Phys. Lett.* **92**, 241102 (2008)
[2] T. Nobis et al., *Phys. Rev. Lett.* **93**, 103903 (2004)
[3] J. Wiersig, *Phys. Rev. A* **67**, 023807 (2003)

HL 37.2 Wed 16:30 POT 51

Localized modes in ZnO random lasers — •Johannes Fallert, Janos Sartor, Roman J. B. Dietz, Daniel Schneider, Viktor Zalamai, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany

Zinc oxide nanoparticles can act as gain and scattering medium in a random laser where light emission can be significantly amplified. In this work we focus on the degree of spatial localization for random lasing modes. By investigating the laser emission of defined microstructured fields, filled with nanocrystalline ZnO powder, we can easily allocate the position of the differently localized modes in SEM images of the sample. The observed emission lines can be attributed to modes provided by random alignment of ZnO nanoparticles at a certain position within the field while emission from single, large grains can be excluded. Recent theoretical papers predict that strongly localized and even extended modes lead to random lasing [1]. In agreement with these predictions we observe the coexistence of laser modes with strong as well as weak localization.

[1] D.S. Wiersma, Nature Physics 4, 359 (2008)

HL 37.3 Wed 16:45 POT 51

Transport investigations on ZnO-based MESFETs — •Heiko Frenzel, Alexander Lajn, Holger von Wenckstern, Matthias Brandt, Gisela Biehne, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

Metal-semiconductor field-effect transistors (MESFETs) were fabricated by reactive dc-sputtering of either Ag, Pt, Pd, and Au as Schottky-gate contacts on ZnO thin films grown by pulsed-laser deposition on *a*-plane sapphire substrates. In contrast to ZnO-based metal-insulator field-effect transistors (MISFETs), MESFETs show high dynamics switching within a gate-voltage range of only ±1 V with an on/off-ratio of up to 10^8 [1]. The channel mobilities are not limited by scattering at the insulator/semiconductor-interface and therefore equal the Hall mobilities of the thin films achieving values up to 27 cm^2/Vs. MESFETs comprised of the four most common Schottky metals on ZnO were electrically investigated in a temperature range between 25°C and 150°C. For Ag, Pt, and Au, the device performance was at least stable until 100°C even showing an improvement due to the annealing [2]. Studies of the dependencies on different gate-geometries as well as reliability tests under the influence of light will be presented.

[1] H. Frenzel *et al.*, Appl. Phys. Lett. **92**, 192108 (2008)
[2] H. Frenzel *et al.*, Proc. of the 2nd Internat. Symp. on Transparent Conductive Oxides, Thin Solid Films, *submitted*

15 min. break

HL 37.4 Wed 17:15 POT 51

Lasing emission in ZnO nanorods — •Victor Zalamai[1], Johannes Fallert[1], Janos Sartor[1], Daniel Schneider[1], Heinz Kalt[1], Claus Klingshirn[1], Veaceslav Ursaki[2], and Ion Tiginyanu[2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Germany — [2]Technical University of Moldova, Moldova

In this work we investigate lasing effects in zinc oxide nanorods. Vertically aligned hexagonal ZnO nanorods have been prepared by low pressure chemical vapour deposition (CVD). The photoluminescence (PL) spectroscopy demonstrates the high crystal quality of the produced nanorods which is comparable with the quality of bulk ZnO single crystals. The transition from spontaneous to stimulated emission is observed in arrays of hexagonal nanorods with an almost uniform diameter of 200 nm and length of 1.5 μm under excitation by 5 ns laser pulses above a certain threshold of excitation power density which depends from nanorod sizes. Multiple sharp peaks representing different lasing modes emerge in the emission spectrum above the lasing threshold. The lasing modes are better resolved when the emission from a single nanorod is analyzed. A broad emission band is characteristic for randomly oriented ZnO nanostructures with a variety of geometrical parameters. This band represents a superposition of lasing modes coming from ZnO nanorods with different diameters and lengths.

HL 37.5 Wed 17:30 POT 51

Inverter Structures based on Zinc Oxide — •Friedrich Schein, Heiko Frenzel, Alexander Lajn, Gisela Biehne, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

The increased interest in wide bandgap semiconductors in the last years is partially due to lots of potential applications in transparent electronics. Zinc oxide is a promising candidate for the fabrication of such transparent devices, e. g. for diodes and transistors. Recent investigations of ZnO-based transistors mostly considered metal-insulator-semiconductor field-effect transistors (MISFETs), suffering from low field-effect mobility and high switching voltages. In this study metal-semiconductor FETs (MESFETs) are used [1]. They possess a higher

channel mobility and with that faster switching speeds. Furthermore typical MESFET switching voltages of ± 1 V are about one order of magnitude smaller than for MISFETs, yielding less power consumption. The transistor's switching performance can be determined using ring oscillator structures, consisting of inverters. In this work, we use Schottky diodes and MESFETs, both based on ZnO thin films grown by pulsed-laser deposition, to fabricate inverter structures. These are known from GaAs technology as Schottky-diode FET logic. The electrical properties including on-off ratio, steepness and transfer characteristic are investigated. Further the integration, necessary for the fabrication of ring oscillators, is discussed.

[1] Frenzel *et al.*, Appl. Phys. Lett., **92**, 192108 (2008)

HL 37.6 Wed 17:45 POT 51

Ferroelectric thin film transistors based on ZnO/$BaTiO_3$ heterojunctions — •Brandt Matthias, Heiko Frenzel, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für ExperimentellePhysik II, Leipzig, Germany

ZnO and $BaTiO_3$ (BTO) are transparent oxide materials. ZnO is a semiconductor showing a spontaneous electric polarization and is very easily doped n–type. BTO is an insulating ferroelectric at room temperature. The ability to control the free carrier concentration in the ZnO by the polarization of the BTO can be used to develop ZnO/BTO based ferroelectric field effect transistors, thus demonstrating fully transparent non–volatile memory elements.

We have grown epitaxial BTO/ZnO heterostructures by pulsed laser deposition on lattice matched $SrTiO_3$ and $SrTiO_3$:Nb substrates. The electrical properties of ZnO/BTO heterostructures have been investigated by current-voltage measurements, showing that the BTO layer is highly insulating ($I_l < 10^{-9}$ A/cm^2 at 5V). Field effect transistors were fabricated with an on–current of up to 6×10^{-5} A and an on/off ratio of 10^6. The FETs are normally on. The structures could be programmed by a positive gate voltage pulse and erased by a negative gate voltage. The ratio in the source–drain currents in both states could be as high as 1000, depending on the gate voltage at read–out. The effect was reproducible in repeated switching cycles, showing the suitability of the structure as a memory device.

HL 38: Focused Session: Different realizations of quantum registers

Time: Thursday 9:30–11:45 Location: HSZ 01

Topical Talk HL 38.1 Thu 9:30 HSZ 01

Quantum control of spins and photons in diamond — •Mikhail Lukin — Physics Department, Harvard University, Cambridge, MA, 02138, USA

We will discuss our recent work involving quantum control of spins and photons in diamond. Potential applications of these techniques to realization of quantum networks, nanoscale magnetic sensors and single photon switches will be discussed as well as the recent progress towards their implementation.

Topical Talk HL 38.2 Thu 10:00 HSZ 01

Quantum Information processing in diamond — •Fedor Jelezko and Jörg Wrachtrup — 3. Physcal Instutute, University of Stuttgart

Quantum Information processing in diamond Solid state quantum information processing often requires important breakthrough in material science. While classical semiconductor materials have had several decades of development with respect to purity and structure, carbon based materials are a relatively new class of substances to this field. Research on carbon systems, like, fullerenes, nanotubes, graphene or recently diamond is often driven by the requirements of having a spin-free lattice. In this talk we will focus on exceptional optical and spin properties associated with single color centers. Such optically active defects have been identified as a prominent candidate for quantum information processing and quantum cryptography a few years ago, but technology for controlling single spins was developed only recently. Here we show that being placed in a spin free lattice, single electron spins show the longest room temperature spin dephasing times ever observed in solid state systems. This benchmark will potentially allow observation of coherent coupling between spins separated by a few tens of nanometres, making it a versatile material for room temperature quantum information processing devices. We also show that single electron spins can be used to detect external magnetic fields with a sensitivity reaching nanotesla and sub-nanometre spatial resolution. References: Balasubramanian et al. Nature 455, 648-651 (2008), Neumann, et al. Science 320, 1326-1329 (2008).

15 min. break

Topical Talk HL 38.3 Thu 10:45 HSZ 01

Coherence of a single spin in a tunable environment — •Ronald Hanson — Kavli Institute of Nanoscience, Delft University of Technology

Diamond-based materials have recently emerged as a unique platform for quantum science and engineering. Spins of Nitrogen-Vacancy (NV) color centers in diamond can be optically imaged and read out, and exhibit long coherence times. Moreover, the dynamics of the spin environment can be adjusted in situ, providing an excellent system for controlled studies of decoherence in the solid state.

We use high-fidelity quantum control of single NV center spins to study the loss of spin coherence due to interactions with the surrounding bath of electron spins. By tuning the internal bath dynamics as well as the coupling between the bath and the NV spin, we gain access to regimes with strikingly different behaviour [1]. Furthermore, we measure the NV spin coherence time T_2 from room temperature down to 1.3 K. We find that T_2 increases sharply when the Zeeman energy exceeds the thermal energy, demonstrating that the fluctuations in the spin bath can be fully eliminated through polarization [2]. We will discuss these insights along with our latest results on counteracting decoherence.

[1] R. Hanson et al., Science **320**, 352 (2008).
[2] S. Takahashi et al., Phys. Rev. Lett. **101**, 047601 (2008).

Topical Talk HL 38.4 Thu 11:15 HSZ 01

Spectroscopy and Coherent Control of Single Spins — •Gregory Fuchs — Center for Spintronics and Quantum Computation, University of California, Santa Barbara, CA, USA

Nitrogen Vacancy (NV) defect centers in diamond are a promising system for spin-based applications in quantum information and communication at room temperature. Using a combination of optical microscopy and spin resonance, the spin of individual NV centers can be initialized, manipulated and read out. There remain significant challenges, however, both in understanding the physics of these defects as well as the development of technologies based on their quantum properties. In particular, knowledge of the detailed structure of the orbital excited-state, which continues to be an active research area, is critical to ultra-fast quantum control schemes. Here we present recent experiments using single-spin resonant spectroscopy of the excited-state of an NV center at room temperature[1]. We observe these spin levels over a broad range of magnetic fields allowing for a direct measurement of the zero-field splitting, g-factor and transverse anisotropy splitting. The latter of these is nearly zero in the ground-state spin levels, but plays an important role in the excited-state. In addition, we find strong hyperfine coupling between the nitrogen nuclear spin and the NV electronic spin in the excited-state. These findings will be discussed in the context of quantum control of single and coupled spins in diamond.

[1] G. D. Fuchs, V. V. Dobrovitski, R. Hanson, A. Batra, C. D. Weis, T. Schenkel, and D. D. Awschalom, Phys. Rev. Lett 101, 117601 (2008).

HL 39: Quantum dots: Optical and transport properties

Time: Thursday 9:30–13:00 Location: BEY 81

HL 39.1 Thu 9:30 BEY 81

Electrical injection of a spin polarized electron into a single quantum dot — •Jie Huang[1], Robert Arians[1], Jörg Nannen[1], Tilmar Kümmell[1], Jan Wenisch[2], Karl Brunner[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen — [2]Experimentelle Physik III, Universität Würzburg

The electrical injection of a carrier with a defined spin into a single quantum dot (SQD) is a fundamental step to electrically driven spin devices. By combining a diluted magnetic semiconductor (ZnMnSe) as a highly effective spin source with InAs quantum dots, we demonstrate a spinpolarized SQD emitter.

The structure is designed as a p-i-n diode with self organized InAs quantum dots embedded into the intrinsic GaAs region and with an n-doped ZnMnSe layer, serving as spin aligner. Nanoapertures in the top contact provide access to SQD emission. The device is placed into a magnetic field in Faraday geometry and biased in forward direction. The spin information can now be extracted directly from the circular polarisation degree of the electroluminescence signal of the SQD, where a spin polarized electron from n-ZnMnSe directly recombines with a hole from p-GaAs. At $U_{bias} = 1.45$ V, we obtain a spin polarisation of nearly 100 % at $T = 5$ K. We discuss the reduction of spin polarisation with rising temperature and at higher currents, and the possibility of biexciton formation in the SQDs.

HL 39.2 Thu 9:45 BEY 81

Experimental realization of a spectrally resonant site-controlled quantum dot-micropillar cavity system — •Alexander Huggenberger, Christian Schneider, Tobias Heindel, Pia Weinmann, Caroline Kistner, Martin Kamp, Stephan Reitzenstein, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, Germany

We present a technology for the integration of site-controlled InAs quantum dots (QD) into GaAs/AlAs micropillar cavities in a spatially deterministic manner. QD formation at pre-defined positions is forced by patterning nano-holes as nucleation centres. The sample layout enabling the site-controlled growth of the QDs and retrieving them by cross markers for the incorporation into micro-pillars cavities are discussed. A combination of morphological studies like scanning electron microscopy and atomic force microscopy characterization is used to establish a fabrication process to precisely control the QD position for device integration. The emission of single QDs is probed by microPL spectroscopy and reveals clear spectra with single lines. An advanced technique has been developed to improve the optical quality of single site-controlled quantum dots. Vertically stacked but different sized and therefore spectrally detuned site-controlled QD layers have been grown. This allows for the selective interaction between only one single QD emission line and a cavity mode in the cavity quantum electrodynamics regime. By temperature tuning of the QD emission into resonance with the cavity mode an enhanced spontaneous emission is observed, thus demonstrating a site-controlled QD-micropillar cavity system.

HL 39.3 Thu 10:00 BEY 81

Triggered single-photon source from a single quantum dot on silicon substrate — •Mohamed Benyoucef[1,2], Hong Seok Lee[1], Juliane Gabel[1], Armando Rastelli[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

Single quantum emitters have become an emerging area of fundamental research during the last years, driven by the need for nonclassical light sources delivering single-photons on demand for future implementation in the field of quantum information. Most of the work concerning photon statistics has been done on III-V materials such as (In,Ga)As quantum dots (QDs) embedded in GaAs matrix or integrated in microcavities. In contrast to this, only few studies on II-VI compounds have been reported. The short lifetime of II-VI QDs could allow operation at high repetition rates. From the technological point of view it would be desirable to obtain single-photons on demand from single QDs grown on Si(001) substrates. In this work, we report on the observation of triggered single-photon emission from a single CdTe QD embedded in a ZnTe layer grown on Si(001). The emission wavelength of single dots can be locally tuned in a wide spectral range (more than 8 meV) by means of a focused laser beam. Moreover, we have carried out time-resolved PL measurements to investigate the lifetime of the single CdTe QDs. We find that, the single-photon emission and the lifetime are preserved after energy tuning of the QD emissions.

HL 39.4 Thu 10:15 BEY 81

Electrically Tunable Single Quantum Dot - Photonic Crystal Nanocavity Systems in the Strong Coupling Regime — •Norman Hauke, Arne Laucht, Felix Hofbauer, Gerhard Böhm, Markus-Christian Amann, and Jonathan James Finley — Walter-Schottky-Institut, Garching, Germany

We present investigations of electrically tunable single quantum dot (QD) - photonic crystal (PC) nanocavity systems, operating in the strong coupling regime. The sample consists of a single layer of $In_{0.4}Ga_{0.6}As$ self-assembled QDs embedded in the center of a 180nm thick p-i-n GaAs membrane, which is patterned by electron beam lithography and reactive ion etching to form a PC slab with a L3 defect nanocavity. Gold contacts are evaporated for electrical access, thus allowing us to create electric fields in the intrinsic GaAs region. By making use of the quantum confined Stark-effect, we can reversibly tune the optical emission of a single exciton into and out of spectral resonance with a nanocavity mode (Q ≈ 11000) at ≈ 1200 meV.
Optical measurements were performed by using low temperature confocal microscopy. In photoluminescence experiments, we observe a clear anticrossing between exciton and mode emission (vacuum Rabi splitting ≈ 70-130μeV), which is a signature for strong coupling between emitter and cavity. We further investigated the pump power and temperature dependence of the vacuum Rabi-splitting, showing that dephasing processes destroy the strong interaction for high pump powers or high temperatures.
Supported financially by the DFG via SFB-631 and NIM

15 min. break

HL 39.5 Thu 10:45 BEY 81

Single mode synchronized precession of electron spins in a quantum dot ensemble — •Stefan Spatzek[1], Alex Greilich[1], Irina Yogova[2], Ilya A. Akimov[1], Dmitri R. Yakovlev[1], Alexander. L. Efros[3], Dirk Reuter[4], Andreas D. Wieck[4], and Manfred Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]Naval Research Laboratory, 20375 Washington DC, USA — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Optically controlled electron spins in ensembles of quantum dots (QDs) provide an attractive proposal to implement quantum information technologies in a solid-state environment. However inhomogeneities within an ensemble lead to the rapid loss of coherence among the phase of the spins. Electron spin coherence in an inhomogeneous, singly charged $(InGa)As/GaAs$ ensemble of dots was studied by means of time-resolved Faraday-Rotation technique [1].

The spin of all electrons confined in the dots can be driven into a single precession mode about a magnetic field. This precession regime is reached by allowing only a single mode within the electron spin precession spectrum of the QD ensemble to be synchronized with the excitation train of optical pulses. Under this condition a nuclear induced frequency focusing effect [2] leads to a shift of all spin precession frequencies to the synchronized mode. [1] A. Greilich et al., Science **313**, 341 (2006) [2] A. Greilich et al., Science **317**, 1896 (2007)

HL 39.6 Thu 11:00 BEY 81

Application of an eight-band $\mathbf{k}\cdot\mathbf{p}$-model to study III-nitride semiconductor nanostructures — •Oliver Marquardt, Tilmann Hickel, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung

The eight band $\mathbf{k}\cdot\mathbf{p}$-formalism is a well established continuum approach for investigations of the electrooptical properties of direct band gap material nanostructures. Though being unable to directly describe atomistic effects, in a previous study this approach has been shown

to be in excellent agreement with atomistic methods for III-nitride nanostructures with characteristic dimensions of a few nanometers [1]. We applied our plane-wave implementation of an eight-band $\mathbf{k} \cdot \mathbf{p}$-Hamiltonian to study various zero-, one- and two-dimensional nanostructures in the common zincblende and wurtzite crystal structures including effects arising from strain and polarization in order to understand light emission processes in realistic nanostructures. Special attention is paid to the investigation of alloy composition as well as strain and polarization effects on charge carrier localization and binding energies in InGaN/GaN quantum dots and films.

[1]: Marquardt, Mourad, Schulz, Hickel, Czycholl, Neugebauer, Phys. Rev. B, in print (2008)

HL 39.7 Thu 11:15 BEY 81

Exciton storage in a nano-scale Aharonov-Bohm ring with electric field tuning — Andrea M. Fischer[1], Vivaldo L. Campo Jr.[2], Mikhail E. Portnoi[3], and •Rudolf A. Roemer[1] — [1]Department of Physics and Centre for Scientific Computing, University of Warwick, Coventry, CV4 7AL, UK — [2]Departmento de Fisica, Universidade Federal de Sao Carlos-UFSCar, 13565-905 Sao Carlos, SP, Brazil — [3]School of Physics, University of Exeter, Exeter EX4 4QL, UK

We study analytically the optical properties of a simple model for an electron-hole pair on a ring subjected to perpendicular magnetic flux and in-plane electric field [1]. We show how to tune this excitonic system from optically active to optically dark as a function of these external fields. Our results offer a simple mechanism for exciton storage and read-out.

[1] AM Fischer, VL Campo Jr, ME Portnoi, RA Roemer, arXiv:0809.3863

HL 39.8 Thu 11:30 BEY 81

Coulomb blockade due to lithographically aligned InAs quantum dots in GaAs/AlGaAs constrictions — •Sebastian Göpfert, Lukas Worschech, Daniela Spanheimer, Christian Schneider, Monika Emmerling, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, 97074 Würzburg

By combination of site-controlled growth of InAs quantum dots with an accurate alignment to narrow constrictions defined in a modulation doped GaAs/AlGaAs heterostructures quantum dots with large Coulomb energies were realized. For that purpose, modulation doped GaAs/AlGaAs heteterostructures were grown by molecular beam epitaxy. The position of the InAs quantum dots was controlled by defining nanoholes as nucleation centers [1,2]. After regrowth with InAs and a capping, narrow constrictions were etched relative to the site-controlled quantum dots with a position accuracy of 50 nm. The site-controlled InAs quantum dots serve as floating gate, and define electronic quantum dots in the narrow channel. By means of transport measurements single-electron addition energies in the order of 10 meV were observed.

[1]Lateral Alignment of Epitaxial Quantum Dots, edited by O. G. Schmidt, Springer, Berlin, 2007.

[2]C. Schneider, M. Strauß, T. Sünner, A. Huggenberger, D. Wiener, S. Reitzenstein, M. Kamp, S. Höfling, A. Forchel, Appl. Phys. Lett. 92, 183101 (2008).

15 min. break

HL 39.9 Thu 12:00 BEY 81

Time-resolved observation of electron tunneling from self-assembled QD using a 2DEG — •Bastian Marquardt[1], Martin Geller[1], Axel Lorke[1], and Dirk Reuter[2] — [1]Experimental Physics & CeNIDE, Universität Duisburg-Essen, Duisburg — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Bochum

We developed a novel technique to probe the tunneling dynamics of quantum dot carriers (QD) into a nearby two-dimensional electron gas (2DEG). This method employs the 2DEG as a detector for the tunneling charge into and out of the InAs-QD-layer. A time-resolved two-terminal resistance measurement allows us to investigate the tunneling times of the emission processes. Furthermore, this new technique allows us to probe samples with very slow tunneling times, in contrast to the commonly used frequency-dependent capacitance-voltage (CV) spectroscopy. The CV-spectroscopy has been proven to be a valuable tool to investigate coupled electron systems with *fast* tunneling times ($\tau << 100$ms). In the case of weakly coupled QD-2DEG electron systems with extremly slow tunneling times $\tau > 1$s, the CV-spectroscopy is not able to probe the tunneling dynamics because of the insufficient s/n-ratio for low frequencies. Additionally, in contrast to CV-spectroscopy the resistance of a 2DEG is given by its aspect ratio and not its size. This enables us to scale down the sample dimensions to few or even single QDs in the future. On the basis of the measured transients the tunneling times for different applied electrical fields are evaluated. Our technique makes it possible to study non-equilibrium tunneling into excited dot-states.

HL 39.10 Thu 12:15 BEY 81

Single-parameter quantized charge pumping in magnetic fields — •Christoph Leicht[1], Bernd Kaestner[1], Vyacheslavs Kashcheyevs[2,3], Klaus Pierz[1], Uwe Siegner[1], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institute for Solid State Physics, University of Latvia, Riga LV-1063, Latvia — [3]Faculty of Physics and Mathematics, University of Latvia, Zellu street 8, Riga LV-1002, Latvia

We present a study of high frequency quantized charge pumping through a GaAs/AlGaAs quantum dot in the presence of a perpendicular magnetic field. Application of a frequency signal in the GHz-range to one of two finger gates, crossing a narrow wire and confining a quantum dot, leads to quantized, pumped current plateaus in the gate characteristics. Magnetic fields up to around 6 T considerably enhance the quality and the number of observed current plateaus. A dimensionless quality factor is determined to rate the flatness of the first plateau and to indicate the achievable accuracy for metrological purposes.

HL 39.11 Thu 12:30 BEY 81

Enhanced performance of a quantum dot based memory device with selective band engineering — •Johannes Gelze[1], Andreas Marent[1], Tobias Nowozin[1], Martin Geller[2], and Dierter Bimberg[1] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstraße 36, 10623 Berlin — [2]Department of Physics and CeNIDE, University of Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

Recently, we have introduced a novel memory concept (QD-Flash) based on self-organized quantum dots (QDs) providing much better performance than nowadays Flash-memory. For InAs/GaAs-QDs we have demonstrated a write time of 6 ns. With an additional Al0.9Ga0.1As barrier, a hole storage time in InAs/GaAs-QDs of 1.6 s at 300 K were shown. The erase process in the QD-Flash is realized by tunnelling through the confining potential in an electric field. Both, storage time and erase time are determined by the activation energy of the charge carriers. Thus, a trade-off exists between storage time and erase time. To reduce this trade-off, we have investigated the influence of more complex barriers below the QDs by simulating the carrier emission rate, using a WKB-Method. Barriers are designed having a much higher emission rate for a given activation energy than originally used triangular barriers. To confirm these results we studied the influence of Al0.6Ga0.4As and Al0.9Ga0.1As barriers on the write/erase times of the QD-Flash by capacitance-voltage measurements. A reduction of the erase time in a good agreement with the simulation was observed, keeping the write time below 10 ns.

HL 39.12 Thu 12:45 BEY 81

Noninvasive detection of molecular bonds in quantum dots — •Maximilian C. Rogge and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We performed charge detection on a lateral triple quantum dot with starlike geometry. The setup allows us to interpret the results in terms of two double quantum dots with one common quantum dot. One double dot features weak tunnel coupling and can be understood with atomlike electronic states, the other one is strongly coupled forming moleculelike states. In nonlinear measurements we identified patterns that can be analyzed in terms of the symmetry of tunneling rates. Those patterns strongly depend on the strength of interdot tunnel coupling and are completely different for atomlike or moleculelike coupled quantum dots allowing the noninvasive detection of molecular bonds.

M. C. Rogge and R. J. Haug, Phys. Rev. B 78, 153310 (2008)
M. C. Rogge and R. J. Haug, Phys. Rev. B 77, 193306 (2008)

HL 40: ZnO: preparation and characterization III

Time: Thursday 9:30–12:45 Location: BEY 118

HL 40.1 Thu 9:30 BEY 118

Experimental and numerical analysis of the waveguiding properties of ZnO nanowires — •Dongchao Hou, Jan-Peter Richters, and Tobias Voss — Institute of Solid State Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Tapered silica fibers can be used as convenient and robust tools to couple external laser light into the waveguide modes of semiconductor nanowires. This coupling technique allows for a systematic study of the low- and high-order mode profile supported by the nanowire as well as of coupling processes between different nanowires. Using a simple flame-heated fiber-pulling method, we fabricated tapered silica fibers from standard multi-mode silica optical fibers with diameters down to below 1 micron. Optical microscopy showed that the fabricated fibers possess a high diameter uniformity and surface smoothness. With such tapered fibers, we coupled light into single ZnO nanowires and observed their waveguiding losses for different alignments between the silica fiber and the ZnO nanowires. We numerically simulated the experimentally observed waveguide properties of the nanowires using the finite-difference time-domain (FDTD) method. The dependence of the coupling efficiency on the diameters, the overlap length and separation was investigated. We found a maximum coupling efficiency of up to 0.8 for silica and ZnO nanowires with typical diameters used in experiment. The results show that silica tapered fibers are well suited to study the waveguiding properties of semiconductor nanowires which are of importance for the design and optimization of nanowires lasers, sub-wavelength waveguides and sensors.

HL 40.2 Thu 9:45 BEY 118

Investigations of ZnO/$Zn_{1-x}Cd_xO$ double heterostructures grown by pulsed laser deposition — •Martin Lange, Jan Zippel, Gabriele Benndorf, Christian Czekalla, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

ZnO/$Zn_{1-x}Cd_xO$ double heterostructures have been grown on a-plane sapphire substrates by pulsed laser deposition. The oxygen partial pressure and the substrate temperature was varied to fabricate samples with high cadmium content and hence smaller bandgap energy than ZnO but though high luminescence yield.

The samples have been studied with temperature dependent photoluminescence in the temperature range from 2 to 295 K. A S-shape behaviour for the peak energy of the $Zn_{1-x}Cd_xO$-luminescence was observed and the standard derivation of the potential σ was estimated with a fit of this S-shape. A large number of phonon replicas indicate localization of excitons. With the help of the Huang-Rhys factor and the fraction of strongly localized excitons the depth of the localization potentials was estimated in good agreement with σ. Using the intensity of the $Zn_{1-x}Cd_xO$-luminescence as function of the temperature the thermal activation energy of non-radiative processes has been determined.

HL 40.3 Thu 10:00 BEY 118

Investigation of ZnO electronic properties by optical deep level transient spectroscopy — •Martin Ellguth, Matthias Schmidt, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, 04103 Leipzig, Germany

Since ZnO is a promising material for future transparent electronic and opto - electronic devices, a classification of defects according to their optical absorption is necessary. We investigated electronic properties of impurities typically present in ZnO with special regard to the photo cross - section as a fundamental property of a defect. The prominent defects E1, E3, E4 and a presently not reported trap E200 with binding energy of approx. 200 meV were detected by deep level transient spectroscopy (DLTS) measurements. Optical DLTS measurements (ODLTS) were conducted and a measurable signal was achieved for E4 and E200. The photo cross - section of these traps was then calculated from the wavelength dependent optical emission rate obtained from the ODLTS signal. Furthermore, the presence of defect states far from the conduction band edge and therefore undetectable by any thermal capacitance spectroscopic methods has been inferred from the detection of the optically excited emission which some of these defects exhibit.

HL 40.4 Thu 10:15 BEY 118

The 3.367eV band in ZnO — •Martin Feneberg, Anton Reiser, Christian M. Krauss, Rolf Sauer, and Klaus Thonke — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

Low temperature photoluminescence experiments in ZnO show frequently a band at 3.367eV, which is broad and overlaps with the sharp bound exciton lines. This feature has been explained as being due to so-called surface excitons, e.g. excitons bound to defects that are located close to the surface of the semiconductor. Here, we show that an excitonic origin of the 3.367eV band is unlikely and instead give an explanation in terms of donor-to-surface acceptor transitions consistent with data reported in the literature.

15 min. break

HL 40.5 Thu 10:45 BEY 118

Strukturelle Charakterisierung der Donator-Akzeptor-Kodotierung von ZnO — •Muhammed Türker, Peter Reichert, Manfred Deicher, Herbert Wolf und Thomas Wichert — Technische Physik, Universität des Saarlandes, 66123 Saarbrücken

Auf Grund seiner optischen Eigenschaften ist ZnO ideal für optoelektronische Anwendungen im blauen und UV-Bereich. Allerdings bereitet im Gegensatz zur n-Dotierung die p-Dotierung nach wie vor große Schwierigkeiten. Als Möglichkeit für eine verbesserte p-Dotierung werden die Donator-Akzeptor-Kodotierung [1] oder die Cluster-Dotierung [2] vorgeschlagen. Dabei führt die Bildung von Donator-Akzeptor-Komplexen zur Verbesserung der Akzeptorlöslichkeit und somit zu einer Steigerung der p-Leitfähigkeit. Experimentell wurde dieser Ansatz für die In-N-Kodotierung durch elektrische Messungen bestätigt [3]. Auf atomarer Ebene sind solche Defektkomplexe durch einen elektrischen Feldgradienten (EFG) am Ort des Donators Indium charakterisiert, der mit Hilfe der gestörten $\gamma\gamma$-Winkelkorrelation (PAC) und des radioaktiven Donators ^{111}In gemessen werden kann. Für verschiedene Verfahren der In-N-Kodotierung (Implantation und/oder Diffusion) wurde neben dem EFG des ungestörten ZnO-Gitters ($\nu_{QGitter}$ = 31 MHz) ein durch ν_Q = 151(1) MHz charakterisierter Defekt beobachtet, der auf eine Bildung von In-N-Komplexen hinweisen kann.
Gefördert durch das BMBF, Projekt 05KK7TS1.
[1] T. Yamamoto *et al.*, Physica B **302-303** (2001) 155
[2] L.G. Wang *et al.*, Phys. Rev. Lett. **90** (2003) 256401
[3] L.L. Chen *et al.*, Appl. Phys. Lett **87** (2005) 252106

HL 40.6 Thu 11:00 BEY 118

Photocurrent measurements on magnesium zinc oxide in the infrared spectral range — •Dieter Stender, Heiko Frenzel, Kerstin Brachwitz, Holger von Wenckstern, Gisela Biehne, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We report on deep defects in $Mg_xZn_{1-x}O$ thin films with different magnesium content x up to 40%, investigated by Fourier-transform infrared photocurrent (FTIR-PC) spectroscopy in the mid and far infrared spectral range. The samples were grown on a-plane sapphire substrates by pulsed-laser deposition at a growth temperature of 700°C and oxygen partial pressure of 0.016 mbar. Analogue studies on pure ZnO were performed in [1], in which the deep defects E1 at ∼110 meV, E3 at ∼320 meV and L2 at ∼260 meV have been observed. In MgZnO, peaks at similar energies have been found indicating the presence of common ZnO point defects. The results are discussed and compared with electrical measurements like deep level transient spectroscopy (DLTS) and temperature dependent admittance spectroscopy (TAS). Based on these results, ZnO/MgZnO single heterostructures as well as quantum wells were investigated in order to observe intersubband transitions.
[1] H. Frenzel *et al.*, Phys. Rev. B **76**, 035214 (2007)

HL 40.7 Thu 11:15 BEY 118

A comparative study of DFT corrections to charge transition levels of transition metals in ZnO — •Marc A. Gluba and N. H. Nickel — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (formerly Hahn-Meitner-Institut Berlin), Kekuléstraße 5,

D-12489 Berlin, Germany

Transition metals (TM) doped into zinc oxide (ZnO) have attracted considerable interest because of their potential application for spintronic devices. Since the experimental realization of dilute ferromagnetic ZnO is still challenging a detailed knowledge of the atomic structure and the energetics of TM ions in ZnO is essential. Density functional theory (DFT) is a feasible tool for the prediction of both, the local structure and stable charge states of single TM ions in a ZnO host matrix. However, since DFT is a ground state theory it shows significant deficiencies in describing the fundamental band gap especially of wide gap semiconductors like ZnO. Therefore, charge transition levels of dopands calculated by DFT have to be carefully interpreted. In this study we compare two different approaches for the correction of the fundamental band gap of ZnO – the *a posteriori* correction by Janotti and Van de Walle [Phys. Rev. B **76**, 165202 (2007)] with an *a priori* approach by Paudel and Lambrecht [Phys. Rev. B **77**, 205202 (2008)]. Hence we determine the corrected charge transition levels of common transition metals in ZnO.

HL 40.8 Thu 11:30 BEY 118

Defect spectroscopy of homoepitaxial ZnO thin films — •Holger von Wenckstern, Alexander Lajn, Matthias Brandt, Christof Dietrich, Gabriele Benndorf, Michael Lorenz, Gisela Biehne, Holger Hochmuth, and Marius Grundmann — Universität Leipzig, Abteilung Halbleiterphysik, Institut für ExperimentellePhysik II

Homoepitaxially grown ZnO thin films exhibit compared to heteroepitaxial thin films a superior structural quality and a lower defect density [1]. In this work nominally undoped ZnO thin films, grown at various oxygen partial pressures by pulsed laser deposition on thermally pretreated hydrothermally grown ZnO single crystal substrates are investigated. Atomic force microscopy and high resolution X-ray diffraction were carried out to determine the morphological and structural properties of the ZnO thin films. Schottky contacts have been fabricated on the thin films by reactive sputtering of Pt. The barrier heights are ≥ 0.6 eV, yielding, despite the low substrate conductivity, rectification ratios of up to 10^2. This permits the application of space charge layer based defect spectroscopy. We correlate electronic properties measured by photoluminescence at 2 K with thermal admittance spectroscopy results and the growth parameters.

[1] H. v. Wenckstern et al.: phys. stat. sol. (RRL) 1,129 (2007).

15 min. break

HL 40.9 Thu 12:00 BEY 118

Influence of uniaxial strain onto the optical and vibrational properties of high quality ZnO substrates — •Gordon Callsen, Markus R. Wagner, Ronny Kirste, Jan Schulze, and Axel Hoffmann — Technische Universität Berlin, Department of solid state physics, Hardenbergstr. 36, 10623 Berlin, Germany

Homoepitaxial growth of ZnO films requires high quality ZnO substrates with minimal strain and a low impurity concentration. Justified by these requirements we evaluate ZnO substrates of several main suppliers. Therefore, we apply Micro-Raman, XRD and uniaxial strain depended PL measurements. XRD measurements clearly show that the c/a ratio is not a constant throughout the selection of our samples. This is mainly due to a varying compressive strain and defects in the samples as revealed by Micro-Raman measurements. In order to gain further insight into these results we investigate the influence of uniaxial strain onto the free and bound excitonic emission lines of the ZnO substrates (PRB 56, 13087). The uniaxial strain induced change of the crystal field causes a shift of the free excitonic lines. This allows the determination of the deformation potentials of the ZnO substrates (JJAP 40, L1089). The results of those measurements give further insight into the symmetry and ordering of the ZnO valence band. The controlled change of the piezo-electric field of the ZnO crystal also provides conclusions concerning the pressure induced shift of the bound excitons with their different localization energies. Based on our evaluation of the ZnO samples we map out necessary requirements for ZnO substrates in order to achieve homoepitaxial growth of ZnO.

HL 40.10 Thu 12:15 BEY 118

Electron Spin Resonance measurements on ZnMgO thin films grown by plasma assisted molecular beam epitaxy — •Thomas A. Wassner[1], Bernhard Laumer[1], Jochen Bruckbauer[1], Martin S. Brandt[1], Martin Stutzmann[1], and Martin Eickhoff[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

ZnO and $Zn_{1-x}Mg_xO$ thin films were grown epitaxially on (0001)-plane sapphire by plasma assisted molecular beam epitaxy (PAMBE). The obtained thin films were investigated by electron spin resonance (ESR) at a temperature of 4K. In ZnO, an ESR signal with a g-value of about 1.955 was observed. By comparison with the literature, the observed g-value may point to a shallow donor, e.g. In or Al. The intensity of this resonance can be significantly increased by above band-gap illumination and remains almost constant for more than 30 min after stopping the illumination. In $Zn_{1-x}Mg_xO$ the g-value of this resonance systematically shifts to higher values with increasing Mg content, accompanied by an attenuated angular dependence of the line position.

HL 40.11 Thu 12:30 BEY 118

Space charge spectroscopy applied to epitaxial ZnO — •Florian Schmidt[1], Holger von Wenckstern[1], Matthias Schmidt[1], Christian Borschel[2], Carsten Ronning[2], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II — [2]Friedrich Schiller Universität Jena, Institut für Festkörperphysik

One advantageous material property of the wide band-gap II-VI semiconductor ZnO is it's higher radiation hardness compared to the most commonly used semiconductor materials Si and GaAs, respectively. Nevertheless, certain defects are introduced by radiation, implantation or even contact metal deposition. For systematic investigations we used pieces of a single 2 inch ZnO thin film grown by pulsed-laser deposition. To study the influence of the contact metal the thin films were used in their as-grown state. The introduction rate of intrinsic defects is determined for argon-ion implanted thin films. All samples were investigated by depth-resolved cathodoluminescence and space charge spectroscopic methods.

HL 41: GaN: preparation and characterization II

Time: Thursday 9:30–13:00 Location: BEY 154

HL 41.1 Thu 9:30 BEY 154

Growth delay in GaInN/GaN multi quantum wells — •Heiko Bremers, Lars Hoffmann, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institut für Angewandte Physik Mendelssohnstr. 2, 38106 Braunschweig

We have grown MQW (multi quantum well) structures under different growth conditions in a MOVPE reactor (AIXTRON 200RF). The combination of high resolution x-ray diffraction with TEM measurements allow the determination of structural parameters of the layered system. By a systematic variation of thickness of QW and V/III ratio we have observed a growth delay in period length (i.e. QW + barrier thicknss). This growth delay of 70 s relates to missing thickness of approximately 1 nm. Based on the obsevation that the TMI (tri methyl indium) flux exhibits a linear relationship with the period length as well as to the indium concentration in the QW we will try to present a model which explains the origin of this growth delay. Finally we will compare these results to PL measurements.

HL 41.2 Thu 9:45 BEY 154

Spectrally and time resolved cathodoluminescence spectroscopy of AlN grown on sapphire by high-temperature MOVPE — •Martin von Kurnatowski[1], Barbara Bastek[1], Juergen Christen[1], Thomas Hempel[1], Outi Rentilä[2], Viola Küller[2], Frank Brunner[2], and Markus Weyers[2] — [1]Otto-von-Guericke-Universität Magdeburg — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik Berlin

We present spectrally and ps-time resolved cathodoluminescence studies of AlN epilayers grown on sapphire by high-temperature MOVPE. The spatially averaged 5 K luminescence spectrum shows bright near band gap (NBG) emission dominated by a sharp (D^0, X) peak at 5.94 eV. Apart from that, a broad luminescence band occurs at lower energies. It consists of two parts, centered at 3.0 eV and 3.8 eV, assigned to an O-DX-center and a Si defect, respectively. The intensity of the emission caused by Si-defects is characterized by a thermal activation, described by an activated Arrhenius-function. An activation energy of 48 meV is determined. Due to this behavior, the Silicon defects are interpreted as DX-centers as well.

For the analysis of the recombination kinetics and its temperature dependence periodic excitation was performed in ps-CL using rectangular e-beam pulses. Appropriately matched repetition frequencies ranging from MHz down to below 1 kHz and matched puls length were chosen, depending on the actual kinetics timescale. For the 3.0 eV band a strongly non-exponential decay is found with time constants ranging from the ns- to the ms-range.

HL 41.3 Thu 10:00 BEY 154

Control of MOVPE InGaN quantum dot density and emission wavelength and applications in light emitting structures — •Christian Tessarek, Timo Aschenbrenner, Stephan Figge, Joachim Kalden, Kathrin Sebald, Jürgen Gutowski, and Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

InGaN quantum dots (QDs) are very promising for the application in laser structures emitting in the blue to green spectral region due to the expected lower threshold currents in comparison to a quantum well (QW) based device.

Our approach to form capped InGaN QDs is a two-step growth method [1] which is composed of an InGaN nucleation layer (NL) followed by an (In)GaN protection layer. There are indications that spinodal decomposition is the driving force for the transition of the NL into self-assembled QDs.

We will show how the emission wavelength can be tuned from 440 nm to 520 nm by varying the NL thickness and the In content in the protection layer. Atomic force microscope and photoluminescence (PL) results reveal a QD density dependence on the NL growth temperature.

The strong room temperature PL emission intensity of the QDs promises an improvement in device performance compared to QW based devices. We will demonstrate the successful implementation of these InGaN QDs into light emitting diodes and laser structures.

[1] T. Yamaguchi et al., phys. stat. sol. (c) 4, No. 7, 2407-2410 (2007)

HL 41.4 Thu 10:15 BEY 154

Kathodolumineszenz-Mikroskopie an InGaN/GaN Pyramiden — •Frank Bertram[1], Sebastian Metzner[1], Jürgen Christen[1], Michael Jetter[2], Clements Wächter[2] und Peter Michler[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Stuttgart Universität

Die optischen Eigenschaften von InGaN Nanostrukturen wurden mittels hochorts- und spektralaufgelöster Kathodolumineszenz untersucht. Regelmäßig in Feldern angeordnete, hexagonale GaN Pyramiden wurden auf einem GaN/Saphir-Substrat mit Hilfe von MOVPE und Photolithographie gewachsen. Die sechs semipolaren $\{1\bar{1}01\}$ Pyramidenfacetten wurden mit einem nominell 6 nm dicken InGaN SQW überwachsen. Das ortsintegrale KL Spektrum zeigt eine breite InGaN Lumineszenz zwischen 1.9-2.6eV sowie eine sehr intensive (D^0,X)-Linie vom GaN. Die InGaN Lumineszenz stammt ausschließlich von den Pyramiden. An der Basis und insbesondere an der Pyramidenspitze leuchtet der InGaN-SQW besonders intensiv. Die InGaN-KL ist an der Basis deutlich durch horizontal verlaufende Intensitätssprünge moduliert welche mit Wellenlängenänderungen einhergehen. Geringere Intensitäten korrelieren eindeutig mit kürzeren Wellenlängen. Die Wellenlänge variiert hier um einen Wert von 55 0nm. Im oberen Pyramidendrittel spaltet die InGaN Bande in zwei separate Linien auf. Eine Wellenlänge um 590 nm tritt bevorzugt an den Kanten/Spitze auf. Dagegen tritt eine KL von 530 nm im Facettenzentrum auf. Diese Änderungen lassen sich mit Dicken-/Konzentrationsänderungen des QW erklären.

15 min. break

HL 41.5 Thu 10:45 BEY 154

Transport freier Exzitonen in HVPE-GaN — •Martin Noltemeyer[1], Frank Bertram[1], Jürgen Christen[1], Tim Wenicke[2], Christian Hennig[2], Markus Weyers[2] und Michael Kneissl[2,3] — [1]Otto-von-Guericke-Universität Magdeburg — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik Berlin — [3]Technische Universität Berlin

Mittels hoch orts- und ps-zeitaufgelöster Kathodolumineszenzspektroskopie (KL) wurde der nanoskopische laterale Transport freier Exzitonen (FX) in HVPE gewachsenen, dicken GaN-Schichten untersucht. Dazu wurden die Diffusionslänge λ_{FX} und die Lebensdauer τ_{FX} in Abhängigkeit von der Temperatur gemessen. Hieraus wurde die FX-Beweglichkeit berechnet, deren Temperaturabhängigkeit Informationen über die zugrunde liegenden Streumechanismen liefert. Die FX-Diffusionslänge wurde mittels KL-Linescans senkrecht zur Kante einer 160 nm dicken, rechteckigen Ti-Maske und numerischer Anpassung mit der analytischen Lösung der 1d-Diffusionsgleichung bestimmt. Weit entfernt von den Ti-Masken wurden an derselben Probe Lumineszenztransienten aufgenommen und die anfängliche Lebensdauer $\tau_{FX}(T)$ ermittelt. Mit fallender Temperatur (300 K bis 5 K) nimmt λ_{FX} monoton zu, während τ_{FX} von 1,3 ns auf 300 ps fällt. Daraus folgt eine monotone Zunahme der Beweglichkeit mit sinkender Temperatur um mehr als drei Größenordnungen (30.000 cm^2/Vs bei 5 K). Die charakteristische Abnahme der Beweglichkeit bei tiefen Temperaturen aufgrund der Streuung von Elektronen und Löchern an ionisierten Störstellen, tritt bei den elektrisch neutralen freien Exzitonen nicht auf.

HL 41.6 Thu 11:00 BEY 154

Defect-related cathodoluminescence in ELOG GaN structures — •Ingo Tischer[1], Martin Schirra[1], Martin Feneberg[1], Rolf Sauer[1], Klaus Thonke[1], Thomas Wunderer[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

Defect-related luminescence was studied in a sample having selectively overgrown triangular shaped GaN stripes with stable $\{1\bar{1}01\}$ facets. This sample was intentionally grown under unfavourable conditions in order to provoke a high density of light emitting structural defects. Spatially resolved cathodoluminescence of both the semi-polar $\{1\bar{1}01\}$ facets and the cross section was recorded. Different emission bands between 3.16 and 3.35eV were observed and systematically investigated using monochromatic CL images and CL linescans with low electron excitation energies to push the spatial resolution to the limit of 40nm. Some of the spectral features are complementary to each other, while others appear commonly in certain regions. A detailed discussion of the spectral and spatial distribution of these defect-related transitions and their possible structural origin will be presented.

HL 41.7 Thu 11:15 BEY 154

Optical properties of GaN nanorods grown catalyst- and mask-free on r-plane sapphire — •Joachim Kalden, Kathrin Sebald, Moritz Seyfried, Tobias Voss, Jürgen Gutowski, Timo Aschenbrenner, Gerd Kunert, Carsten Kruse, Stefan Figge, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

In the UV spectral region GaN is an up-and-coming material system for the realization of nanostructures with high crystalline quality. So far, such nanorods have been realized by either applying a mask or using a catalyst. Both approaches lead to an unintentional doping and the creation of deep centers, the latter one reducing the efficiency of the near-band edge emission. We present GaN nanorods which were grown catalyst- and mask-free in two steps. After nitridation via metal-organic vapor phase epitaxy the nanorod growth is realized via molecular beam epitaxy. These nanorods have brilliant optical properties. Microphotoluminescence measurements are performed at temperatures between 4 and 300 K. The excitonic emission band reveals several distinct lines which can be attributed to donor-bound (D^0X) and acceptor-bound (A^0X) excitons, respectively. The full width at half maximum (FWHM) of the D^0X emission is 1.2 meV, proving the high crystalline quality. Furthermore, the free exciton is visible as a shoulder already at 4 K, while no yellow defect-related luminescence occurs. Microphotoluminescence experiments on single nanorods reveal strong luminescence intensity up to room temperature.

HL 41.8 Thu 11:30 BEY 154

Optical and magnetic properties of Gd doped GaN — •Ole Hitzemann[1], Martin Kaiser[1], Enno Malguth[1,2], Markus R. Wagner[1], Jan H. Schulze[1], Wolfgang Gehlhoff[1], Axel

Hoffmann[1], Shalini Gupta[2], Ian T. Ferguson[2], Martin Röver[3], Dong-Du Mai[3], and Angela Rizzi[3] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, USA — [3]IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August Universität Göttingen, Germany

Gd doped GaN is of high interest for spintronics because it shows a ferromagnetic behavior with a high magnetic moment per Gd atom as well as good conductivity at RT. To investigate the coupling mechanism behind the strong magnetization we examined MOCVD and MBE grown samples of epitaxial layers of this diluted magnetic semiconductor containing Gd at concentrations ranging from 10^{18} cm^{-3} to 10^{21} cm^{-3}. p-type and n-type co-doping allowed the investigation of the effect of the position of the Fermi level. We present high resolution photo luminescence (PL) spectra of a doublet peak at 1.7876 eV with a FWHM of 40 μeV in all Gd doped samples which we associate with an internal Gd^{3+} transition. The relatively long time constant of 3.5 ms found in time resolved PL experiments confirms the attribution to an intra f-shell transition. Excitation spectra of this luminescence reveal efficient excitation bands between 2.0 and 2.6 eV. The results are discussed in terms of a bound state that might play a significant role in the ferromagnetic behavior reported for GaGdN.

15 min. break

HL 41.9 Thu 12:00 BEY 154

Swift heavy ion irradiation induced recrystallization of implanted GaN — •Anne-Katrin Nix[1], Sven Müller[1], Ulrich Vetter[1], Christina Trautmann[2], and Hans Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Germany — [2]Gesellschaft für Schwerionenforschung, Darmstadt, Germany

Preparing GaN:Mg by ion implantation is a widely used technique of doping, but results in a high level of lattice defects. Thermal annealing can be used for recrystallization, but sample decomposition often hampers the annealing effect. Here, we present swift heavy ion irradiation as an alternative annealing method. Due to high electronic energy loss along the ion track, the sample is locally heated during a time span of 10^{-12} seconds. Thus, surrounding material stays unaffected. Implanted GaN samples were irradiated with several ion species at different energies with the objective to vary the electronic energy loss. Directly after implantation and after irradiation, the photoluminescence excited with a laser emitting in the UV-regime was examined at low temperature. The obtained spectra are compared to well known spectra of GaN and GaN:Mg. An annealing effect is seen after 578 MeV Cr-irradiation. GaN samples were irradiated with 668 MeV Ni-ions with varying fluences, obtaining a similar electronic energy loss compared to 578 MeV Cr-ions, with the goal to examine a fluence dependence of the annealing process. In addition, irradiation with light ions, and thus much lower electronic energy loss, was performed with the aim of analyzing a possible threshold value of the electronic energy loss.

HL 41.10 Thu 12:15 BEY 154

Role of the parasitic Mg_3N_2 phase in post-growth activation of p-doped Mg:GaN — •Björn Lange, Christoph Freysoldt, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, 40237 Düsseldorf, Germany

A critical issue in further improving the efficiency of modern white light-emitting diodes is the rather limited p-type conductivity achievable in GaN. The limited doping efficiency is a direct consequence of the low solubility of Mg in GaN due to the formation of the parasitic Mg_3N_2 phase. While the presence of this phase is well known and often unavoidable its consequences on the acceptor activation mechanism (H codoping with subsequent H removal) have not been studied so far. We have therefore studied the possibility to exploit these Mg_3N_2 inclusions as potential hydrogen traps by means of DFT calculations. For this, Mg_3N_2 has been modeled in the anti-bixbyite structure. The calculated structural properties are in good agreement with available experimental data. Based on these studies hydrogen has been explored in various positions and charge states. Our results show significantly higher H solubilities compared to GaN. Further a strongly bound N-H complex is identified which is more stable than the Mg-H complex in GaN. The implications for Mg activation in Mg:GaN above the Mg solubility limit will be discussed.

HL 41.11 Thu 12:30 BEY 154

Growth modes of thick InGaN films on GaN — •Martin Leyer, André Kruse, Joachim Stellmach, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

We have investigated the growth of thick (d > 10 nm) InGaN layers grown by metal-organic vapour phase epitaxy (MOVPE). The composition was controlled by varying the growth temperature between 700 °C and 850 °C. The indium content and the strain was determined by X-ray diffraction. We observed two distinct peaks in the ω-2Θ scans for most of the samples. For lower growth temperatures a relaxed top layer was found in reciprocal space maps. For higher growth tempratures a lateral decomposed top layer was observed. The variation of the indium content with growth temperature was exponential.

We propose the following model: In a first step a smooth strained InGaN wetting layer is grown in the Stranski-Krastanov growth mode. Then a transition from 2D to 3D growth takes place. For growth temperatures below 750 °C a rough layer is grown pseudomorphic up to the crititcal layer thickness and subsequently relaxes. For growth temperatures above 750 °C a strained, but laterally inhomogeneous layer is grown.

For the strained layer the activation energy for indium incorporation was ∼2.2 eV and for the relaxed layer ∼0.6 eV. Growth rate(s) and the critical thickness(es) were obtained by in-situ ellipsometry.

HL 41.12 Thu 12:45 BEY 154

Katalysator- und maskenfreies Wachstum von GaN-Nanosäulen — •Gerd Kunert[1], Timo Aschenbrenner[1], Carsten Kruse[1], Stephan Figge[1], Detlef Hommel[1], Marco Schowalter[2] und Andreas Rosenauer[2] — [1]Institut für Festkörperphysik - Halbleiterepitaxie - Universität Bremen, 28359 Bremen, Otto-Hahn Allee, NW1 — [2]Institut für Festkörperphysik - Transmissionselektronenmikroskopie - Universität Bremen, 28359 Bremen, Otto-Hahn Allee, NW1

In den letzten Jahren gab es umfangreiche Untersuchungen in Bezug auf Galliumnitrid basierten Nanosäulen. Viele Herstellungsmethoden verwenden dabei katalysatorinduziertes Wachstum oder eine Maskierung der Oberfläche. In diesem Beitrag wird ein Verfahren präsentiert, was die Schwierigkeiten dieser Methoden in Bezug auf Materialqualität umgeht. In einem ersten Schritt wird die Saphir-Oberfläche mit r-Flächenorientierung mit Hilfe metallorganischer Gasphasenepitaxie nitridiert. Es bilden sich AlN Inseln auf dem Substrat. In einem zweiten Schritt wird das Wachstum mittels MBE durchgeführt. Das Verfahren führt zu um 28° zur Oberflächennormalen geneigten Nanokristallen. Deren sehr gute kristalline Qualität wurde durch TEM-Untersuchungen gezeigt. Zeitgleich zum Wachstum der Nanokristalle wächst eine kompakte, zweidimensionale Schicht Galliumnitrid, die zur Kontaktierung späterer Bauelemente genutzt werden kann. Es wurden Nanosäulen hergestellt mit einer Länge von bis zu 3μm. Deren Dichte lässt sich zwischen $10^7 cm^{-2}$ und $10^9 cm^{-2}$ variieren.

HL 42: Interfaces/surfaces

Time: Thursday 9:30–10:45 Location: POT 51

HL 42.1 Thu 9:30 POT 51

How a hydrogen passivated surface could appear to be metallic: the story of the 3C-SiC (001) 3x2 surface — •Peter Deak, Balint Aradi, and Thomas Frauenheim — Bremen Center for Computational Materials Science, University of Bremen, Am Fallturm 1, D-28359 Bremen, Germany

Photo electron and scanning tunneling spectroscopy has revealed partially filled states near the conduction band edge of the silicon rich (3x2)-reconstructed (001) surface of cubic SiC, after exposure to atomic hydrogen. These were attributed to a row of unsaturated singly occupied Si dangling bonds by experimentalists, and to a defect band due to a row of Si-H-Si tri-center bonds by theorists. Here we show that the surface is, in fact, completely passivated by hydrogen (no partially filled defect band) but, in doped samples, the accumulation of conduc-

tion band electrons at a polar surface can explain the experimental observations.

HL 42.2 Thu 9:45 POT 51

Control of Donor Charge States with the Tip of a Scanning Tunnelling Microscope — •K. Teichmann[1], M. Wenderoth[1], S. Loth[1], R. G. Ulbrich[1], J. K. Garlef[2], A. P. Wijnheijmer[2], and P. M. Koenraad[2] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen — [2]PSN, Eindhoven University of Technology, the Netherlands

The functionality of nanoscale semiconductor devices crucially depends on details of the electrostatic potential landscape on the atomic scale and its microscopic response to external electric fields. We report here an investigation of charge state switching of buried single Si donors in $6 \cdot 10^{18}$ cm^{-3} n-doped GaAs with scanning tunnelling microscopy (STM) under UHV conditions at 5K. The effect of tip induced band bending (TIBB) through the freshly cleaved (110)-surface was used to change the charge state of individual donors from neutral to positively charged and reverse. Scanning tunnelling spectroscopy (STS) revealed a ring like feature around each donor center. The ring radius depends on tip bias voltage [1] . The charge state of each donor in the random arrangement of dopants was in most cases unambiguously fixed by the extension of the tip-induced space charge cloud, which was located under the tip and controlled by the applied voltage. For certain geometric configurations the system showed bi- (or multi-) stable behaviour, this lead to dynamic flickering of the ionization sequence. This work was supported by DFG SFB 602 and DFG SPP 1285.

[1] PRL 101, 076103 (2008)

HL 42.3 Thu 10:00 POT 51

Application of catalytic nanoparticles to wide bandgap semiconductor surfaces — •Susanne Schaefer[1], Sonja Wyrzgol[2], Yizhen Wang[1], Johannes Lercher[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Technische Chemie 2, Technische Universität München, Lichtenbergstr. 4, 85747 Garching, Germany

Wide bandgap semiconductors are investigated as materials for the electronic control of catalytic reactions via metal nanoparticles. To conduct test reactions like selective hydrogenation, platinum nanoparticles are applied to the semiconductor surface. GaN substrates, which were grown by MOCVD as well as PAMBE, were used as nanoparticle support. The nanoparticles were prepared by two methods: spin-coating with polymer-encapsulated Pt nanoparticles and evaporation of Pt at elevated temperatures. For polyvinyl-pyrolidone (PVP)-coated nanoparticles, an avarage size of 2.4 nm was observed with TEM. The PVP-coated particles were applied to the semiconductor support via spin coating and activated by oxygen plasma. For particles applied by evaporation, Pt layers with a nominal thickness of 0.2-5 nm were deposited, as determined by EDX. Under defined heating and gas flow, the platinum atoms coalesce to particles. Particle sizes and distributions were investigated with AFM. For testing the electronic properties of these semiconductor-metal interfaces, Schottky diodes were processed with standard lithography. UI-characteristics were measured for various particle sizes.

HL 42.4 Thu 10:15 POT 51

Surface states and origin of the Fermi level pinning on non-polar GaN($1\bar{1}00$) surfaces — •Lena Ivanova[1], Svetlana Borisova[2], Holger Eisele[1], Mario Dähne[1], Ansger Laubsch[3], and Philipp Ebert[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]OSRAM Opto-Semiconductors GmbH, 93055 Regensburg, Germany

Group-III nitrides raised considerable attraction because of their ideal properties for green, blue, and ultraviolet laser and LED devices. One particular challenge of the epitaxial growth is the impurity, dopant, and defect incorporation during growth, which often depends on the position of the Fermi level at the growth surface. For the non-polar GaN surfaces only little is known about the exact positions of the surface states and thus their possible influence on the Fermi energy. Therefore, we investigated GaN($1\bar{1}00$) cleavage surfaces by cross-sectional scanning tunneling microscopy and spectroscopy [1]. We identified the energy positions and types of surface states as well as the origin of the Fermi level pinning on GaN($1\bar{1}00$) cleavage surfaces. It is found that both the N and Ga derived intrinsic dangling bond surface states are outside of the fundamental band gap. The observed Fermi level pinning 1.0 eV below the conduction band edge is attributed to the high step and defect density at the surface but not to intrinsic surface states. [1] L. Ivanova et al., APL 93, 192110 (2008). This work is supported by the DFG.

HL 42.5 Thu 10:30 POT 51

Initial stages of GaN(0001)-2x2 - oxidation — •Pierre Lorenz[1], Richard Gutt[2], Juergen A. Schaefer[1], and Stefan Krischok[1] — [1]Institute of Physics and Institute of Micro- und Nanotechnologies, Technical University Ilmenau, P.O. Box 100565, D-98684 Ilmenau, Germany — [2]Fraunhofer Institute for Applied Solid State Physics, Tullastr. 72, 79108 Freiburg, Germany

We studied the initial oxidation stages of 2x2 reconstructed Ga-face GaN(0001) grown in-situ by PAMBE. The oxidation process was characterized using X-ray and ultraviolet photoelectron spectroscopy (XPS, UPS), as well as reflection high energy electron diffraction (RHEED). In particular, the evolution of the valence band structure, the work function and the core levels of gallium and nitrogen as well as the increase of the oxygen O 1s emission were studied in combination with the corresponding RHEED pattern as a function of oxygen exposure. The clean GaN(0001)-2x2 surface exhibits two surface states at 2 eV (S1) and 3.5 eV (S2) below the Fermi level. The exposure to O_2 results in two well pronounced valence band structures at binding energies of about 6 eV and 11 eV, respectively, which are caused by the adsorbed oxygen. The 2x2 reconstruction as well as the S1 state disappear rapidly, revealing an extremely high reactivity of the as grown GaN surface, whereas the S2 state vanishes considerably slower.

HL 43: Photonic crystals I

Time: Thursday 9:30–12:30 Location: POT 151

HL 43.1 Thu 9:30 POT 151

Electro-optical modulator in a polymer- infiltrated silicon slotted photonic crystal waveguide heterostructure resonator — •Jan Hendrik Wülbern, Alexander Petrov, and Manfred Eich — Institut für Optische und Elektronische Materialen, Technische Universität Hamburg-Harburg, 21073 Hamburg

We present a novel concept of a compact, ultra fast electro-optic modulator, based on photonic crystal resonator structures that can be realized in two dimensional photonic crystal slabs of silicon as core material employing a nonlinear optical polymer as infiltration and cladding material. The novel concept is to combine a photonic crystal heterostructure cavity with a slotted defect waveguide. The photonic crystal lattice can be used as a distributed electrode for the application of a modulation signal. An electrical contact is hence provided while the optical wave is kept isolated from the lossy metal electrodes. Thereby, well known disadvantages of segmented electrode designs such as excessive scattering are avoided. The optical field enhancement in the slotted region increases the nonlinear interaction with an external electric field resulting in an envisaged switching voltage of less than 1 V at modulation speeds up to 100 GHz.

HL 43.2 Thu 9:45 POT 151

Room Temperature Tuning of Photonic Crystal Cavities — •Karoline A. Piegdon[1,2], Heiner Matthias[3], Heinrich-S. Kitzerow[3], Dirk Reuter[4], and Cedrik Meier[2] — [1]University of Duisburg-Essen, Physics Department — [2]University of Paderborn, Nanophotonics and Nanomaterials — [3]University of Paderborn, Physical Chemistry — [4]Ruhr University of Bochum

Photonic crystal (PC) cavities are in the focus of interest due to the strong light-matter interaction, that makes them suitable for quantum electrodynamics in cavities containing semiconductor quantum dots (QDs). Recent experiments with single QDs coupled to a high

quality factor cavity mode got most attention, since they show strong cavity-QED effects. However, the inability to fabricate cavities with a designated resonant wavelength makes their tuning indispensable.

In our room temperature photonic crystal cavities we implemented different techniques for reversible or permanent tuning of the resonant mode. We fabricated photonic crystal membranes from a (Al,Ga)As heterostructure; the membrane slab contains self-assembled InAs QDs exhibiting luminescence at 300K between 1000nm and 1300nm. In all experiments we employed control of the refractive index of the surrounding of the photonic crystals in order to gain control over the resonant mode wavelength. Depending on the application, reversible or irreversibel tuning is desired. This is achieved by deposition of thin layers of material on the PC or by using the tunability of liquid crystals.

HL 43.3 Thu 10:00 POT 151

Multiple Scattering of Light in Three-dimensional Photonic Quasicrystals — •Alexandra Ledermann[1], Michael Kallenberg[1], Diederik S. Wiersma[2], Martin Wegener[1], and Georg von Freymann[1] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]European Laboratory for Nonlinear Spectroscopy (LENS) and INFM, Firenze

Quasicrystals (QC) represent a class of solids which lack translational symmetry, yet exhibit perfect long-range order and high-degree rotational symmetries, not necessarily consistent with periodicity. Using direct laser writing [1] we fabricate three-dimensional SU-8 photonic QCs of high quality [2] and study their optical properties. The results of our Laue diffraction experiments and our time-resolved pulse propagation studies are reproduced by our simulations [3], showing that multiple scattering of light plays an important role in describing the unusual properties of QCs. We find features of both, disordered optical systems as well as periodic photonic crystals.

[1] M. Deubel et al., Nature Materials, 3, 444 (2004).
[2] A. Ledermann et al., Nature Materials, 5, 942 (2006).
[3] A. Ledermann et al., Optics Express, submitted (2008).

HL 43.4 Thu 10:15 POT 151

Stereometamaterials — Na Liu[1], •Hui Liu[2], Shining Zhu[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, 70569 Stuttgart, Germany — [2]Department of Physics, Nanjing University, Nanjing 210093, P. R. China

Abstract: We introduce a novel concept to nano-photonics, namely stereometamaterials. As model system of stereometamaterials, we theoretically and experimentally study meta-dimers, which consist of a stack of two identical split-ring resonators[1] in each unit cell with various twist angles. We demonstrate that the interplay between electric and magnetic interactions plays a crucial role for the optical properties[2]. Specifically, the influence of higher-order electric multipoles becomes clearly evident. The twisting of stereometamaterials paves the road towards engineering of complex plasmonic nanostructures with tailored electric and magnetic interactions.

[1] N. Liu et al., *Three-dimensional photonic metamaterials at optical frequencies*. Nature Mater. 7, 31 (2008). [2] H. Liu et al., *Magnetic plasmon hybridization and optical activity at optical frequencies in metallic nanostructures.*Phys. Rev. B. 76, 073101 (2007).

15 min. break

HL 43.5 Thu 10:45 POT 151

3D Vectorial Wannier Functions for the Design of Functional Defect Structures in Photonic Crystals — •Chrisitan Wolff[1,2,4], Christopher Kölper[1], Patrick Mack[1,3], Daniel Hermann[1,2], and Kurt Busch[1,2,3,4] — [1]Institut für theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft — [4]Karlsruhe School of Optics and Photonics (KSOP), Universität Karlsruhe

Photonic circuits formed by defect arrays in photonic crystals are a promising approach for integrated optics applications. However, such systems combine large spatial extents and highly structured, very regular geometries. As a consequence, conventional numerical methods are challenged by excessive resource consumption. In contrast, the Wannier functions of the unperturbed photonic crystal offer an efficient expansion basis which had been verified in the past for 2D systems, in which the decoupling of the polarizations leads to a scalar problem. We report on the generalization of the method towards fully vectorial 3D photonic Wannier functions and their application to defect structures in 3D photonic crystals and photonic crystal slabs.

HL 43.6 Thu 11:00 POT 151

Silicon-based low-loss photonic crystal waveguides — •Daniel Pergande[1] and Ralf B. Wehrspohn[1,2] — [1]Institut of Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle — [2]Fraunhofer Institute for Mechanics of Materials, 06120 Halle

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

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

HL 43.7 Thu 11:15 POT 151

Influence of (Geometrical) Micropillar Properties on the Cavity Quality Factor — •Matthias Karl[1], Benjamin Kettner[2], Sven Burger[2], Frank Schmidt[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Zuse Institut Berlin (ZIB), 14195 Berlin, Germany

We present numerical studies of optical cavity modes in Bragg micropillars based on a finite element method (FEM). The modes are either obtained by solving an eigenvalue or a scattering problem. Good agreement to experimental data is demonstrated and various influences on the quality (Q) factor of the fundamental pillar mode are investigated.

On the one hand we determine absolute maximum Q factors which depend on the absorption of the semiconductor cavity material. On the other hand geometrical parameters are varied in detail to calculate their influence: Pillar diameter and sidewall inclination show critical features with respect to the Q factor. Furthermore, the top and bottom Bragg stacks are modified in the number of pairs and the etching depth.

15 min. break

HL 43.8 Thu 11:45 POT 151

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

In structured noble-metal films, surface-plasmon polaritons (SPPs) can be excited optically. SPPs consist of electromagnetic surface waves accompanied by longitudinal electron-density waves. Polaritonic crystals made from planar metal films covered with dielectric gratings have been shown to exhibit band gaps in the polariton dispersions. Here, we experimentally and theoretically investigate the polaritonic band gaps of gold films coated with high-refractive index ($n > 2$) gratings. The band-gap widths achievable in these structures are studied. In particular, the dependence of the band-gap width on the refractive index and filling factor of the gratings are discussed. We find that the polaritonic band-gap collapses for certain combinations of these parameters. Furthermore, strong variations of the polariton line width as a function of the refractive index and filling factor are predicted.

HL 43.9 Thu 12:00 POT 151

Feature size reduction of silicon inverted direct laser written photonic crystal structures — •Isabelle Staude[1,2], Martin Hermatschweiler[1,3], Georg von Freymann[1,3], and Martin Wegener[1,2,3] — [1]DFG-Centrum für Funktionale Nanostrukturen (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe —

[3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe GmbH, 76021 Karlsruhe

Direct laser writing of photonic crystal polymer templates in combination with a subsequent silicon double inversion procedure allows for the fabrication of high quality photonic band gap materials [1]. However, for structures made along these lines, the fundamental band gap has so far been located in the spectral range well above 2 microns wavelength, disqualifying the procedure for applications at telecommunication wavelengths. We could now demonstrate experimentally that feature sizes can be reduced with an improved fabrication scheme. Modifications mainly affect the pre- and post-exposure treatment of the employed photoresist SU-8. The crucial step consists of omitting the standard post-exposure bake relying on optical curing as suggested in [2]. In this manner we have realized silicon woodpile photonic crystal structures with 600 nm lateral rod distance showing prominent photonic stop bands centred around 1.4 microns wavelength, where suppression of transmittance of up to two orders of magnitude is achieved.
[1] N. Tétreault *et al.*, Adv. Mater. **18** (4), 457 (2006)
[2] K. K. Seet *et al.*, Appl. Phys. Lett.. **89** (2), 024106 (2006)

HL 43.10 Thu 12:15 POT 151

Localization limits in slow light photonic crystal waveguides — •Alexander Petrov and Manfred Eich — Technische Universität Hamburg-Harburg, E-12, Eissendorfer Strasse 38, D-21073 Hamburg, Germany

The disorder in photonic crystal waveguides leads to distributed back scattering of guided modes. The backscattering intensity scales with inverse group velocity squared and leads to localization phenomena in slow light waveguides. The use of slow light components above the localization length is not possible due to the phase distortion of the signal. The reflection at a single defect is calculated with eigenmode expansion method and localization lengths are estimated as functions of group velocity in 1D and 2D photonic crystal structures. The effect of absorption and vertical scattering as well as gain on localization phenomena is discussed. It is demonstrated that absorption and vertical scattering effectively diminish localization phenomena and allow use of longer slow light components, whereas gain enhances localization and should be used carefully in slow light structures.

HL 44: Organic semiconductors I

Time: Thursday 10:45–13:00 Location: POT 51

HL 44.1 Thu 10:45 POT 51

Charge transfer and polarization screening at organic-metal interfaces — •Heiko Peisert, Daniel Kolacyak, and Thomas Chassé — University of Tübingen, Institute of Physical and Theoretical Chemistry, Auf der Morgenstelle 8, 72076 Tübingen, Germany

Core hole screening effects at organic/metal interfaces were studied using core level X-ray photoemission spectroscopy (XPS), x-ray excited Auger electron spectroscopy (XAES) and valence band ultraviolet photoemission spectroscopy (UPS). The comparison of energetic shifts in XPS and XAES enables the estimation of electronic relaxation energy (screening ability). Magnesium phthalocyanine (MgPc), zinc phthalocyanine (ZnPc) and perfluorinated zinc phthalocyanine (ZnPcF16) evaporated on single crystalline Au(100) were used as model molecules. Two different features in the metal Auger spectra can be clearly separated for (sub-)monolayer coverages while only minor changes of the shape of corresponding photoemission features are observed. In contrast, Auger spectra of fluorine in ZnPcF16 do not show different components for ultrathin films. Applying a dielectric continuum model, the major screening mechanism cannot be described sufficiently by polarization screening due to mirror charges, significant contributions by charge transfer screening have to be considered. The work was supported by the German Research Council Ch 132/20-1.

HL 44.2 Thu 11:00 POT 51

In-situ study of electronical properties of pentacene transistors during growth — •Daniel Beckmeier[1,2], Matthias Fiebig[1], and Bert Nickel[1] — [1]Department für Physik, Ludwig-Maximilians-Universität, D-80539 München — [2]Institut für Physik, Universität der Bundeswehr München, D-85579 Neubiberg

Organic thin film transistors (TFT) with pentacene as semiconductor material were grown by molecular beam deposition (MBD). They were electrically characterized in situ during growth at vacuum conditions to analyze the dependence of the electronic properties on the film thickness of the pentacene layer.

TFT structures were electrically connected inside the MBD chamber. The channel length of the structures was 25 μm. A 150 nm thick silicon oxide was used as gate dielectric. To improve the pentacene film growth, polymer layers (polystyrene and cyclic olefin copolymer) were spin-coated on top of the oxide. Pentacene was evaporated onto the structures. Simultaneously, the transfer and output characteristics were measured. The data was analyzed using TFT theory to extract the mobility and threshold voltage as a function of film thickness. Starting from about 1 nm film thickness, a linear increase of mobility with film thickness was observed. The mobility saturated at film thicknesses between 8 and 30 nm, depending on substrate and growth conditions. Once transferred to ambient conditions, the TFTs showed a strong hysteresis, a reduction in mobility and a shift of the threshold voltage towards more positively biased values.

HL 44.3 Thu 11:15 POT 51

Potential Measurements in the channel of organic field-effect transistors in top gate geometry — •Richa Sharma, Benedikt Gburek, Torsten Balster, and Veit Wagner — Jacobs University Bremen, Bremen, Germany

It has been found that the ordering of the semiconductor adjacent to the dielectric interface, where charge transport takes place, is crucial. Additional information on charge transport by measuring the voltage distribution over the channel can be obtained. This is not trivial in top-gate geometry due to the buried semiconductor layer. To enable potential measurements in this geometry, source and drain electrodes along with two sense fingers are patterned in the channel by optical lithography. In the experiment the drain current along with the potential values at the sense fingers are recorded simultaneously during drain and gate voltage variations. Model simulations of the transistor yielding current and potential values are compared to the experimentally obtained values. The measured voltage distributions show considerable deviations from the calculated values obtained by the gradual channel approximation. These deviations are mainly attributed to contact effects and major modifications of the voltage distribution in the channel in the sub-threshold regime.

HL 44.4 Thu 11:30 POT 51

Electronic Spectroscopy of Organic Semiconductors in Helium Nanodroplets — •Matthieu Dvorak[1], Oliver Bünermann[1], Frank Stienkemeier[1], and Alexander Eisfeld[2] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder Str. 3, D-79104 Freiburg — [2]MPI-PKS, Nöthnitzer Str. 38, D-01187 Dresden

Spectroscopy of molecules or molecular complexes embedded in helium nanodroplets is an outstanding tool to characterize electronic and geometric structures. Due to the unique properties of the superfluid droplets, helium nanodroplets isolation (HENDI) spectroscopy reaches far better spectral resolution than usually obtained in organic solvents or on thin films.

We applied HENDI to investigate the absorption and emission spectra of the PTCDA molecule and its complexes. The PTCDA monomer shows sharp vibronic lines (<1 cm-1) that can be assigned to different internal vibration modes as well as overtones and combination modes. PTCDA complexes show different spectral features. Sharp lines, red shifted compared to the monomer absorptions are assigned to T-structured dimers. Additionally, very broad absorption lines are observed. These are assigned to complexes forming sandwich structures [1]. Recent theoretical calculations can reproduce the spectra and support this interpretation. Furthermore, in comparison to absorption spectra, emission intensities allow to study the amount of internal relaxation before emitting a photon, giving further insight into the involved processes.

[1] M. Wewer and F. Stienkemeier, Phys. Rev. B 67, 125201, 2003

15 min. break

HL 44.5 Thu 12:00 POT 51

The impact of oxygen on trap states in P3HT:PCBM blends — •Julia Schafferhans[1], Roland Marx[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

Conjugated polymers receive a growing interest for application in organic solar cells due to their low cost processability from solution. Efficiencies of almost 6% for organic solar cells have already been achieved. A limiting factor, so far, is the lifetime of these devices. To investigate the stability and to obtain an understanding of the underlying degradation mechanism is an important prerequisite for a stable performance. Accordingly, the presence of defect states can be critical, as they reduce the charge carrier mobility, affect the driving voltage, disturb the internal field distribution and can act as recombination centers. We present investigations on the influence of oxygen on defect states in P3HT:PCBM blends, one of the most promising candidates for organic solar cells, by applying the thermally stimulated current technique. The results for the blends are compared with these obtained for pristine P3HT samples. The influence of the trap states on the charge carrier mobility as well as the reversibility of the oxygen-induced degradation are discussed.

HL 44.6 Thu 12:15 POT 51

Degradation of phosphorescent blue organic light-emitting diodes — •Chien-Shu Chiu[1,3], Frank Steinbacher[2,3], Ralf Krause[3], Arvid Hunze[3], and Wolfgang Kowalsky[1] — [1]Department of Electrical Engineering & Information Technology, Technical University of Braunschweig, Germany — [2]Department of Materials Science VI, University of Erlangen-Nuremberg, Germany — [3]Siemens AG, CT MM 1, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany

Development of phosphorescent materials has significantly improved the efficiency of organic light-emitting diodes (OLEDs). By using efficient red, green and blue phosphorescent emitter materials high efficient white OLEDs can be achieved. However, due to low stability of blue phosphorescent materials the lifetime of phosphorescent white OLEDs remains an issue. As a result, degradation of blue phosphorescent materials needs to be further investigated and improved.

In this work, blue OLED devices based on the phosphorescent emitter FIrpic were investigated. Single-carrier hole-only as well as electron-only devices were fabricated. For investigation of degradation process the devices were stressed with electrical current and UV-light to study the impact of charge carriers as well as excitons and exciton-polaron quenching on the stability of the blue dye.

HL 44.7 Thu 12:30 POT 51

Oxygen-Influence on P3HT studied by Photoluminescence and Electron Spin Resonance — •Andreas Sperlich[1], Hannes Kraus[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg

The influence of oxygen on polymers is crucial to understand and prevent aging effects of organic polymer:fullerene solar cells. We simultaneously performed photoluminescence (PL) and light-induced electron spin resonance (L)ESR studies of the influence of oxygen on thin films of poly(3-hexylthiophene) (P3HT). The samples were illuminated by a 532nm green laser at 100K. In vacuum, P3HT shows a strong PL, as the optically excited singlet excitons (spin=0) recombine completely radiatively, whereas no ESR-signal is observed. When introducing oxygen, the PL is quenched within seconds and a growing ESR-signal from polarons on the P3HT can be observed. This is due to oxygen absorbing an electron by the polymer, leaving an ESR-active hole behind. The influence of oxygen on the polymer is slow in dark and very rapid under illumination. When turning off the illumination, the ESR-signal remains almost constant, which indicates that the signal is corresponding to deep traps. The process is mostly reversible by applying vacuum and 140°C for several minutes. We discuss our findings with respect to the application in organic solar cells.

HL 44.8 Thu 12:45 POT 51

Enhanced magnetoresistance in organic light emitting diodes — •Ulrich Niedermeier[1,2], Wiebke Sarfert[1], Sergey Bagnich[2], Christian Melzer[2], and Heinz von Seggern[2] — [1]Siemens AG, CT MM 1, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Technische Universität Darmstadt, Fachbereich Material- und Geowissenschaften, Petersenstr. 23, 64287 Darmstadt, Germany

Magnetic fields can influence the electro-optical properties of organic light emitting diodes via the organic magnetoresistance effect. We investigated the magnetoresistance in poly(paraphenylene vinylene)-based devices as a function of magnetic field and driving voltage. Electrical conditioning at high current densities has been identified as an efficient method to significantly enhance the magnetoresistance effect [1]. Depending on duration and intensity of the conditioning process the absolute value of the magnetoresistance effect can be increased from 1 % to values even exceeding 20 % at 4 V and 40 mT. Qualitatively, the increase in magnetoresistance during conditioning can be correlated with a decrease in electro- and photoluminescence. We attribute these results to a change in the charge carrier transport properties of the bulk emitter material during conditioning. Finally, we discuss our results in the framework of recently published theories on the possible origin of the organic magnetoresistance effect.

[1] U. Niedermeier *et al.*, Appl. Phys. Lett. **92**, 193309 (2008).

HL 45: Invited Talk Liu

Time: Thursday 11:45–12:30 Location: HSZ 01

Invited Talk HL 45.1 Thu 11:45 HSZ 01

Strain Induced Growth Instability and Island Nucleation on Patterned Substrate — •feng Liu — University of Utah, Salt Lake City, USA

Strain induced self-assembly provides an attractive route to nanofabrication of semiconductor quantum dots on surfaces. Recent experiments have demonstrated that combining the strain induced self-assembly with surface patterning provides an effective method to further improve the size uniformity and spatial ordering of quantum dots. However, the underlying mechanisms responsible for such improvement remain poorly understood. In this talk, I will present theoretical analyses of strain induced growth instability and island nucleation on patterned substrates. We show that the growth of a strained film is inherently less stable on a wavy substrate than on a flat substrate. For small surface undulation, the critical wavelength characterizing the initial instability on a wavy substrate is effectively half of that on a flat substrate. Furthermore, on patterned substrates, island nucleation is directed to the preferred sites by a much lower energy barrier and smaller critical size. Strain relaxation directs island nucleation to the bottom of a pit rather than the top of a ridge as commonly perceived, while large surface energy anisotropy leads to nucleation at both places. Our theory explains some puzzling experimental results and provides useful guidelines for future exploration of directing the self-assembly of quantum dots on patterned substrates.

HL 46: Hybrid systems

Time: Thursday 12:30–13:00 Location: POT 151

HL 46.1 Thu 12:30 POT 151

Optoelectronic Properties of Hybrids made of the Photosynthetic Reaction Center (PS I) and Carbon Nanotubes — •Matthias Brandstetter[1], Simone Kaniber[1], Alexander Holleitner[1], and Itai Carmeli[2] — [1]Walter Schottky Institut, Technical University Munich, Am Coulombwall 3, 85748 Garching, Germany — [2]Department of Chemistry and Biochemistry, Tel-Aviv University, Tel-Aviv 69978 (Israel)

The photosystem I (PS I) reaction center is a chlorophyll protein complex located in thylakoid membranes of chloroplasts and cyanobacteria. The PS I mediates a light-induced electron transfer through a serial of redox reactions [1]. The nanoscale dimension and the generation of 1 V photovoltage make the PS I reaction center a promising unit for applications in molecular optoelectronics. Utilizing a unique cysteine mutation at the end of the PS I, we demonstrate a four-step chemical procedure based on carbodiimide chemistry for covalent binding of the PS I to carbon nanotubes. The method allows studying nanosystems for the construction of optoelectronic devices based on PS I - carbon nanotube hybrids [2]. In addition, we present optoelectronic data of such hybrids consisting of carbon nanotubes and the PS I. We demonstrate that the integrated proteins are optoelectronically active [3].

[1] L. Frolov et al., Adv. Mater. 17, 2434 (2005). [2] I. Carmeli, M. Mangold, L. Frolov, B. Zebli, I. Carmeli, C. Carmeli, S. Richter and A.W. Holleitner, Adv. Materials 19, 3901 (2007). [3] S. Kaniber et al., (2009).

HL 46.2 Thu 12:45 POT 151

Coupling of self assembled Quantum Dots with nanoantennas — •Markus Pfeiffer[1,2], Markus Lippitz[1,2], Harald Giessen[1,2], Lijuan Wang[1], Armando Rastelli[3], and Oliver G. Schmidt[3] — [1]Max Planck Institut für Festkörperforschung, Stuttgart — [2]4. Phys. Institut, Universität Stuttgart — [3]Institute for Integrative Nanosciences, IFW Dresden

The interaction between electronic and photonic systems on the nanoscale has attracted much interest in recent years. Important issues are the increase of the coupling efficiency of single quantum systems to light with optical nanoantennas and the differently modified radiative and nonradiative decay rates of this localized excitation. As particle plasmons in metal nanostructures (MNS) show a strong coupling to the light field, they seem to be promising candidates for this purpose. Here, we try to engineer the emission properties of excitations in self assembled GaAs QDs.

For the experimental investigation of the emission properties, we use a detection scheme with two fast avalanche photo diodes for polarization dependent time correlated single photon counting (TCSPC). Characterization of many single QDs with random distances (10 to 170nm) to resonant MNS shows a variation of the radiative decay rate of QD-excitons by the local field enhancement.

We will further demonstrate our results for preparation and characterization of well defined single Quantum Dot-Nanoantenna pairs.

HL 47: Invited Talk Meyer

Time: Thursday 14:00–14:45 Location: HSZ 01

Invited Talk HL 47.1 Thu 14:00 HSZ 01

Homoepitaxy and optical properties of ZnO epilayers grown on Zn- and O-polar substrates — Bruno Meyer[1], Stefan Lautenschlaeger[1], Markus Wagner[2], and •Axel Hoffmann[2] — [1]Justus Liebig University Giessen — [2]Technical University Berlin

Homoepitaxial growth of ZnO has the great potential to provide high quality epilayers without strain or dislocations induced by the mismatch of lattice or thermal expansion coefficients. The current understanding of the impact of surface polarity on unintentional impurity incorporation, strain and doping is still on an early stage. We report on the effect of the substrate polarity on the structural and optical properties of homoepitaxially grown ZnO epilayers. Essential for 2D-growth is the surface preparation of the bulk substrates. Nominally undoped ZnO layers of approximately 1.2 μm in thickness were grown by chemical vapor deposition on Zn- and O-polar ZnO substrates. The epilayers were grown simultaneously in the same reactor to ensure direct comparability between the samples. The effect of impurities and their correlation to local strain fields in the epilayers and substrates is evaluated. Bound exciton recombinations differ significantly for the two polar surfaces. The Zn termination favours the incorporation of nitrogen acting as a shallow acceptor. First results of growth on a-plane ZnO will be presented.

HL 48: Poster 2

Time: Thursday 15:00–17:30 Location: P2

HL 48.1 Thu 15:00 P2

Scanning tunneling microscopy and spectroscopy of phase change alloys — •Dinesh Subramaniam[1], Christian Pauly[1], Marco Pratzer[1], Marcus Liebmann[1], Pascal Rausch[2], Michael Woda[2], Matthias Wuttig[2], and Markus Morgenstern[1] — [1]II. Physikalisches Institut B, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen — [2]I. Physikalisches Institut A, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen

Phase change random access memory (PCRAM) is a very promising candidate for the next generation of memories. In contrast to the standard Si-based RAM, PCRAM is a non-volatile storage system which exploits the high electrical contrast between the amorphous and the crystalline phase. However, the origin of this contrast is not well understood. Scanning tunneling microscopy gives insight into the local atomic structure and the electronic properties of phase change materials. Using the topography mode of STM, we realized images of $Ge_1Sb_2Te_4$ on the nanometer down to the atomic scale, revealing the morphology as well as the complex atomic arrangement of the sputter-deposited material. The spectroscopy mode enabled us to analyse the local density of states in the amorphous and crystalline phase. The band gap varied continuously from 0.5 eV in the amorphous phase to 0.2 eV in the crystalline phase. The Fermi level moved from the center of the gap in the amorphous phase into the valence band within the crystalline phase.

HL 48.2 Thu 15:00 P2

Lattice dynamics in thermoelectric materials — •Anne Möchel[1], Werner Schweika[1], Karin Schmalzl[2], Jörg Voigt[2], and Raphaël P. Hermann[1] — [1]Institut für Festkörperforschung, Streumethoden, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Institut für Festkörperforschung, JCNS, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Peltier elements are well known and commonly used for noiseless cooling or heating without any cryogenic agent nor mechanical movement. The thermoelectric materials used in these Peltier elements can also be used to recover waste heat, e.g. from exhaust gas of cars or industry, in order to protect our environment.

The application of thermoelectric materials as power converter is still rare, because of the poor efficiency in today's known and used materials. A good thermoelectric material must show a high electric

conductivity, but it has to be a poor thermal conductor on the same time and an increase in efficiency requires, among other tuning, a decrease of the thermal conductivity.

Therefore a good understanding of the lattice dynamics in thermoelectric materials is necessary. New classes of promising thermoelectric materials are filled skutterudites and clathrates. We have studied the lattice dynamics in filled gallium germanium clathrates and ytterbium skutterudites with macroscopic methods, such as heat capacity measurements and resonant ultrasound spectroscopy, and neutron and X-ray scattering.

HL 48.3 Thu 15:00 P2

Surface plasmons in terahertz metamaterials — Guillermo Acuna[1], Stephan Heucke[1], Florian Kuchler[1], •Stefan Schloegl[1], How Tong Chen[2], Anton J. Taylor[2], and Roland Kersting[1] — [1]Photonics and Optoelectronics Group & Center for NanoScience, University of Munich, 80799 Munich, Germany — [2]Los Alamos National Laboratory, MPA-CINT, MS K771, Los Alamos, New Mexico 87545, USA

Many metamaterials consist of miniaturized electronic circuits, which are arranged in periodic patterns. Most commonly, the electromagnetic response of such lattices is attributed to the properties of the circuit within an individual unit cell. Examples are the resonances given by the inductances and capacitances (fundamental modes) or other modes within the unit cell such as Mie resonances. In this contribution, we will show that surface plasmons contribute to the overall response of metamaterials and in some cases even modify the fundamental response. We present an experimental study on metamaterials using terahertz near-field microscopy. The extreme subwavelength resolution of our technique provides the local properties of the individual resonances in all detail. The results show the fundamental mode as well as a resonance at higher frequency. Our study reveals that this resonance, which is commonly interpreted to be a Mie resonance, in fact results from the excitation of surface plasmons [1]. [1] G. Acuna, et al., *Surface plasmons in terahertz metamaterials*, Optics Express Vol. 16, 23, pp.18745-18751 (2008)

HL 48.4 Thu 15:00 P2

Simulation of wurtzite-type nanostructures with an Effective Bond-Orbital model — •Stefan Barthel, Daniel Mourad, and Gerd Czycholl — ITP Universität Bremen

Empirical Tight-Binding models use a discrete set of atomic orbitals on each atomic position in order to calculate the electronic structure of a given material, while the hopping matrix elements are fitted in a self consistent way to empirical parameters. An Effective Bond-Orbital model (EBOM) uses the Tight-Binding approach, but considers the Bravais lattice instead of the atomic basis. This results in a less dimensional Hamiltonian, which reduces the computational time drastically e.g. for the simulation of nanostructures. In this work an EBOM for wurtzite type semiconductors is developed from scratch for nearest and second-nearest neighbour couplings in a basis set of sp^3 orbitals. The LCAO-method or two-center-integral approximation has been extended to the needs of the wurtzite structure and is applied in order to relate all hopping parameters to a complete and known set of kp-parameters as well as critical point energies in the first BZ. Spin-orbit-coupling and crystal-field splitting is included too. Results for GaN and InN are in good agreement with existing Tight-Binding and ab-initio bandstructure calculations throughout the whole BZ and reproduce the accuracy of the kp-model around the zone-center exactly. This model is applied for the simulation of GaN/InN quantum dots by diagonalizing the Hamiltonian directly in the set of atomic orbitals. Nearest- and Second-Nearest-Neighbour results are compared to existing Tight-Binding calculations with focus on computational speed.

HL 48.5 Thu 15:00 P2

Theoretical investigation of Cu-Containing with different valance structure type $BaCu_2S_2$, Li_2CuSb and LiCuS. — •S. Soliman[1], Gerhard H. Fecher[1], A. Elfalaky[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Physics, Faculty of Science, Zagazig University, Zagazig, Egypt

This work reports on the structural investigation of Cu-containing, with different ternary structure type $BaCu_2S_2$, Li_2CuSb and LiCuS. The unusual semiconductor properties exhibited by these Cu-contaning have attracted much attention. Using the scalar-relativistic full potential linearized augmented plane wave method (FLAPW).The exchange-correlation functional was evaluated within the GGA, using the Perdew-Burke-Ernzerhof parametrization. The investigation on the equilibrium lattice parameters, the equilibrium atomic position in the unit cell, and inter atomic distances is bing carried out. The band structure and density of states (DOS) have been calculated and compered to the available experimental and theoretical results.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

HL 48.6 Thu 15:00 P2

OEP-DFT computation of spin current densities and Wigner transition in a one-dimensional ring — •Thorsten Arnold, Marc Siegmund, and Oleg Pankratov — Lehrstuhl für Theoretische Festkörperphysik - Institut für Theoretische Physik IV - Staudtstr. 7-B2 - 91058 Erlangen

We investigate by exchange-only DFT, using the OEP-method in the KLI-approximation, a quasi one-dimensional Wigner crystallisation transition. We consider interacting electrons on a ring, assuming a Fermi liquid behaviour of the electron system. The transition from a gas-like to a pinned (by an impurity potential) crystal state can be identified totally within DFT, i.e. using collective variables (density and current) only, and not employing the correlation function. This is achieved by calculating a persistent current in magnetic field. Varying the electron-electron interaction strength in terms of parameter r_s, we found that the current decays exponentially for $r_s > r_s^c$. In a case of spinless electrons, we found a critical value of $r_s^c = 2.05$ (for 10 electrons). [1]

In this work, the model is extended for particles with spin. Fixing the total spin moment, we found both spin subsystems undergoing the Wigner transition successively at r_s^c of the order of 0.1. The ground state magnetisation for 10 electrons rises from $S = 0$ for $r_s < 0.1$ (gas state) to $S = 1$ ($0.1 < r_s < 0.2$) in a crystalline state.
[1] M. Siegmund, M. Hofmann, and O. Pankratov, arXiv:0711.2937v1

HL 48.7 Thu 15:00 P2

A Treasure Map for Phase-Change Materials — •Dominic Lencer[1], Martin Salinga[1], Blazej Grabowski[2], Tilmann Hickel[2], Jörg Neugebauer[2], and Matthias Wuttig[1] — [1]JARA-FIT, RWTH Aachen, I. Physikalisches Institut (IA), 52056 Aachen — [2]Max-Planck Institut für Eisenforschung, 40237 Düsseldorf

Phase-change materials are characterized by a unique property portfolio well suited for data storage applications. They exhibit a pronounced optical and electrical contrast between the crystalline and the amorphous state. In a recent study, we have identified the occurrence of resonance bonding in the crystalline state as being responsible for the optical contrast. The search for novel phase-change materials can hence be redirected to materials exhibiting resonance bonding. In order to supplement this effort, we introduce a coordinate scheme [1] based on the work of P. B. Littlewood. It is spanned by two coordinates calculated just from the composition. These coordinates represent the degree of ionicity and the tendency towards hybridization (covalency) of the bonding. A small magnitude of both quantities is an inherent characteristic of phase-change materials and marks the region of this map, where resonance bonding occurs. Furthermore, this map also enables a prediction of trends for the physical properties upon changing stoichiometry.

[1] Lencer, D., Salinga, M., Grabowski, M., Hickel, T., Neugebauer, J. & Wuttig, M. A Map for Phase-Change Materials. Nature Materials, in the press (2008).

HL 48.8 Thu 15:00 P2

Photocapacitance measurements on MOS light emitting devices — •Michael Seeger, Danilo Bürger, Lars Rebohle, Wolfgang Skorupa, Manfred Helm, and Heidemarie Schmidt — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany)

The photocapacitance (PC) has been probed on MOS diodes with an Eu-implanted SiO_2 layer. In general, rare earth implanted SiO_2 layers in MOS diodes are of great interest for possible applications in integrated metal-oxide-semiconductor light emitting devices (MOSLEDs). For example, green and ultraviolet electroluminescence has been probed on SiO_2:Tb-MOSLEDs and SiO_2:Gd-MOSLEDs, respectively. MOSLEDs reach external quantum efficiencies between 1% and 16%, and the electroluminescence peaks are typically ascribed to 4f-intrashell transitions of trivalent rare earth ions. A clear capacitance change has been observed for different wavelengths under monochromatic illumination. Some of the detected peaks correspond to the energies of 4f-intrashell transitions of the Eu ions. According to this,

the number of active luminescence centers in MOSLEDs may be determined from PC measurements. Some 4f-intrashell transitions have been also observed by means of electroluminescence measurements on the same MOSLEDs. To emphasize the physical significance of the PC data recorded on SiO_2:Eu-MOSLEDs, we also compare PC data recorded on different MOSLEDs implanted with other rare earth ions.

HL 48.9 Thu 15:00 P2

Experimental investigation of InN-based terahertz surface emitters — •Jan Wallauer, Hanspeter Helm, and Markus Walther — Department of Molecular and Optical Physics, University of Freiburg

Owing to its characteristic material properties, such as a strong optical absorption, a small band gap, and its unusual band structure, indium nitride (InN) promises a much stronger terahertz emission than present terahertz surface emitters [1]. This makes InN to a very promising terahertz radiation source, suitable for potential applications in research and industry. Here we investigate photo-induced terahertz surface emission from epitactically grown InN. Our study is based on femtosecond laser pulse excitation and broadband terahertz detection [2]. By systematically varying the excitation conditions we aim to characterize and optimize the emitted terahertz radiation. The influence of various parameters, such as laser spot size or excitation angle are discussed. Our results for InN are compared with the emission from standard surface emitters like indium arsenide (InAs).

[1] V. Cimalla et al., Phys. Stat. Sol. (b) 244, 1829 (2007)

[2] C. Winnewisser, P. Uhd Jepsen, M. Schall, V. Schyja, and H. Helm, Appl. Phys. Lett. 70, 3069 (1997)

HL 48.10 Thu 15:00 P2

Spatially resolved resonance fluorescence from quantum wells: A tool to study exciton wavefunctions — •Gerolf K. G. Burau — Universität Rostock, Institut für Physik, D-18055 Rostock, Germany

The nature of the electronic states in weakly disordered quantum wells recently has received considerable attention, both from experiment [1,2] and theory [3]. A very promising method for experimental investigation is to spatially and spectrally resolve the elastic part of the resonance fluorescence from the exciton states while varying the excitation wavelength. Here the measured intensity is directly proportional to the modulus to the fourth power of the exciton center of mass wave function. This was demonstrated in [2], unfortunately with a rather low spatial resolution. We have developed a new setup using high numerical aperture objectives giving a spatial resolution of 350 nm. As the setup is able to detect light emitted into different sides of a quantum well (4pi- microscope, [3]), the resolution can be improved by using the full potential of the microscope (with immersion lenses) to about 85 nm which will be comparable to that of a near-field setup [1] but allows much lower temperatures (< 5K).

[1] K. Matsuda, T. Saiki, S. Nomura, M. Mihara, Y. Aoyagi, S. Nair, and T. Takagahara, Phys. Rev. Lett. 91, 177401 (2003), [2] D. Schwedt, R. Schwartz, H. Stolz, D. Reuter, and A. Wieck, phys. stat. sol. (c) 3, 2477 (2006), [3] P. Bozsoki, P. Thomas, M. Kira, W. Hoyer, T. Meier, S. W. Koch, K. Maschke, I. Varga, and H. Stolz, Phys. Rev. Lett. 97, 227402 (2006)

HL 48.11 Thu 15:00 P2

Development of Photonic Sensors for Parallel Molecule Detection on the Basis of Toroidal Microresonators — •Tobias Grossmann, Christian Schäfer, Cristian Gohn-Kreuz, Torsten Beck, Mario Hauser, and Heinz Kalt — Universität Karlsruhe (TH), Karlsruhe, Germany

We report on the progress of the development of a versatile photonic sensor for label-free detection of proteins and DNA sequences based on toroidal semiconductor microresonators.

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

For detection of the modal shift of WGMs a setup using a tapered single mode fiber will be shown. An approach for the fabrication of a microfluidic channel and integrated waveguides passing the resonators in a small distance will be presented. First results of the fabrication and characterization of the optical modes will be discussed.

HL 48.12 Thu 15:00 P2

Carrier spin dynamics in GaAs/AlGaAs quantum wells, studied by time-resolved Kerr rotation — •Liudmila Fokina[1], Vladimir Petrov[3], Dmitri Yakovlev[1,2], and Manfred Bayer[1] — [1]Experimental Physics 2,Technical University Dortmund, 44221 Dortmund, Germany — [2]A.F. Ioffe Physico-Technical Institute, 194017 St. Petersburg, Russia — [3]Saint-Petersburg State University, 198504 Saint-Petersburg, Russia

In recent years, electron-spin orientation in semiconductors is considered as a promising way of realization of quantum information processing in solid-state systems. Therefore, the problem of lifetime and relaxation mechanisms of spin coherence in real systems becomes highly topical. We study experimentally electron spin coherence in GaAs/AlGaAs quantum wells with a low-dense as well as with high dense two-dimensional electron gas by means of pump-probe time-resolved Kerr rotation technique. To explore spin relaxation mechanisms, we have performed a systematic study of the spin dephasing time as a function of temperature, magnetic field and electron concentration. Electron spin beats have been measured in magnetic field up to 10 T, which allows to determine the transverse component of the electron g-factor. In case when the spin dephasing times becomes longer than several ns, we used the technique of the resonant spin amplification (RSA), which has been developed to extract spin lifetimes that exceed the pulse repetition interval of 13.2 ns. Finally we describe an unusual behaviour of the RSA signal in vicinity of zero magnetic field, which is caused by interaction of the electron spins with the nuclei.

HL 48.13 Thu 15:00 P2

Photoluminescence of extremely dilute Si nanoparticle films — •Matthias Offer[1], Cedrik Meier[1,3], Martin Geller[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen, Duisburg — [2]IVG and CeNIDE, University of Duisburg-Essen, Duisburg — [3]Experimental Physics, University of Paderborn

Light-emitting silicon nanoparticles are attractive candidates for future optoelectronic applications. For the realization of such devices, a detailed knowledge of the recombination dynamics is an important prerequisite. The photoluminescence (PL) of silicon nanoparticles exhibits an interesting exitonic fine structure with a bright and a dark state, which, surprisingly, have very similar radiative recombination lifetimes [1]. To elucidate the intriguing excitonic properties of Si nanoparticles, it is highly desirable to investigate single particles or few-particle ensembles to answer questions regarding homogeneous line broadening and Zeeman shift. We have dispersed Si nanoparticles in organic solvents and deposit extremely dilute films of Si particles on arbitrary surfaces. These can be covered by metallic micro-apertures ($\approx 1\mu m$ in diameter), which make it possible to study the optical properties of ensembles of about 100 particles and below. Furthermore, a scanning micro-PL setup was designed and realized to map out the local optical properties of nanoscopic semiconductor structures. First results of spatially resolved PL on nanoparticles will be presented and compared to spectra of large-scale ensembles.

[1] S. Lüttjohann et al., Europhys. Lett. **79**, 37002 (2007)

HL 48.14 Thu 15:00 P2

Optical spectroscopy of Ga(N,As,P)/GaP MQW structures — •Christian Karcher, Andreas Schneider, Bernardette Kunert, Kerstin Volz, Wolfgang Stolz, and Wolfram Heimbrodt — Dept. Physics and Material Sciences Center, Philipps-University of Marburg, Germany

Pseudomorphically grown multiple-quantum-well heterostructures of the dilute nitride Ga(NAsP)/(Ga,B)P material system have been studied by means of modulation-, photoluminescence- (PL) and PL excitation - spectroscopy. It is a promising system to achieve integrated optoelectronic devices on Si substrates. By applying hydrostatic pressure upon the samples we are able to determine the offsets of the direct Ga(N,As,P)-bandgap with regard to the indirect bandgap of the GaP-barrier. The obtained results yield additional knowledge about the band structure of the quantum wells, which is essential for achieving room-temperature lasing in the near future. Furthermore, we perform spatially-resolved Raman- and PL-measurements on a sub-μm-level to gain insight into the potential fluctuations caused by the varying composition within the quaternary QWs. By observing significant features such as the Ga-N vibration mode as well as the excitonic PL it is possible to map the mean distribution of Nitrogen and Phosphorous within

the sample, which helps to identify statistical effects such as formation of N-clusters within the crystal.

HL 48.15 Thu 15:00 P2

Excitonic Rayleigh scattering spectra for metallic single-walled carbon nanotubes — •Ermin Malic[1], Stephanie Reich[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Fachbereich Physik, Freie Universität Berlin

We present a microscopic calculation of the excitonic Rayleigh scattering cross section for metallic single-walled carbon nanotubes. Our approach combines the density matrix formalism including the Coulomb and electron-light interaction with the tight-binding approximation. We go beyond the two-band picture taking all nanotube subband contributions into account.

Due to the strong screening in metallic tubes, the Coulomb interaction is weak resulting in smaller excitonic binding energies (around 100 meV) in comparison to semiconducting nanotubes with a similar diameter. In agreement with experiments, the Rayleigh spectra of metallic nanotubes are shown to have a double-peaked structure caused by the triangular equi-energy contour around the K point (trigonal warping effect). Furthermore, the non-resonant contributions of the optical susceptibility account for the asymmetry of Rayleigh peaks towards lower energies.

HL 48.16 Thu 15:00 P2

Characterization of Spatially Indirect Excitons in Coupled Quantum Wells — Georg Schinner[1], •Markus Stallhofer[1], Katarzyna Kowalik[1], Dieter Schuh[2], Werner Wegscheider[2], Alexander Holleitner[1,3], and Jörg Kotthaus[1] — [1]Fakultät für Physik and Center for NanoScience, LMU Munich, Geschwister-Scholl-Platz 1, D-80539 München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, Universitätsstraße 31, D-93040 Regensburg, Germany — [3]TU Munich, Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

In coupled quantum wells photo-generated and spatially indirect excitons can be widely manipulated via an externally applied voltage. The quantum-confined Stark effect (QCSE) results in a large enhancement of excitonic lifetime and a red shift in energy. A number of photoluminescence (PL) experiments have been performed on indirect excitons in GaAs double quantum wells (DQW) that were tuned via a metallic top gate. We characterize an especially designed InGaAs DQW-heterostructure with PL and transmission experiments at liquid Helium temperatures. The QCSE was measured with PL and determined to be around 150 meV/V, a very high value compared to literature. Therefore, it is possible to achieve a large energy shift by applying relatively low voltages in our sample. In a confocal microscope we perform transmission experiments on the indirect excitons in a field-effect structure with a semitransparent titanium top gate. They allow investigating electron-hole pairs under resonant excitation.

HL 48.17 Thu 15:00 P2

Collective fluorescence of quantum dot molecules and arrays — •Anna Sitek[1,2] and Pawel Machnikowski[1] — [1]Institute of Physics, Wroclaw University of Technology, Wroclaw, Poland — [2]Institute for Theoretical Physics, Technical University of Berlin, Berlin, Germany

The optical properties of quantum dot molecules (QDMs) are affected by collective interaction of the QDs with radiation modes. In atomic systems, such collective effects lead to pronounced superradiant fluorescence [1]. Superradiance has also been observed in a QD sample [2]. In contrast to a gas of atoms, the properties of QDs are never exactly uniform. On the other hand, QDs can be arranged in regular arrays.

In this presentation, we study the collective interaction of excitons in closely spaced QDMs and small arrays of nearly identical QDs with electromagnetic modes. We discuss how collective fluorescence builds up in the presence of a small mismatch of the transition energy and study the resulting optical properties (decay of luminescence) of quantum dot molecules. It turns out that the collective effects are very sensitive to the difference between the dots but coupling between the dots may stabilize the collective fluorescence if the dots are arranged in a regular way [3].

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HL 48.18 Thu 15:00 P2

Plasmons in graphene — •Antonio Hill, Sergey A. Mikhailov, and Klaus Ziegler — Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany

Electromagnetic response of graphene (the dielectric function) and the spectrum of collective excitations in it are studied as a function of wave vector and frequency. Our calculation is based on the full band structure, calculated within the tight-binding approximation. As a result, we find plasmons whose dispersion is similar to that obtained in the single-valley approximation [1,2] but in contrast to the latter, we find a stronger damping of the plasmon modes due to inter-band absorption. Our calculation also reveals effects due to deviations from the linear Dirac electronic spectrum as we increase the Fermi energy, indicating an anisotropic behavior with respect to the wave vector of the external electromagnetic field.

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[2] B. Wunsch et al, New J. Phys. **8**, 318 (2006)

HL 48.19 Thu 15:00 P2

Defect Induced Photoluminescence from Dark Excitonic States in Individual Single-Walled Carbon Nanotubes — •Tobias Gokus[1], Hayk Harutyunyan[2], Alexander A. Green[3], Mark C. Hersam[3], Maria Allegrini[2], and Achim Hartschuh[1] — [1]Department Chemie und Biochemie, Ludwig-Maximilians-Universität München and CeNS, 81377 München, Germany — [2]Dipartimento die Fisica "E. Fermi", Universitá di Pisa and CNISM, Largo Pontecorvo 3, 56127 Pisa, Italy — [3]Department of Chemistry, Northwestern University, Evanston, Illinois 60208-3108, USA

We show that new low-energy photoluminescence (PL) bands (ΔE$\sim$30-190 meV) can be created in the spectra of individual semiconducting single-walled carbon nanotubes (SWNT) by intense pulsed laser irradiation at room temperature. These new bands are attributed to emission from different nominally dark excitons that are "brightened" due to defect-induced mixing of states with different parity and/or spin. Time-resolved PL studies on single nanotubes reveal a significant reduction of the bright exciton lifetime (1-40 ps) upon brightening of the dark excitons. The lowest energy dark state (ΔE$\sim$190 meV) has longer lifetimes up to 177 ps and is not in thermal equilibrium with the bright state. In addition we show that the same satellite bands can be observed by exposure of the SWNTs to a gold solution, and using low power CW laser excitation, indicating that the lowest energy emission is due to triplet exciton recombination facilitated by magnetic defects or impurities.

HL 48.20 Thu 15:00 P2

Electroluminescence from silicon nanoparticle layers — •Jens Theis[1] and Cedrik Meier[2] — [1]Experimental Physics, University of Duisburg-Essen, Duisburg — [2]Group Nanophotonics and Nanomaterials, Department of Physics, University of Paderborn

We have fabricated an electroluminescence devices using silicon nanoparticles as an emitter by using a micropatterned GaAs heterostructure as a template. The Si nanoparticles have been fabricated from the gas phase in a low-pressure microwave plasma using SiH4 as a precursor. The nanoparticles have been dispersed onto the patterned GaAs sample from an aqueous solution. For carrier injection, the sample has been placed in a capacitor-like structure, where a transparent oxide layer served as the top-electrode. By applying an AC-voltage, field-emission of electrons and holes from the electrodes leads to electron-hole pairs in the nanoparticles. Thus, optical emission from both Si nanoparticles and GaAs is observed. We study the influence of various parameters on the electroluminescence, such as waveform, frequency and amplitude.

HL 48.21 Thu 15:00 P2

Tailoring the Emission Properties and the Axial Light Confinement in Microtube Resonators — •Christian Strelow, Kay Dietrich, Christoph Schultz, Hagen Rehberg, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum

Microtube resonators are optical cylindrical microresonators which are formed by rolled-up strained InGaAs/GaAs bilayers [1]. We demonstrate that these structures are microresonators whose properties can be tailored very precisely. The growth by molecular beam epitaxy allows to integrate diverse optical internal emitters like quantum wells or self-assembled InAs quantum dots. Another very interesting possibility is that due to the strong evanescent fields of the very thin walls also external emitters like chemically synthesized nanoparticles can be coupled to the resonator modes. Samples with different semiconduc-

tor compositions and thus strain field and bandstructure have been tailored to control the emission properties and the confinement of the light for the particular emitters are compared. We present several mechanisms of axial light confinement experimentally and prove these by spatially and energetically resolved photoluminescence measurements. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508 "Quantum Materials"and GK 1286 "Functional Metal-Semiconductor Hybrid Systems".

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HL 48.22 Thu 15:00 P2

Temperature Tuning of Nonlinear Photoluminescence in Gallium Selenide — •Christoph Angermann[1], Lothar Kador[1], Kerim R. Allakhverdiev[2,3], Tarik Baykara[2], and Eldar Salaev[3] — [1]University of Bayreuth, Institute of Physics and BIMF, 95440 Bayreuth, Germany — [2]Marmara Research Centre of TÜBİTAK, Materials Institute, P. K. 21, 41470 Gebze/Koçaeli, Turkey — [3]Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

The non-centrosymmetric ϵ modification of the layered semiconductor gallium selenide (GaSe) is characterized by a very high coefficient $\chi^{(2)}$ of quadratic optical nonlinearity. Photoluminescence spectra of the material were investigated with a HeNe laser as excitation source, whose quantum energy is slightly lower than the band edge. Hence, the photoluminescence is ascribed to second-harmonic generation in the laser focus causing the excitation of electrons into the conduction band and, subsequently, the formation and radiative decay of Wannier excitons. With increasing temperature, the band edge shifts to lower energies across the laser line. The concomitant strong increase of the photoluminescence signal is interpreted in terms of resonance enhancement of the $\chi^{(2)}$ coefficient. The photoluminescence studies are supplemented by Maker fringe data recorded with different cw diode lasers.

HL 48.23 Thu 15:00 P2

Influence of uniaxial pressure on the optical properties of Tl_2S single crystals — •H. Danylyuk, Y. Stakhira, and V. Belyukh — Ivan Franko Lviv National University, Department of Electronics Dragomanov Str. 50, UA-79005 Lviv, Ukraine

Tl_2S single crystals were grown by the Bridgman-Stockbarger method. Samples with $50 - 130\mu m$ of thickness were freshly cleaved along the (00.1) cleavage plane from the ingot. In all investigated samples the absorption edge shape is good described by Urbach's rule. The energy gap of Tl_2S crystal was determined by sharp change of slope of the absorption spectrum curve: $E_g \approx 1eV$. To study the low-dimensional effects in layered Tl_2S crystals we have investigated influence of uniaxial pressure on Tl_2S optical properties in absorption edge range. Pressure (0,3-1 MPa) was applied in c-axis direction. We have observed considerable increase of the absorption coefficient in transparency range near fundamental absorption edge after 1-2 days of pressure effect. For long-continued (10-12 days) pressure effect on samples, the absorption coefficient increased in a few times. However, the optical properties of Tl_2S single crystals are partly restored after stopping of pressure effect. This restoring was the better, the shortly the pressure effected the samples. For long-continued pressure effect on samples the absorption edge shape is also changed, but still it is described by Urbach's rule. However, the characteristic Urbach's parameters are changed.

HL 48.24 Thu 15:00 P2

Transport through the quantum dot connected to external leads — •Agnieszka Donabidowicz-Kolkowska[1,2] and Tadeusz Domanski[1] — [1]Institute of Physics, Maria Curie-Sklodowska University,Lublin, Poland — [2]Institute for Theoretical Physics, Technische Universität Dresden,Germany

In this work we study the transport properties of a single level quantum dot connected to two normal electrodes and/or one normal (N) and one superconducting (S) lead using the nonequilibrium Green*s function formalism. For a description of the N-QD-N/S junction we consider the single impurity Anderson model.The effects of the electron pair coherence, Coulomb interactions are discussed with a particular account of their influence on a charge tunnelling through the quantum dot. We observe that the long range off-diagonal superconducting order induces the proximity effect in the quantum dot due to a particle-hole mixing at small energies . Influence of the proximity effect on transport properties of the systems manifests itself in the Andreev conductance. Additionally, in presence of the strong on-dot correlations some qualitatively new features were observed. One of them is the zero bias anomaly which occurs due to formation of the Kondo state at sufficiently low temperatures. We show that quantum transport in superconducting devices is controlled by the interplay between the Kondo effect and Andreev reflection processes.

HL 48.25 Thu 15:00 P2

Electrolyte Gated Silicon Nanowire FETs — •Oren Knopfmacher, Michel Calame, and Christian Schönenberger — University of Basel, Department of Physics, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Silicon Nanowire field effect transistors (SiNW FETs) have been shown to be very sensitive to charged molecules adsorbed on their surface and therefore are ideal candidates for basic sensing units in integrated bio- or chemical sensors [1]. The disadvantage linked to the positioning of grown nanowires on a substrate can be circumvented by using a top-down approach where SiNW are directly etched in silicon-on-insulator (SOI) wafers [2]. This approach allows parallel processing at the wafer scale while opening the possibility to integrate the sensing units with signal conditioning electronics. In our system, a gate voltage can be applied via the Si substrate (back gate, as for conventional FETs,) while a liquid cell system brings the liquid in contact with the nanowire surface. By inserting an additional electrode in the liquid cell, we benefit from an additional handle to control the response of the SiNW FET. We compare the combined effects of the back gate and liquid gate on the transport characteristics of the SiNW FET and show that both gates are essential to perform well-defined sensing experiments.

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HL 48.26 Thu 15:00 P2

Gate-controlled conductance fluctuations in InN nanowires — •Sergio Estévez Hernández[1,2], Gunnar Petersen[1,2], Robert Frielinghaus[1,2], Ralph Meijers[1,2], Raffaella Calarco[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute for Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, 52425 Jülich Germany — [2]JARA-Fundamentals of Future Information Technology

Nanowires based on InN are interesting because of their large surface conductivity and their low energy band gap. For nanoscaled devices operated at low temperatures electron interference effects can largely affect the transport properties. Typical phenomena are universal conductance fluctuations or weak localization. The characteristic fluctuation pattern observed in the conductance was employed to obtain information on phase-coherent transport. The conductance fluctuations were measured at low temperatures as a function of the gate voltage at fixed magnetic fields. By analyzing the root mean square and the correlation field of the conductance fluctuations at various temperatures, the phase-coherence length was determined. From the conductance traces as a function of gate voltage the variance of the conductance var(G) was determined at different magnetic fields. The largest variance was found close to zero magnetic field while at finite magnetic fields var(G) is reduced to almost half value. This reduction can be explained by the broken time-reversal symmetry in the presence of a magnetic field.

HL 48.27 Thu 15:00 P2

Phase-coherent transport and spin-orbit coupling in InN nanowires connected in parallel — •Shima Alagha[1,2], Sergio Estévez Hernández[1,2], Raffaella Calarco[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute for Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, 52425 Jülich Germany — [2]JARA-Fundamentals of Future Information Technology

Semiconductor nanowires based on InN are interesting candidates for future nanolelectronic devices because the surface accumulation layer guarantees a highly conductive channel. However, the spin-transport properties are basically unknown for this material system. In order to obtain information regarding the spin transport, we investigated the low-temperature magnetoconductance of InN nanowires connected in parallel. Usually, phase-coherent transport in small conductors results in conductance fluctuations. By connecting N nanowires in parallel a considerable decrease of the fluctuation amplitude and a reduction of the variance proportional to $\sqrt{N}$ can be achieved. This suppression of the fluctuations permits to study weak localization and weak

antilocalization effects which are manifested in negative and positive magnetoconductivity around zero magnetic fields, respectively. From these features, information about the phase-coherence length and the spin-orbit scattering length can be obtained. At low magnetic fields we found a clear signature of the weak antilocalization effect indicating the presence of spin-orbit coupling in InN nanowires.

HL 48.28 Thu 15:00 P2

Tunable transverse rectification in density-modulated 2D-Systems: Ballistic of thermoelectric effect? — •Arkadius Ganczarczyk[1], Christian Notthoff[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimental Physics and CeNIDE, Universität Duisburg-Essen — [2]Ruhr-Universität Bochum

We investigate tunable transverse rectification in a density-modulated two-dimensinal electron gas (2DEG) at low temperatures (4.2 K). The 2DEG is patterned into a long narrow conductive channel with source and drain contacts and a voltage probe on each side of the channel. Using gate electrodes we induce two stripes of different charge carrier density running parallel to the channel. The resulting density gradient perpendicular to the channel induces a transverse voltage, which - due to the symmetry of the device - does not change polarity when the current direction is reversed. We observe that the rectified transverse voltage increases with increasing density modulation and is proportional to $1/n_1$ - $1/n_2$, where n_1 and n_2 are the charge carrier densities in the two stripes. The observed transverse voltage can attributed to two different physical phenomena: Ballistic rectification and a thermoelectric effect. The results are discussed by using a billiard model, which describes the propagation of ballistic electrons in density-modulated 2D-systems. Furthermore, possible thermoelectric effects in the structure are discussed. Both models are compared in order to obtain a deeper insight into this novel rectification effect.

HL 48.29 Thu 15:00 P2

Manipulation of minority-majority mobility-lifetime-product behavior in microcrystalline silicon by field effect — •Oliver Neumann, Rudolf Brüggemann, and Gottfried H. Bauer — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

Mobility-lifetime-products ($\mu\tau$) of minority and majority carriers are a general criterion for the quality of semiconductors. The particular magnitudes can be separately analyzed by photoconduction experiments e.g. with the steady-state photocarrier grating technique (SSPG) [1] for the minority-carrier ($\mu\tau$) products and traditional photoconductivity studies for the majority-carrier ($\mu\tau$) products. The share between electrons and holes is used to be governed by the Fermi level which as well decides on minority and majority status.

We have performed SSPG (for minority ($\mu\tau$)-products) as well as photoconductivity measurements on different hydrogenated microcrystalline silicon (μc-Si:H) samples with simultaneous application of an electric field in field-effect configuration for carrier depletion respectively accumulation. By this approach we proof experimentally with our SSPG- and photoconductivity-experiments to increase majority densities and decrease minority concentrations and we accordingly also shift the original majority behavior of electrons towards minority behavior. From our experiments we deduce the necessary electric field strengths for inversion in nominally undoped μc-Si:H.

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HL 48.30 Thu 15:00 P2

Electrical Properties of Phase Change Memory Cells — •Daniel Krebs[1,2], Martin Salinga[1,2], Stephan Kremers[1], Hanno Volker[1], Matthias Wuttig[1,2], Simone Raoux[2], Charles T. Rettner[2], Robert M. Shelby[2], and Geoffrey W. Burr[2] — [1]I. Physikalisches Institut IA, RWTH Aachen University, 52056 Aachen, Germany — [2]IBM/Macronix PCRAM Joint Project: IBM Almaden Research Center, 650 Harry Road, San Jose, California 95120

Phase change random access memory has become one of the most promising candidates for future non-volatile memory applications, prompting an intensive search for suitable phase change materials with optimized properties. Attaining both rapid cyclability and long-term retention requires the proper combination of fast crystallization speed yet high crystallization temperature. In addition, it has been observed that the resistance of the amorphous phase tends to increase slowly yet significantly after device programming, which complicates multilevel storage. In this work, the phase change memory candidates $Ge_{15}Sb_{85}$, Ag and In doped Sb_2Te, $Ge_2Sb_2Te_5$, GeTe and thin Sb are systematically analyzed by electrical and optical testing of bridge cell devices and thin films. We show that the as-deposited and melt-quenched amorphous phases exhibit pronounced differences in crystallization speed and temperature. Our experimental evidence shows clearly that the critical parameter for threshold switching is a critical electrical field rather than a threshold voltage. The post-programming resistance dynamics of bridge cells are also analyzed, and linked to electrical and structural relaxation in the phase change material.

HL 48.31 Thu 15:00 P2

Transverse Peltier effect in $Pb-Bi_2Te_3$ multilayer structures — •Christina Reitmaier, Franziska Walther, Amir Kyarad, and Hans Lengfellner — University of Regensburg, 93040 Regensburg, Germany

Metal-semiconductor multilayer structures show, according to model calculations, large anisotropy in their electrical and thermal transport properties. Multilayer stacks consisting of alternating layers of Pb and n-type Bi_2Te_3 and prepared by a heating procedure displayed large thermoelectric anisotropy up to $\Delta S \approx 200\mu V/K$, depending on the thickness ratio $p = d_{BiTe}/d_{Pb}$, where d_{BiTe} and d_{Pb} are the thicknesses of Bi_2Te_3 and Pb layers, respectively. From multilayer stacks, tilted samples with layers inclined with respect to the sample surface where obtained by cutting stacks obliquely to the stack axis. Non-zero off-diagonal elements in the Seebeck-tensor describing the thermopower of tilted samples allow for the occurance of a transverse Peltier effect. Experimental results demonstrate cooling by the transverse Peltier effect and are compared to model calculations.

HL 48.32 Thu 15:00 P2

Electronic transport at the interface between diamond and aqueous electrolyte — Markus Dankerl, Eberhard Ulrich Stützel, •Andreas Lippert, Martin Stutzmann, and Jose Antonio Garrido — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching.

Undoped single crystalline diamond with a hydrogen-terminated surface shows a p-type surface conductivity. This surface conductivity is based on a two-dimensional hole channel formed by the band bending beneath the surface. It is not only stable in electrolyte but can also be modulated by an applied potential through the electrolyte, enabling the design of solution gate field effect transistors (SGFETs). Owing to the remarkable stability and biocompatibility of diamond, SGFETs based on diamond are highly interesting for biosensing and medical applications. We have investigated the surface conductivity of hydrogen-terminated single crystalline diamond using in-liquid Hall effect measurements under potential control. Thus, we were able to independently determine the carrier concentration and the carrier mobility. We observe that the mobility shows different variations with the carrier concentration at different levels of the carrier concentration. We discuss this in the context of localization and scattering mechanisms e.g. surface scattering. Studies on the effect of temperature on the mobility reveal no activated behavior beyond the influence of the carrier concentration. The effect of temperature on the concentration of carriers itself fits the concept of an interfacial capacitance at the diamond/electrolyte interface.

HL 48.33 Thu 15:00 P2

Magnetotransport properties of epitaxial graphene — •Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Konstantin V. Emtsev[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Lehrstuhl für Technische Physik, Friedrich-Alexander Universität Erlangen-Nürnberg

We have investigated the magnetotransport properties of epitaxial graphene films grown on 6H-SiC(0001). We demonstrate that the temperature dependence of the charge carrier density and mobility is correlated to the annealing conditions during the graphitisation process. Devices in a Hall-bar geometry are characterised in a perpendicular magnetic field up to 8 T at temperatures between 1.5 K and 110 K. The electron density is determined from Shubnikov de Haas oscillations of the longitudinal resistance R_{xx} and, for comparison, from Hall-effect measurements of the transverse resistance R_{xy}. The mobility is derived from the conductivity. For graphene films annealed in an Ar atmosphere close to atmospheric pressure (sample A) a mobility (charge carrier density) of $2400\,\mathrm{cm^2(Vs)^{-1}}$ ($3 \cdot 10^{12}\,\mathrm{cm^{-2}}$) at 4.2 K is extracted. Whereas for sample B annealed under a reduced pressure a lower mobility of $1000\,\mathrm{cm^2(Vs)^{-1}}$ and a slightly higher charge carrier density of $4{\cdot}10^{12}\,\mathrm{cm^{-2}}$ is estimated. Sample A shows a nearly constant carrier mobility for low temperatures (1.5 K up to 60 K) and a linear

decrease for higher temperatures. The charge carrier density is constant in the temperature range. For sample B with rising temperature the mobility (charge carrier density) decreases (increases).

HL 48.34 Thu 15:00 P2

Herstellung und Charakterisierung von Nanosäulen für silizium basierte Thermoelektrika — •Andrej Stranz, Ünsal Sökmen, Erwin Peiner und Andreas Waag — Institut für Halbleitertechnik, TU Braunschweig, Deutschland

Si-basierte Nanosäulen unterschiedlicher Durchmesser, Höhe und Morphologie werden durch Strukturierung mit Nanoimprint und anschließendes anisotropes Trockenätzen hergestellt. Die Herstellung der niederdimensionalen Strukturen beruht auf der kontrollierten top-down Strukturierung. Durch diese Herstellungsmethode lässt sich die thermische Leitfähigkeit über die Variation der Durchmesser der Nanosäulen gezielt einstellen. Durch die Reduktion der thermischen Leitfähigkeit kann die Effizienz (ZT) von Si-basierten thermoelektrischen Kühlern und Generatoren erheblich verbessert werden. Die hergestellten Nanosäulen haben Durchmesser im sub-μ Bereich, eine Höhe bis 80μ, und sie sind in einem Säulen-Feld angeordnet mit einem Abstand von 700nm bis 10μ zueinander. Neben der Herstellung und der strukturellen Charakterisierung von Silizium-Nanosäulen wird die Messung thermoelektrischer Eigenschaften einzelner Nanosäulen, sowie von Nanosäulenarrays beschrieben. Für die Messung von Kräften auf der sub-μN Skala wurden piezoresistive Silizium-Cantilever-Sonden entwickelt und realisiert. Sonden mit Spitzenradien von wenigen zehn Nanometern wurden für die Vermessung von Nanosäulen in einem Rasterelektronenmikroskop mit Hilfe von Nanomanipulatoren eingesetzt. In der Messsonde wurden für die Messung der Temperatur ein Thermowiderstand bzw. ein Thermoelement an der Spitze integriert.

HL 48.35 Thu 15:00 P2

Comparison of different techniques to determine long spin lifetimes in slightly n-doped GaAs bulk and GaAs/AlGaAs quantum wells — •Michael Griesbeck, Andreas Maurer, Sebastian Fehringer, Robert Schulz, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Universität Regensburg, Germany

A key issue of spintronics research is the search for materials with long spin lifetime. The commonly used technique for the determination of spin lifetimes, ultrafast time-resolved Faraday/Kerr rotation (TRFR/TRKR), is limited to a short time window of a few ns by some reasons like the pulse repetition rate of the used pulsed laser or the length of the available delay line.Here we present a study about the comparison of the well-known TRFR technique with two other optical techniques, the so-called resonant spin amplification technique (RSA) on the one hand and Hanle-MOKE measurements on the other hand. The measurements are done on samples of slightly n-doped GaAs bulk and Mn-doped GaAs/AlGaAs quantum wells, where long spin lifetimes were detected earlier. We compare the results for spin lifetime from the different techniques in 3D and 2D systems. Spin lifetimes were extracted for different excitation and probing intensities for different Laser spot sizes, partially using a microscope setup, focussing the spot down to a few microns. The observed spin lifetimes range from about 1 ns to 120 ns and could be measured with an accuracy of a few percent.

HL 48.36 Thu 15:00 P2

Spin dynamics in symmetric high-mobility GaAs/AlGaAs quantum wells, grown in (110) direction — •Michael Griesbeck, Sebastian Fehringer, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Universität Regensburg, Germany

In semiconductor spintronics research, there is growing interest on (110)-grown GaAs/AlGaAs quantum wells because of the long spin lifetime in such systems, which results from the geometry of the Dresselhaus spin-orbit coupling. If the Rashba spin-orbit interaction is suppressed by symmetrical growth and doping of the quantum well, the spin lifetime is no longer limited by the D'yakonov-Perel mechanism and very long spin lifetimes can be observed. We investigate the spin dynamics in symmetric high-mobility (110)-grown GaAs/AlGaAs quantum wells using ultrafast time-resolved Faraday rotation (TRFR) and time-resolved photoluminescence (TRPL). In measurements at low temperatures and high magnetic fields we study the dependence of the spin lifetime on the strength of the applied external magnetic field.

HL 48.37 Thu 15:00 P2

Observing and controlling hole spin dynamics in 2D hole systems at sub-Kelvin temperatures — •Michael Kugler, Tobias Korn, Sebastian Fehringer, Anton Wagner, Robert Schulz, Christian Gerl, Marika Kubova, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

In recent years, due to the rapidly growing field of semiconductor spintronics, much interest has been focused on the spin dynamics of electrons in semiconductors, while the hole spin dynamics have not been investigated as rigorously. Here, we report on time-resolved Faraday rotation (TRFR) measurements on 2D hole systems within p-doped GaAs quantum wells (QWs) of different width. In the TRFR measurements, the sample is excited by a circularly-polarized laser pulse tuned to the exciton energy. A large in-plane magnetic field is applied within the sample plane, causing a precession of the photocreated carriers. At sample temperatures below 4 K, superimposed on the electron spin dynamics, we observe the long-lived precession of hole spins, which becomes even more pronounced at 400 mK. In the narrower QWs, the energy splitting between light and heavy hole is increased, leading to a reduced hole state mixing, which increases the hole spin lifetime further. In a gated sample, we observe a pronounced shift of the hole precession frequency as the gate voltage is changed. This indicates that the hole g factor may be strongly dependent on the growth-axis symmetry of the QW, which can be changed by the applied voltage.

HL 48.38 Thu 15:00 P2

Coherent LO phonons in optically excited double quantum wells — •Thomas Papenkort[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

In a double quantum well with a sufficiently thin barrier between the wells the two wells couple, i.e. the subbands are no longer localized in one of the wells but extend over both. By optically exciting such a double well under the influence of a static electric field an electron density can be obtained which is localized in one of the two wells. Because of tunneling the electrons oscillate between the two wells with the frequency of the subband splitting. This causes an oscillating polarization which couples strongly to a polar lattice, thereby creating coherent LO phonons.

We present numerical calculations of this efficient phonon generation process in an AlGaAs-GaAs double quantum well. Using a quantum kinetic approach we calculate both the dynamics of the electronic subsystem driven by a semi-classical laser field and of the phonons created via the Fröhlich interaction. We study the coherent amplitude and the fluctuations of the generated phonon states. They depend on the subband structure, which is defined by the dimensions of the double quantum well and the strength of the electric field, as well as on the exact excitation conditions.

HL 48.39 Thu 15:00 P2

Non-classical acoustic phonon states from the decay of optical phonons — •Jonas Daniels[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

While in quantum optics non-classical states of photons, such as squeezed states, have already been intensively studied, their investigation in phonon systems is only at the beginning. Besides fundamental interest in quantum effects in interacting many-particle systems, well-prepared non-classical phonon states could have applications e.g. for phonon based communications between nanostructures.

Here we consider fluctuation and coherence properties of non-equilibrium phonons after optical excitation in quantum dots. The optical excitation is accompanied by the generation of coherent optical phonons. These phonons in turn decay into acoustic phonons, which are the subjects of our investigation. From studies in bulk semiconductors it is known that this decay may lead to the formation of squeezed acoustic phonon states. While in the bulk only optical modes with $q = 0$ can be generated, in quantum dots also modes with nonvanishing q occur, corresponding to spatially inhomogeneous displacement fields. In our calculations we analyze the spatio-temporal dynamics of the acoustic phonon distributions including their fluctuation properties resulting from the decay of coherent optical phonons in a quantum dot.

HL 48.40 Thu 15:00 P2

Collinear generation of few-cycle UV and XUV laser pulses

for studying electron dynamics in solids — •Elisabeth Bothschafter[1], Ulrich Graf[1], Eleftherios Goulielmakis[1], Ralph Ernstorfer[1,2], Reinhard Kienberger[1,2], and Ferenc Krausz[1,3] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany. — [2]Lehrstuhl für Experimentalphysik I (E11, Experimentalphysik), Technische Universität München, James Franck Strasse, D-85748 Garching, Germany. — [3]Department für Physik, Ludwig-Maximilians-Universität, Am Coulombwall 1, D-85748 Garching, Germany.

The generation of isolated attosecond XUV pulses has been established in recent years [1]. More recently, the generation of few-cycle low-order harmonics has been demonstrated: sub-4 fs UV pulses are produced by third and fifth harmonic generation of few-cycle near-infrared (NIR) laser pulses in a gas target [2]. Now we investigate the possibility of the simultaneous generation of low-order harmonics and high-harmonic by two subsequent gas targets in a collinear geometry. Future experiments employing these unique light pulses for the study and control of electronic motion in nano-structured semiconductors will be discussed.

[1] E. Goulielmakis, M. Schultze, M. Hofstetter, V. S. Yakovlev, J. Gagnon, M. Uiberacker, A. L. Aquila, E. M. Gullikson, D. T. Attwood, R. Kienberger, F. Krausz, and U. Kleineberg (20 June 2008). Science 320 (5883), 1614.

[2] U. Graf, M. Fieß, M. Schultze, R. Kienberger, F. Krausz, and E. Goulielmakis, Opt. Express 16, 18956-18963 (2008)

HL 48.41 Thu 15:00 P2

Emission from s- and p-states in self-assembled InAs quantum dots — Andreas Schramm[1,2], Christian Heyn[2], and •Wolfgang Hansen[2] — [1]Optoelectronics Research Centre, Tampere University of Technology, Finland — [2]Institute of Applied Physics, University of Hamburg, Germany

We study the temperature- and electric-field dependence of the electron emission from charged InAs quantum dots. The semiconductor quantum dots are grown with molecular beam epitaxy on (001) GaAs and embedded in Schottky diodes designed for high-resolution transient capacitance spectroscopy. The emission rates of s- and p-shell electrons are determined at different electric fields controlled by the bias voltage at the Schottky diode. Our data demonstrate that the emission rate not only strongly depends on the shell the carrier is emitted from but also on its charge state. The observed behaviour of the emission rates can be quantitatively understood with a model for thermionic-tunnelling through a Coulomb barrier. The tunnel-barrier height is given by charge state independent s- or p-shell binding energies and its shape is assumed to arise from the Coulomb potential of the dot charge and a bias voltage controlled triangular contribution.

HL 48.42 Thu 15:00 P2

Fabrication of nanoholes and rings by local droplet etching with In_xGa_{1-x} — •Andrea Stemmann, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstr. 11C, 20355 Hamburg

We fabricate nanoholes and quantum rings on GaAs and AlGaAs surfaces by local droplet etching (LDE) with In_xGa_{1-x}. During the LDE process liquid metal droplets consisting of an In_xGa_{1-x} alloy are deposited on (001) GaAs at substrate temperatures ranging from 450 °C to 540 °C without an As flux. Subsequently, the samples are heated up to 600 °C in the absence of As and the liquid material is removed. In this way deep nanoholes are formed at the position of the initial droplets. The nanohole openings are surrounded by walls which act as quantum rings with tuneable size and composition. The nanostructures are inspected with atomic force microscopy. The technique is compatible for in-situ overgrowth of the nanostructures with molecular beam epitaxy in order to fill the holes with optical active material and to cap the structures with barrier material. We find a strong dependence of hole density, depth, and diameter as well as of the wall structural properties on process temperature T and In content x. Interestingly, with increasing In content x the hole density is reduced up to a factor of 0.1. On the other hand, the hole and wall diameter and the hole depth strongly increase.

HL 48.43 Thu 15:00 P2

HSQ e-beam lithography for ultrasmall single electron transistors on SOI — •Walter Daves, Matthias Ruoff, Monika Fleischer, David A. Wharam, and Dieter P. Kern — Institut für Angewandte Physik, Eberhard Karls Universität Tübingen

Single electron transistors (SETs) are a widely investigated alternative to MOSFET devices for sub-10 nm regime because of outstanding properties such as low power consumption and huge scaling potential. In this work SET devices on Silicon on Insulator (SOI) substrate were fabricated, using electron beam lithography (EBL) with Hydrogen Silsesquioxane (HSQ) as a high-resolution negative resist. The developed HSQ patterns were directly transferred into the active Si layer by Reactive Ion Etching (RIE). Geometric constriction sizes in the sub-10 nm range and dot diameters between 20 and 30 nm were achieved without the need of further oxidation of the nanostructures. Transport measurements on the fabricated SET devices showed clear blockade characteristics at room temperature. This process represents thus a promising candidate for efficient fabrication of SET devices operating at high temperatures.

HL 48.44 Thu 15:00 P2

Selective molecular epitaxial growth of InAs quantum dots on pre-patterned GaAs substrates — •Mathieu Helfrich and Daniel M. Schaadt — Institut für Angewandte Physik/DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

To successfully integrate quantum dot structures into optoelectronic devices and for possible future applications such as quantum computing it is crucial to control different parameters in the formation of quantum dots. It has been shown that size, shape and distribution of quantum dots can be influenced by patterning the substrate on which the quantum dots are formed. Nonetheless, the mechanisms to control the formation by pre-patterning are not fully investigated yet. In our work we grow self-assembled InAs quantum dots on pre-patterned GaAs (100) substrates by molecular beam epitaxy. The substrates are pre-structured by electron beam lithography. We focus on the pre-patterning of substrates and study the influence of various growth parameters and post-growth treatment. The aim is to achieve good size and shape homogeneity. Scanning electron microscopy, atomic force microscopy and photo-luminescence measurement techniques are used to analyse the quality of the grown quantum dots.

HL 48.45 Thu 15:00 P2

Self-catalyzed molecular beam epitaxy growth and electrical characterization of InAs nanowires — •Sonja Heiderich[1,2], Mihail Ion Lepsa[1], Jakob Wensorra[1], Thomas Richter[1], Hans Lüth[1], and Detlev Grützmacher[1] — [1]Institute of Bio- and Nanosystems (IBN-1) and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich — [2]Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

Semiconductor nanowires (NW) have become an attractive research field both for novel device concepts and the investigation of fundamental physical aspects regarding the electronic transport in quasi-one-dimensional quantum systems. InAs NW present a special interest related to the material related properties: low effective mass, narrow gap, high electron mobility and strong electron accumulation layer on its surface. Based on previous experiences obtained for the growth of GaAs NW by molecular beam epitaxy (MBE, we have successfully grown InAs NW using In droplets as a seed. The NW have been grown both on InAs and GaAs (100) substrates covered with a thin hydrogen silsesquioxan (HSQ) film. After the growth, they have been transferred on a Si substrate with SiO2 on the surface. By mean of e-beam lithography, the NW have been connected to large pads using nonalloyed Ti/Au metallization. DC electrical measurements carried out at room temperature show ohmic, linear I-V characteristics and low resistance. Using a field effect transistor configuration with back gate, the nanowire carrier concentration and mobility have been estimated.

HL 48.46 Thu 15:00 P2

SAW driven ratchet-like effects in AlGaAs/GaAs nanostructures — •Marcin Malecha[1], Jens Ebbecke[2], Hubert J. Krenner[1], and Achim Wixforth[1,3] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg — [2]Heriot-Watt University, School of EPS-Physics, EH14 4AS, Edinburgh — [3]Center for NanoScience (CeNS), Geschwister-Scholl-Platz 1, 80539 München

Recently we have reported our results [1] on electron transport through strong coupled quantum dots on AlGaAs/GaAs heterostructures. The major feature is a strong Coulomb interaction which leads to broken electron-hole symmetry. Due to the designed lateral asymmetry of the quantum dots and applied surface acoustic waves for driving electrons the whole system is highly non-symmetric and thus ratchet effects are expected. The experimental data clearly shows one of the most promi-

nent ratchet effects - the current reversal - when a SAW is applied. For further investigations, a new sample design is developed where more parameters can be tuned separately - from the height of the barriers to the shape and coupling strength of the quantum dots. Details of the new sample design and first measurements will be presented.
[1] F.J. Kaiser, et al, J. Phys.: Condens. Matter 20, 374108 (2008)

HL 48.47 Thu 15:00 P2

Formation of molecular clusters of selenium as an alternative to precipitation of CdSe nanoparticles in a borosilicate glass — •Yuriy Azhniuk[1], Vasyl Lopushansky[1], Yuriy Hutych[1], Alexander Gomonnai[1], and Dietrich R. T. Zahn[2] — [1]Institute of Electron Physics, Ukr. Nat. Acad. Sci., Uzhhorod, Ukraine — [2]Chemnitz University of Technology, Semiconductor Physics, D-09107 Chemnitz, Germany

Solid-state precipitation in a borosilicate glass is a well-elaborated technique for obtaining II-VI semiconductor nanocrystals. The obtained nanocrystal size depends on the growth conditions (heat treatment temperature and duration). Here we present Raman evidence for an alternative process, precipitation of molecular clusters of selenium, which is also possible at certain growth conditions.

Decoloured CdSe-doped borosilicate glass samples were subjected to thermal treatment at 625 to 700^{o}C during 2 to 12 h. Resonant micro-Raman measurements were performed using a Dilor XY 800 spectrometer and different Ar^+ laser lines for excitation. Besides the CdSe LO and 2LO phonon bands, the Raman spectra of the samples obtained at thermal treatment duration and temperature beyond the range, most suitable for the formation of CdSe nanocrystals, contained pronounced features at 323 and 646 cm^{-1}. Based on their frequency positions, widths, intensities, and resonant behaviour, these features are attributed to Se_2 clusters being formed in the glass during the thermal treatment.

HL 48.48 Thu 15:00 P2

MOVPE growth studies for InGaN quantum dots — •Michael Högele[1], Christian Meissner[1,2], Simon Ploch[1], Markus Pristovsek[1], and Michael Kneissl[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

The growth of InGaN for uncapped quantum dots (QDs) on GaN/sapphire templates was studied in a horizontal and a close coupled showerhead metal-organic vapour phase epitaxy (MOVPE). At a reactor pressure of 100 mbar and a N_2 atmosphere the growth temperature was varied between 620°C and 740°C. For a fixed ammonia partial pressure of 2500 Pa different ratios of trimetylindium (TMIn) and trimethylgallium (TMGa) or triethylgallium (TEGa) were used. The InGaN growth process was investigated by in-situ spectroscopic ellipsometry (SE). After growth the samples were analysed by X-ray diffraction (XRD) and atomic force microscopy (AFM).
For pure InN quantum dots we found a Volmer-Weber growth mode. With increasing gallium content in the InGaN nanostructures a transition to the Stranski-Krastanov growth mode is expected due to the decreasing lattice mismatch to the GaN templates.

HL 48.49 Thu 15:00 P2

Spectroscopy on charge-tunable InGaAs quantum dots — •Dennis Franz[1], Tim Köppen[1], Andreas Schramm[2], Christian Heyn[1], Detlef Heitmann[1], and Tobias Kipp[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Optoelectronics Research Center, Tampere University of Technology, Finland

We investigate electronic excitations in charge-tunable InGaAs quantum dots by resonant Raman and resonant photoluminescence spectroscopy in magnetic fields. In contrast to earlier measurements at the $E_0 + \Delta$ gap [1,2], we excite resonantly at the fundamental E_0 gap. Exploiting capacitance-voltage measurements one can control the electron number in the quantum dots. We study the zero, one, and two electron case and observe strongly resonant emission signals. For the one and two electron case, besides photoluminescence resonant electronic Raman transitions are identified.

This project is supported by the Deutsche Forschungsgemeinschaft via SFB 508 “Quantenmaterialien”.
[1] L. Chu et al., *Appl. Phys. Lett.* **77**, 3944 (2000)
[2] T. Brocke et al., *Phys. Rev. Lett.* **91**, 257401 (2003)

HL 48.50 Thu 15:00 P2

Fine structure tuning in self-assembled (In,Ga)As quantum dots by uniaxial stress — •Klaus D. Jöns[1], Robert Hafenbrak[1], Sven M. Ulrich[1], Lijuan Wang[2], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [3]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Entangled photon pairs are an important prerequisite to implement e.g. quantum cryptography. The biexciton-exciton cascade in (In,Ga)As quantum dots (QDs) is a promising source of such quantum states. Still, intrinsic quantum dot fine structure splitting inhibits entanglement. Therefore, the fine structure splitting as a limiting factor has to be reduced using a post-growth technique. In our work we present fine structure tuning of self-assembled (In,Ga)As QDs by uniaxial stress. For this purpose we glued the sample tightly on a piezo actuator and applied tunable uniaxial stress along a crystal axis parallel to the sample surface. Our setup enables us to apply both tensile and compressive stress on the sample in a helium-flow cryostate so the confining potential can be tuned in two directions to achieve zero fine structure. The photoluminescence was detected by a high resolution setup using a Fabry-Pérot interferometer. Our results at 8K temperature show that the spectral emission of the QDs shifts by applying piezo voltage and that the fine structure splitting can be tuned considerably.

HL 48.51 Thu 15:00 P2

Optical Investigations of the Mode Spectra of InP–Quantum Dots Embedded in (Al_xGa_{1-x})InP Micro Pillars. — •Moritz Bommer[1], Tim Thomay[2], Wolfgang–Michael Schulz[1], Martin Tomas[2], Robert Rossbach[1], Michael Jetter[1], Alfred Leitenstorfer[2], Rudolf Bratschitsch[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, D-70569 Stuttgart, Germany — [2]1. Department of Physics and Center for Applied Photonics, University of Konstanz, D-78464 Konstanz, Germany

InP–quantum dots (QDs) are promising sources of single–photons and as active laser medium, emitting in the red part of the visible spectrum and thus in the range of the highest sensitivity of current silicon detectors.

The self assembled QDs were grown by metal organic vapor phase epitaxy and are embedded in between distributed Bragg reflectors (DBRs), afterwards the sample was processed by a Focused Ion Beam to fabricate micro–pillars. The DBRs and the high refractive index step between pillar and air results in a three dimensional mode confinement and highly directed emission and thus higher intensity.

We have investigated the mode spectra by micro–photo luminescence measurements for different pillar diameters and compared the spectra with a theoretical model showing up good consistency. Q–factors up to 3600 were achieved.

HL 48.52 Thu 15:00 P2

Interferometric measurement of polarization dynamics in QDs — •Manuel Huber[1,2], Christian Wolpert[1,2], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]4th Physical Institute, University of Stuttgart

Most coherent experiments on excitonic states in QDs investigate an absolute value of the polarization. We want to be able to measure both the real and imaginary part to fully reconstruct the azimuthal state of the Bloch-vector. To achieve this aim we propose a method for a pump-probe setup using an interferometer, inspired by differential interference contrast microscopy. The interference of superposed reference and signal pulses is used to either perform phase- or amplitude-sensitive measurements.
We will show the principle of the setup and theoretical simulations as well as first experimental results for pump-induced excitonic states.

HL 48.53 Thu 15:00 P2

Photon statistics as a probe for exciton correlations in Coulomb-coupled quantum dots — •Alexander Carmele[1], Malek Bagheri Harouni[2], Marten Richter[1], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Physics Department, Quantum Optics Group, University of Isfahan, Isfahan, Iran

Recently, quantum optical spectroscopy of semiconductor nanostruc-

tures is suggested [1]. Within a density-matrix approach, we include Coulomb-contributions in coupled quantum dots via an exciton basis [2] and investigate for fixed light intensity the impact of photon statistics on the creation of optically active excitons. We find measurable differences for the creation efficiency. Furthermore, we calculate the degree of entanglement of photon pairs from radiative cascades of biexcitons [3] in dependence on different Coulomb-coupling mechanisms.

[1]M. Kira, S.W. Koch, Phys. Rev. Phys. Rev. A 78, 022102 (2008)
[2]M. Richter, K.J. Ahn, A. Knorr, A. Schliwa, D. Bimberg, M. E.-A. Madjet, T. Renger, Phys.Status Solidi B, 243(10):2302-2310, 2006
[3]U. Hohenester, G. Pfanner, and M. Seliger, Phys. Rev. Lett. 99, 047402 (2007)

HL 48.54 Thu 15:00 P2

Ultrafast gain dynamics in InGaAs quantum dot based semiconductor optical amplifiers — Jordi Gomis-Bresco[1], Sabine Dommers[1], Vasily Temnov[1], Ulrike Woggon[1], Matthias Lämmlin[2], Dieter Bimberg[2], •Ermin Malic[3], Marten Richter[3], Eckehard Schöll[3], and Andreas Knorr[3] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin — [3]Institut für Theoretische Physik, Technische Universität Berlin

The application of quantum dot (QD) semiconductor optical amplifiers (SOAs) in high-speed ethernet networks demands a high frequency response. To understand the elementary processes limiting the recovery time in quantum dot based SOAs, we present pump-probe studies of femtosecond pulse trains with up to 1 THz repetition rates and investigate the gain response of a QD-SOA at high electrical injection current and elevated device temperatures.

We discuss fundamental limits for THz optical pulse train amplification based on semiconductor Bloch equations including microscopically calculated, temperature-dependent Coulomb scattering rates between quantum dot and wetting layer states.

HL 48.55 Thu 15:00 P2

The impact of strain waves travelling across a quantum dot on the optical response of the dot — •Jan Huneke[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

We analyze the influence of phonon wave packets travelling across a semiconductor quantum dot on the optical response resulting from the lowest dot transition. For this purpose we compare two different structures: (i) a phonon wave packet is generated by the optical excitation of a single quantum dot near a surface, which after reflection at the surface reenters the dot; (ii) a phonon wave packet is generated by the excitation of a nearby second dot and then travels across the quantum dot.Our theoretical model includes pure dephasing interactions between electronic and phononic degrees of freedom in quantum dot systems that are driven by ultrafast laserpulses. We discuss the linear response as well as pump-probe and four-wave-mixing signals for both situations. It is shown that the phonon wave packets leave a distinct signature which allows their detection in time-integrated as well as time-resolved regimes. We study the dependence of the signals on the origin of the phonon wave packets and find, although the strain fields are very similar, clear differences in the optical response allowing for a distinction between wave packets of different origins.

HL 48.56 Thu 15:00 P2

Monitoring threshold dynamics by ultrafast direct observation of correlations between individual photon emission events in microcavity lasers — •Marc Assmann[1], Thorsten Berstermann[1], Manfred Bayer[1], Jan Wiersig[2,5], Christopher Gies[2], Frank Jahnke[2], Caroline Kistner[3], Stephan Reitzenstein[3], Christian Schneider[3], Sven Höfling[3], Alfred Forchel[3], Carsten Kruse[4], and Detlef Hommel[4] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute for Theoretical Physics, University of Bremen, 28334 Bremen, Germany — [3]Technische Physik, University of Würzburg, 97074 Würzburg, Germany — [4]Institute for Solid State Physics, University of Bremen, 28334 Bremen, Germany — [5]Institute for Theoretical Physics, University of Magdeburg, 39016 Magdeburg, Germany

The onset of coherent emission in lasers is identified by a change in the photon statistics. In semiconductor lasers the short coherence times below the lasing threshold complicate such measurements as the temporal decay of correlations is considerably faster than the time resolution of usual photodiodes. A novel experimental approach using a streak camera allows us to overcome this problem with a time resolution of 2 ps. This allows for a very detailed characterization of microcavity lasers and enables us to describe the lasing process in detail. Especially around the lasing threshold phenomena like the emission of nonclassical light in few-QD-VCSELs, dynamical antibunching and relaxation oscillations in the second order correlation function are found.

HL 48.57 Thu 15:00 P2

Theory of Electron Phonon Interaction for Relaxation and Luminescence in Semiconductor Quantum Dots — •Matthias–René Dachner, Janik Wolters, Andreas Knorr, and Marten Richter — Institut für Theoretische Physik, Technische Universität Berlin

Using an effective Hamiltonian approach in which the states of a quantum system are divided into relevant and remote states, we derive equations of motion to describe higher order phonon processes.

As an application we calculate relaxation and dephasing times of electron-hole excitations in self assembled quantum dots where the energetic gaps between wetting layer and discrete states are on the order of several phonon energies.

Additionaly we discuss the influence of pure dephasing through acoustic phonons on the quantum dot luminescence. We stress that the choice of the quantum dot wavefunction is crucial for coupling matrix elements comparing calculated luminescence spectra with spectra from single quantum dot spectroscopy.

HL 48.58 Thu 15:00 P2

Theory of indirect spin dephasing in optically driven semiconductor quantum dots — •Anna Grodecka[1], Paweł Machnikowski[2], and Jens Förstner[1] — [1]Computational Nanophotonics Group, Theoretical Physics, University Paderborn, Paderborn, Germany — [2]Institute of Physics, Wrocław University of Technology, Wrocław, Poland

Optically driven spin control schemes in quantum dot (QD) systems exploiting spin dependent charge evolution are considered as the most promising candidates for quantum computers. We show that even in the absence of direct spin-reservoir coupling, the spin state of a confined carrier in QD can undergo dephasing. The indirect dephasing process is studied in detail for specific optical spin control protocols using off-resonant trion excitations in doped semiconductor QDs [1,2]. The microscopic description of the interaction between charges and their phonon reservoir as well as its non-Markovian nature is included. Moreover, the decoherence channels resulting from radiative decay of the trion and imperfections of an adiabatic evolution are discussed.

1. A. Grodecka, C. Weber, P. Machnikowski, and A. Knorr, Phys. Rev. B 76, 205305 (2007).
2. A. Grodecka, P. Machnikowski, and J. Förstner, arXiv:0811.2108 (2008).

HL 48.59 Thu 15:00 P2

Theory of electron-phonon coupling in semiconductor quantum dots: non-diagonal coupling, phonon memory and initial correlations — •Marten Richter and Andreas Knorr — Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstraße 36 EW 7-1, 10623 Berlin

Memory effects play an important role in the theory of dephasing processes of semiconductor quantum dots. To describe strong electron-phonon coupling (e.g. in nitrid materials) beyond perturbation theory, typically methods such as generating functions, cumulant expansion, time convolution less theories (TCL) are used. These methods are usually restricted to a diagonal electron-phonon interaction, that does not include transitions between different electronic levels. Non-diagonal electron-phonon coupling is of dramatic importance, if coupled quantum dots or several levels contribute to the optical response. In order to address this problem, we present an extended TCL theory, which makes an inclusion of nondiagonal electron-phonon coupling to the calculation of the nonlinear optical response function possible.

HL 48.60 Thu 15:00 P2

Theory of Time-resolved Raman and Fluorescence Emission of Semiconductor Quantum Dots — •Julia Kabuss[1], Stefan Werner[2], Axel Hoffmann[2], Andreas Knorr[1], and Marten Richter[1] — [1]Institut für Theoretische Physik, Technische Univer-

sität Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin

Resonant light scattering experiments provide information about the optical and electronic properties of semiconductor quantum dots. We develope a quantized description for the spontaneous light emission of a coupled phonon-semiconductor quantum dot system after resonant optical excitation. A perturbative approach to the density matrix leads to an analytic expression for the quasi-stationary spectrum, while the time-dependent spectrum is computed numerically. Our results allow the simultaneous discussion of Raman scattering and Fluorescence. They can be discriminated from each other by their spectral properties and their decay times respectively as both processes occur simultaneously in a resonant scattering experiment. Our results are compared to experimental data.

HL 48.61 Thu 15:00 P2

Optical spin switching in a Mn doped QD under influence of a magnetic field — •Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

The combination of semiconducting and ferromagnetic materials has interesting possible applications in the field of spintronics. In a CdTe quantum dot doped with a single Mn atom the exciton line in photoluminescence spectra splits into six lines clearly demonstrating the strong exchange interaction between the exciton and the Mn spin. As we have shown recently the Mn spin state can be controlled in an indirect optical way by a sequence of laser pulses, which create, destroy or manipulate excitons in the system. Thus the Mn spin can be driven from a given initial value into all the other spin states. By adding a magnetic field in Faraday configuration the efficiency of this process can be strongly enhanced and the total switching time can be reduced from 100 ps to about 40 ps, when dark and bright excitons are brought to resonance. The timescales for the switching process are of the order of the lifetime of the bright exciton. Therefore we consider a model which includes radiative decay in terms of a decay time. In this contribution we discuss the influence of the finite lifetime of the exciton as well as the influence of magnetic fields on the optical switching process.

HL 48.62 Thu 15:00 P2

Time-resolved electroluminescence measurement setup for single quantum dots — •J. Zimmer, P. Asshoff, H. Füser, H. Flügge, W. Löffler, M. Hetterich, and H. Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

We describe a time-correlated single-photon counting setup for the analysis of the spin-injection process in spin-injection light-emitting diodes (spin-LEDs). We are able to measure the temporal electroluminescence polarization dynamics of the quantum dot ensemble and even single dots. To get optical access to single quantum dots, we use gold submicron apertures located on top of the spin-LEDs. The electroluminescence polarization dynamics of the quantum dots exhibit remarkable characteristics. We relate this to certain non-equilibrium effects in the device.

HL 48.63 Thu 15:00 P2

Self-assembled lateral GaAs quantum dot molecules — •Lijuan Wang[1], Armando Rastelli[2], Suwit Kiravittaya[1], Mohamed Benyoucef[2], and Oliver G. Schmidt[2] — [1]Max-Planck-Institut für Festkörperforschung,Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden,Helmholtzstr. 20, D-01069 Dresden, Germany

Semiconductor quantum dot molecules (QDMs) is an exciting area of research since they are ideal candidates for the possible implementation of quantum gates for quantum computation. Two main classes of QDMs have been explored, i.e. vertical and lateral QDMs according to the spatial arrangement of two quantum dots (QDs) composing a QDM. Here we demonstrate that using a multi-step growth technique, strain-free GaAs/AlGaAs lateral QDMs can be created. The QDMs are formed by filling two laterally spaced AlGaAs holes with GaAs.

The optical properties of such QDMs and single GaAs QDs grown in a similar way are characterized by photoluminescence. Different QDMs show similar spectral features. Because of fluctuations inherent in the self-assembled growth, the two QDs composing a QDM are generally not identical and thus their mutual coupling is tuned by an external electric field parallel to the QDM axis. The comparison between the emission of single QD and QDMs in a lateral electric field indicates the existence of lateral coupling.

HL 48.64 Thu 15:00 P2

Resonant Raman Profiles in GaAs and AlGaAs Nanowires at the Bandgap — •Oliver Schimek[1], Megan Brewster[2], Silvija Gradecak[2], and Stephanie Reich[1] — [1]Fachbereich Physik, Freie Universität, Berlin — [2]Massachusetts Institute of Technology, Cambridge

The properties of low dimensional systems like nanowires hold promise for novel electronic devices like nanowire-based transistors, sensors and single photon sources. Here we are investigating the physical properties like electron-phonon coupling by means of Raman spectroscopy. We present resonance data of GaAs and AlGaAs nanowires at the bandgap energy. The photoluminescence is effectively quenched in nanowires and therefore the bandgap can directly be probed. Such nanowires show an unexpectedly strong second order LO phonon such that the ratio 2LO:1LO reaches values up to 6 under resonant conditions. We also present a model of two phonon resonant Raman scattering via excitons. This model explains the observed 2LO resonance profile. The resonance data of the AlGaAs nanowires show a dip in the 1LO curve at the position of the 2LO maximum which suggests that the 2LO intensity occurs at expense of the 1LO intensity. Additionally, we present data of Si doped GaAs nanowires whose increased concentration of free carriers results in a interference known as the Fano effect.

HL 48.65 Thu 15:00 P2

Time-resolved Phonon Interactions in InAs/GaAs Quantum Dots — •Stefan Werner, Patrick Zimmer, Julia Kabuss, Martin Richter, Axel Hoffmann, and Andreas Knorr — Institut für Festkörperphysik, TU Berlin, EW 5-1, Hardenbergstraße 36, 10623 Berlin, Deutschland

We present a time- and temperature-resolved photoluminescence study of different carrier-phonon interactions in self-organized InAs/GaAs quantum dots (QD) under resonant excitation of the QD system. Resonant excitation leads to an enhancement of cross-sections of processes attributed to phonon interactions, like Raman scattering or hot-electron luminescence. Resonant PL techniques enable us to retrieve the energies of localized phonon modes. Time-resolved PL measurements allow us to differentiate between coherent and incoherent phonon-coupled processes. For the QD LO-phonon mode (34.6 meV), a very short radiative lifetime of under 30 ps is found, giving proof of the coherent character of the Raman scattering. In addition, temperature-dependent measurements are performed. Our results are compared with theoretical calculations.

HL 48.66 Thu 15:00 P2

Excited state spectroscopy of single laterally coupled InGaAs quantum dot molecules — •Matthias Heldmaier[1], Claus Hermannstädter[1], Marcus Witzany[1], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Lijuan Wang[2], Armando Rastelli[3], Oliver Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Helmholtzstr. 20, 01069 Dresden

The investigated structures contain self-assembled laterally coupled InGaAs quantum dots embedded in a planar microcavity, which are grown using a combination of metal-organic vapor phase and molecular beam epitaxy. The individual quantum dot molecules (QDMs) consist of two single dots that are coupled along the [1-10] crystal direction via electron tunneling. The coupling strength and the ground and excited state energies of the QDMs can be manipulated applying a lateral electric field. A change in the relative intensities of the excitonic emission lines is observed in the photoluminesence (PL) spectra. PL excitation measurements were conducted using a wide-range tunable Ti:sapphire laser to obtain spectra of the excited QDM states as a function of electric field tuning. Pumping an excited exciton state (p-shell) at increasing pulse amplitudes leads to oscillatory behavior in the detected excitonic s-shell recombination. Special pulse amplitudes ($\pi/2$, π, etc.) can be extracted and used for subsequent coherent experiments.

HL 48.67 Thu 15:00 P2

Non-local control of cotunneling currents in a two-impurity

Kondo system — •Daniel Tutuc[1], Matthias Reinwald[2], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, 93040 Regensburg

We present measurements on non-local cotunneling current control in a system of two magnetic impurities - realized by two quantum dots - coupled through an open conducting region, which can be attributed to the influence of the effective interaction between magnetic moments [1-3]. The sample consists of two lateral quantum dots connected via an open region of about 300 nm, created by Local Anodic Oxidation with an AFM on a GaAs/AlGaAs heterostructure with a 2DEG 34nm beneath the surface. The measurements have been performed with the standard lock-in technique, in a dilution refrigerator, at about 100 mK electron temperature. We investigate the effective interaction between magnetic moments in dependence on the dot coupling to the central region and on an in-plane magnetic field. The interaction between the magnetic moments is destroyed for weak dot coupling to the central region and for magnetic fields higher than 8T.

[1] N. J. Craig *et al.*, Science **304**, 565 (2004)
[2] P. Simon, *et al.*, Phys. Rev. Lett. **94**, 086602 (2005)
[3] M. G. Vavilov and L. I. Glazman, Phys. Rev. Lett. **94**, 086805 (2005)

HL 48.68 Thu 15:00 P2

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

The influence of the electron density on the output characteristic of ballistic rectifiers is investigated. The rectifier is a nanoscale four-terminal Ψ-shaped cross junction consisting of a straight voltage stem (200 nm wide and 2 μm long) and two opposing 200 nm wide branches which merge under 45° into the central stem. Different devices are fabricated from a high-mobility Si/SiGe heterostructure by using a mix-and-match process which combines high-resolution electron-beam lithography and UV-lithography. With a low-damage CF_4/O_2 plasma step the resist pattern is transferred into the heterostructure. After the preparation of ohmic contacts a nanoscale Schottky gate is locally deposited on top of the voltage stem. A rectified inertial ballistic voltage develops between the upper and lower end of the central stem if a current is injected between the branches [1]. At $T = 4.2\,\mathrm{K}$ we observe an increase of the rectified signal with decreasing electron density in the voltage stem achieved by applying a negative voltage at the local Schottky gate. The improved efficiency at low electron density is tentatively attributed to a reduced screening of the stationary dipole.
[1] M. Knop *et al.*, Appl. Phys. Lett. **88**, 082110 (2006)

HL 48.69 Thu 15:00 P2

Electronic transport in InAs nanowires controlled by high-k dielectric gates — •Karl Weis[1,2], Sergio Estévez Hernández[1,2], Mihail Ion Lepsa[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Stefan Trellenkamp[1,2], Jürgen Schubert[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

Quantum dots in semiconductor nanowires are promising candidates for the realization of quantum bits. It is well known that using gate electrodes is a convenient way to form and tune quantum dots.

Here, the electronic transport properties of n-doped InAs nanowires grown by MBE and MOVPE are examined. For a sample of 22 wires, the length and diameter are (1700 ± 400) nm and (170 ± 20) nm, respectively. The tunability of the carrier concentration in the conductive channel is compared for different gate geometries, e. g. fingers or nearly wrapping gates. Furthermore, we investigate if gate performance can be improved by using a high-k dielectric, namely $GdScO_3$, instead of SiO_2. Four-terminal transport measurements are performed both at room temperature and at low temperatures down to 300 mK.

Preliminary field effect transistor measurements were performed at room temperature for the aforesaid sample of 22 wires. We used a SiO_2 back gate, varied the gate voltage and measured the drain current. At a source-drain bias of 0.1 V, the pinch-off voltage was $U_{\mathrm{th}} = (-40\pm20)\,\mathrm{V}$ and the maximum transconductance $g_{\mathrm{m}} = (1.6 \pm 0.8) \times 10^{-6}\,\mathrm{S}$.

HL 48.70 Thu 15:00 P2

Wavefunctions in the valence band of InAs quantum dots — •Razvan Roescu[1], Dirk Reuter[1], Andreas D. Wieck[1], Ulrich Zeitler[2], and Jan C. Maan[2] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, Germany — [2]High Field Magnet Laboratory, Radboud University Nijmegen, Toernooiveld 7, 6525 ED Nijmegen, The Netherlands.

Magneto-capacitance spectroscopy of InAs self-assembled quantum dots allows the momentum space wavefunctions mapping of conduction and valence band states. To do this, a magnetic field is varied (strength and direction) in the base plane of the quantum dots.

The perpendicular magnetic field would also influence the wavefunctions, therefore capacitance-voltage spectroscopy in a tilted field should reveal this effect.

We will present the result of such experiments performed on self-assembled InAs/GaAs quantum dots embedded in a Schottky diode with a carbon doped p-type back contact. The results cannot be explained by a simple model and possible consequences are discussed.

HL 48.71 Thu 15:00 P2

Investigations of a photovoltaic power generator in an Electromagnetic Ambience — •Markus Drapalik[1], Julian Schmid[1], Erika Kancsar[1], Viktor Schlosser[1], and Gerhard Klinger[2] — [1]Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Department of Meteorology and Geophysics, University of Vienna, 1090 Vienna, Austria

Up to date little attention has been paid to the interaction of photovoltaic solar cell arrays with electromagnetic fields. Primary arrays of solar panels can act as passive shields, reflectors and antennas for RF radiation. The reception of electromagnetic radiation from the ambience by the solar modules introduces electrical noise into the subsequent system. Under laboratory conditions we currently investigate electrical AC signals detected at the terminals of single solar cells and small modules under well controlled ambient parameters. The signals are introduced by RF radiation emitted by function generators in the range between 10Hz and 4GHz. Beside the laboratory examinations an outdoor facility on the roof top of the department building in central Vienna was equipped with the necessary instruments to record RF signals from the ambience and the electrical noise of a solar module under realistic operating conditions. Results of these investigations will be discussed in order to evaluate the contributions of solar arrays to electromagnetic ambience.

HL 48.72 Thu 15:00 P2

Determination of the a.c. parameters of photovoltaic solar cells — •Erika Kancsar, Markus Drapalik, Julian Schmid, and Viktor Schlosser — Faculty of Physics, University of Vienna, 1090 Vienna, Austria

Photovoltaic solar cells are widely used for direct sunlight to electricity conversion. Principally a solar cell generates a current which is proportional to the incident light intensity which includes current fluctuations caused by photon noise. A solar power generator therefore may become a significant source of electromagnetic distortion which can cause malfunction of other electrical equipment and increase biological risks associated with a higher level of electromagnetic noise in the ambience. In order to predict the response of a solar cell to light fluctuations, the transfer function or the equivalent circuit must be known. In this work we investigate the a.c. behaviour of single solar cells and small modules connected to a simple load circuit in order to evaluate the necessary elements which describe the equivalent a.c. circuit under operating conditions. The results will be discussed with respect to different designs of photovoltaic devices.

HL 48.73 Thu 15:00 P2

Investigations of the response of a photovoltaic power generator to mechanical vibrations — •Julian Schmid[1], Erika Kancsar[1], Markus Drapalik[1], Viktor Schlosser[1], and Gerhard Klinger[2] — [1]Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Department of Meteorology and Geophysics, University of Vienna, 1090 Vienna, Austria

Due to their large area and the exposure to wind forces photovoltaic solar modules are subjected to mechanical vibrations which can generate electrical oscillations. The resulting electromagnetic signal is partly emitted to the ambience and partly carried through the leads to the power conditioning system of the solar power generator. Purpose of the current work is (i) to investigate the response of photovoltaic devices to mechanical vibrations in the laboratory under well

controlled conditions and (ii) to perform exemplary outdoor studies of the mechanical vibrations caused by wind forces in Vienna. The results collected so far will be presented and discussed with respect to the impact of mechanical vibrations of solar arrays on the level of electromagnetic distortion.

HL 48.74 Thu 15:00 P2

Sputter deposition of Cu_2O thin films from oxidic targets — •Swen Graubner, Daniel Reppin, Angelika Polity, Detlev Hofmann, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen

Cu_2O is an intrinsic p-type semiconductor with energy of the band gap in the visible spectral range. Thus it is considered to be a promising material for thin film solar cell applications. Our approach is to deposit Cu_2O films using ceramic targets and to explore the parameter space in comparison to the deposition from metallic targets. The first step was to develope a sinter technique to produce a stoichiometric and stable sputter target. We deposited layers using this ceramic target by a RF sputter process. Morphological investigations of the films by x-ray diffraction (XRD) show a strong $Cu_2O < 200 >$ reflex. Carrier concentrations were determined by Hall-measurements to $10^{13} - 10^{14}$ cm^{-3}. The use of oxygen as reactive sputter gas leads to higher carrier concentrations, a direct and forbidden bandgap of $1,9$ to $2,0$ eV and an improved morphological quality. Oversized O_2 flows lead to the formation of CuO thin films. Using a nitrogen/argon mixture as sputter gas changes the electrical and morphological properties.

HL 48.75 Thu 15:00 P2

Hard x-ray photoelectron spectroscopy of chalcopyrite based solar cells — •Christian D.R. Ludwig[1], Catherine A. Jenkins[2], Xuefang F. Dai[3], Andrei Gloskovskii[3], Gerhard H. Fecher[3], Claudia Felser[3], Benjamin Johnson[4], Joachim Klaer[4], Iver Lauermann[4], and Raquel Caballero[4] — [1]Institute for Physics, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Materials Science and Engineering, University of California, Berkeley, 94720, USA — [3]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [4]Helmholtz-Zentrum für Materialien und Energie, 14109 Berlin

Chalcopyrite based solar modules combine advantages of thin-film technology with the high efficiency and stability of conventional crystalline silicon cells. Hard x-ray photoemission spectroscopy (HAXPES) allows the investigation of a total buffer/absorber/substrate device stack, due to a mean free path of the excited electrons of a few tens of unit cells. The chalcopyrite compounds $Cu(In,Ga)Se_2$ and $CuInS_2$ with a CdS capping were investigated at BESSY, Berlin and at SPring8, Japan. The excitation energy was varied from 2.2 keV to 8 keV. The experimental results are compared to first principle electronic structure calculations based on density functional theory. The densities of states of the valence bands of uncapped compounds agree well with photoemission spectroscopy data and it is shown that HAXPES is a technique capable of resolving the valence bands of interfaces, buried under a CdS capping. This work is funded by the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (project 0327665A).

HL 48.76 Thu 15:00 P2

New buffer layer materials for CIGS solar cells — •Thomas Gruhn[1], David Kieven[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Glienicker Str. 100, 14109 Berlin

Test

HL 48.77 Thu 15:00 P2

New buffer layer materials for CIGS solar cells. — •Thomas Gruhn[1], David Kieven[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Glienicker Str. 100, 14109 Berlin

The compound semiconductor $CuIn_xGa_{(1-x)}Se_2$ (CIGSE) are used as absorber material in thin-film photovoltaic cells. In conventional CIGSE based solar cells a thin CdS layer (buffer) significantly improves the photovoltaic performance and efficiencies up to 19.9% have been realized. Since Cd is a toxic heavy metal there is a demand for suitable substitute materials. The first requirements for these materials are an adequate band gap, a crystal structure compatible to that of CIGSE, and an n-type conductivity. An interesting class of materials are half-Heuslers, which are ternary compounds with a $C1_b$ MgAgAs structure. For many half-Heusler compounds the crystal structure matches well with the [100] layer of the tetragonal CIGS unit cell. Using ab initio calculations based on B3LYP hybrid functionals, we have studied electronic properties of the most promising half-Heusler materials. Our results affirm the band gap rule for 8-electron half-Heuslers presented in [1].

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

[1] H. C. Kandpal, C. Felser, and R. Seshadri, J. Phys. D: Appl. Phys. **39**, 776 (2005).

HL 48.78 Thu 15:00 P2

Electronic bandstructure of the ZnTe absorber material — Daniel Fritsch[1] and •Heidemarie Schmidt[2] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, PO Box 270116, D-01171 Dresden, Germany — [2]Forschungszentrum Dresden-Rossendorf, PO Box 510119, D-01314 Dresden, Germany

Due to its large absorption coefficient, zinc telluride proved to be useful for the production of high-efficiency multi-junction solar cells. Nowadays ZnTe with a mixture of zincblende and wurtzite phases is fabricated by thin film growth techniques. The optical properties of both phases have been extensively studied by ab initio density functional methods [1]. Here we focus on the question whether the effective electron and hole mass in ZnTe are small enough to meet the high-efficiency expectation of the ZnTe absorber material in solar cells and present direction dependent effective mass and Luttinger and Luttinger-like parameters of cubic and wurtzite ZnTe, respectively. Making use of the transferability of ionic model potential parameters [2] and the experimentally known transition energies of different II-VI compounds ZnX (X=O, S, Se, Te), we obtained one single set of cationic model parameters for the Zn atom. The calculations have been performed by means of the empirical pseudopotential method using a simple empty core model potential. [1] S. Zh. Krazhanov, P. Ravindran, A. Kjekshus, H. Fjellvåg, and B.G. Svensson, Phys. Rev. B 75, 155104 (2007). [2] D. Fritsch, H. Schmidt, M. Grundmann, Appl. Phys. Lett. 88, 124104 (2006), Phys. Rev. B 69, 165204 (2004)

HL 48.79 Thu 15:00 P2

Surface Modification of ZnO-Films as Transparent Conductive Oxide Layer for Silicon Thin Film Solar Cells — •Florian Lükermann[1], Viola Mönkemöller[1], Armin Brechling[1], Marc Sacher[1], Ulrich Heinzmann[1], Henning Kurz[2], Frank Hamelmann[2], and Helmut Stiebig[2] — [1]Molecular and Surface Physics, Bielefeld University, Germany — [2]Malibu GmbH, Bielefeld, Germany

Transparent conductive oxides are used as front electrode in thin film solar cells. Especially ZnO deposited by Low Pressure Chemical Vapor Deposition provides useful features for solar cells. On the one hand ZnO shows a good conductivity and on the other hand a rough surface consisting of pyramidal grains which possess a good light scattering capability.[1]

To influence this light scattering, two different kinds of treatments have been applied on the ZnO surface: etching with diluted HCl and Reactive Ion Etching with Ar and O_2. The main interest is focused on the change of surface morphology and the resulting changes in light scattering and transmission. HCl etching leads to an increasing surface roughness as well as diffuse transmittance. Ar/O_2 bombardment decreases the roughness and thus the scattering. The lowered roughness enhances the growth of the a-Si absorber layer and reduces the formation of pinholes. Finally the properties of amorphous silicon solar cells deposited on treated ZnO-films are compared with those deposited on untreated films.

[1] Addonizio et al., Proc. of the 22nd EPVSEC, 2129 (2007).

HL 48.80 Thu 15:00 P2

Microscopic investigations of the damp-heat degradation of Al-doped ZnO on structured surfaces — •Uli F. Wischnath[1], Thomas Madena[1], and Dieter Greiner[2] — [1]Univ. Oldenburg, Inst. f. Physik, C. v. Ossietzky Str., 26129 Oldenburg — [2]Helmh. Zent. Berlin, Glienicker Str. 100, 14109 Berlin

The conductivities of unencapsulated Al-doped ZnO (ZAO) thinfilm layers on structured surfaces show a strong degradation under damp-heat stress. From earlier investigations [1] it was deduced that extend grain boundaries are the prevalent source of this phenomenon.

The extended grain boundaries are regions where the growth of the ZAO is perturbated due to the underlying microstructure. They have been realized for the current investigations as parallel rectangular ridges. We show here AFM-based investigations of the local potential on the structured ZAO samples. These measurements allow insight into the microscopic processes causing the macroscopic detectable degradation.

[1] Greiner et al., Thin Solid Films, article in press, (2008)

HL 48.81 Thu 15:00 P2

Spectral photoluminescence from semiconductor emitters without temporal and spatial coherence — •Sebastian Wilken, Sebastian Knabe, and Gottfried H. Bauer — Institute of Physics, University of Oldenburg, Germany

Photoluminescence (PL) provides means to determine physical semiconductor properties, such as spectral absorption, defect densities and their respective energy levels, and excess carrier densities which might be expressed in terms of quasi-Fermi levels. However, the luminescence emission from locally sufficiently extended emitters is lacking of temporal as well as of spatial coherence. For the modeling of those pl-photon fluxes which occur e. g. in luminescence photon coupling between tandem solar cell absorbers or in absorbers overcoated by photonic stop gaps we have applied a finite difference time domain algorithm for the photon flux in and around the semiconductor and the Fraunhofer approximation for the far field of the photon flux.

We have numerically reproduced the wavelength dependent local photon fluxes emitted from a x-tal Si waver overcoated with a one-dimensional grid on one surface and compared the numerical results with the experimental pl-fluxes detected versus angle dependence.

HL 48.82 Thu 15:00 P2

Optical and electrical characterisation of InP-based multi-junction solar cells — •Nadine Szabo, Erol Sagol, Christian Höhn, Marinus Kunst, Klaus Schwarzburg, and Thomas Hannappel — Helmholtz Zentrum Berlin, Glienicker Str. 100, 14109 Berlin

Currently, triple-junction solar cells realized from III-V semiconductor compounds hold the solar energy conversion efficiency world record. To improve the efficiency significantly, it is necessary to increase the number of junctions and to involve a subcell with an absorber layer in the band gap range of 1eV. We show on the example of the low band gap tandem cell how the choice of the materials, the quality of the bulk, the optimization of the band gap energies and the preparation of the critical interfaces are essential to build a high efficiency solar cell. A four-junction device can be realized by mechanically stacking of a GaAs-based GaInP/GaAs tandem cell with a InP-based InGaAsP/InGaAs tandem cell. We have grown InGaAsP and InGaAs-layers lattice matched to InP substrates, and investigated the properties of the absorber bulk material. We will present time resolved photoluminescence measurements of low band gap InGaAs and InGaAsP double heterostructures and I-V curves of InGaAs/GaAsSb tunnel junctions. Our results show that the InGaAsP/InGaAs tandem cells reach efficiencies above 10% under GaAs, which is considerably higher than a conventional germanium subcell.

HL 48.83 Thu 15:00 P2

Influence of damp-heat exposure on the electronic properties of Cu(In,Ga)(S,Se)$_2$ thin film solar cells — •Robin Knecht, Martin Knipper, Ingo Riedel, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany

Thin film solar cells made of the chalcopyrite compound semiconductor Cu(In,Ga)(S,Se)$_2$ (CIGSSe) exhibit strong potential for achieving high efficiency at relatively low production costs. Volume production of CIGSSe-modules started in different companies because of their favorable attributes, e.g. low cost and good efficiency.

Environmental stability of the entire solar cell structure is a major issue for the competetiveness of chalcopyrite thin film photovoltaics. In particular long-term stress by heat and humidity could play an important role for the device degradation. We carried out climate stress tests on CIGSSe-solar cells and characterized the samples in situ via current-voltage (dark/illuminated) as well as capacitance-voltage measurements. These measurements were supported by defect spectroscopic techniques in order to investigate the interplay of damp-heat exposure on the extrinsic changes of the electronic properties.

HL 48.84 Thu 15:00 P2

Influence of thermal annealing and light soaking on the electronic properties and device performance of Cu(In,Ga)Se$_2$ thin film solar cells — •David Adelmann[1], Nils Könne[1], Konstantin Kloppstech[1], Janet Neerken[1], Martin Knipper[1], Jürgen Parisi[1], Robert Kniese[2], and Michael Powalla[2] — [1]Energy- and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, D-26111 Oldenburg, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW), Industriestr. 6, D-70565 Stuttgart, Germany

We have investigated the effect of mid-temperature annealing and light soaking on the metastable device performance of Cu(In,Ga)Se$_2$ thin film solar cells. Thermal treatments at 85°C and 165°C as well as exposure to intense broadband photon flux have been carried out under inert gas atmosphere. A variety of identically processed devices have been investigated by measurements of current-voltage, capacitance *voltage and their spectral response. The changes of the device performance as well as of the diode characteristics upon exposure to heat and light are discussed. Moreover, thermal annealing was found to induce a significant shift of the activation energy of electronic defect states as confirmed by impedance spectroscopy. Although these studies are not finished yet we will try to deliver a consistent explanation of our experimental findings.

HL 48.85 Thu 15:00 P2

Characterization of Cu(In,Ga)S$_2$-thin film solar cells with varied gallium concentration — •Stephanie Malek[1], Janet Neerken[1], Martin Knipper[1], Saoussen Merdes[2], Roland Mainz[2], Ingo Riedel[1], and Jürgen Parisi[1] — [1]Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, D-26111 Oldenburg, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Glienicker Straße 100, D-14109 Berlin, Germany

During the last decades interest in thin film solar cells based on chalcopyrite semiconductors (e.g. Cu(In,Ga)(S,Se)$_2$) has steadily increased. Particularly, chalcopyrite compounds exclusively based on sulfides are of interest because of their low cost potential as compared to selenium-containing devices. In this contribution we present recent investigations of Cu(In,Ga)S$_2$ thin film solar cells with varied gallium incorporation in the absorber layer. Doping the absorber with gallium has twofold meaning: moderate gallium concentrations lower the increase of the efficiency by decreasing the band gap energy while high concentrations result in a decrease of the open circuit voltage. We investigate the effects of Ga-doping by admittance spectroscopy and capacity-voltage measurements. These methods were chosen to get information about the local doping concentration and activation energies of the traps.

HL 48.86 Thu 15:00 P2

Lateral Inhomogeneities and Potential Fluctuations in Chalcopyrite Thin-Films and Solar Cells — •Thomas Unold, Markus Wendt, Christina Manclus, Raquel Caballero, Christian Kaufmann, and Hans-Werner Schock — Helmholtz-Zentrum Berlin für Materialien und Energie Gmbh, Berlin, Germany

Polycrystalline chalcopyrite-type semiconductors such as Cu(In,Ga)Se2 show great potential for use in photovoltaic devices with 20% solar conversion efficiency demonstrated for small area thin film devices. These devices exhibit micrometer grain sizes which are of the same order as the film thickness and are found to exhibit significant lateral inhomogenities in their recombination properties. In addition it is found that the highest conversion efficiencies are reached for copper-poor material composition with Cu/III < 0.8, where a large number of defects and compensation is present. We investigate a series of Cu(In,Ga)Se2 thin-film devices with constant gallium content but varying Cu/In+Ga content by temperature-dependent photoluminescence spectroscopy and micro-photoluminencence imaging. We find that the copper-poor samples show much less spatial fluctuations in the recombination properties than the material which is close to stochiometry. The results will be discussed in view of current models of potential fluctuations in chalcopyrite-type thin films.

HL 48.87 Thu 15:00 P2

Molecular beam epitaxy of InN layers on Sapphire, GaN and indium tin oxide — •Christian Denker[1], Boris Landgraf[1], Henning Schuhmann[1], Jaime Segura-Ruiz[2], Maribel Gomez-Gomez[2], Joerg Malindretos[1], Michael Seibt[1], Andres Cantarero[2], and Angela Rizzi[1] — [1]IV.Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [2]Materials Science Institute, University of Valencia, 46980 Paterna (Valencia), Spain

Among the group-III nitrides semiconductors, InN is the one with the narrowest gap (0.67 eV), lowest effective electron mass and highest peak drift velocity. It is therefore a very interesting material for several applications, in particular semiconductor solar cells. Furthermore, the high electron affinity makes it suitable also as electrode material for organic solar cells.

InN layers were grown by molecular beam epitaxy on MOCVD GaN templates, on bare c-plane sapphire and on polycrystalline indium tin oxide. On all substrates the III-V ratio as well as the substrate temperature was varied. A RHEED analysis of InN growth on GaN showed a relatively sharp transition from N-rich and columnar growth to In-rich growth with droplet formation by increasing the In flux impinging on the surface. The InN layers on single crystalline substrates were characterized by SEM, AFM, XRD, PL and Raman. The InN layers on ITO were mainly analyzed with respect to the surface morphology with SEM. HRTEM in cross section gives insight into the structure of the interface to the ITO substrate.

HL 48.88 Thu 15:00 P2

Kelvin probe force and scanning capacitance microscopy on MOS structures — •Christine Baumgart[1], Stefan Jaensch[2], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany) — [2]ElKiDo, v/ Stefan Jaensch, stre Alle 73, DK-6900 Skjern (Danmark)

As the size of semiconductor devices is decreasing permanently, new techniques are required to probe their dopant profile reliably on a nanometer scale. Kelvin probe force microscopy (KPFM) and scanning capacitance microscopy (SCM) are the most promising techniques for this demand. KPFM (LevelAFM from Anfatec) enables the detection of the contact potential difference (CPD) between tip and sample and SCM (DI3100 from Veeco Instruments) probes the capacitance of the metal oxide structures formed in contact. In order to demonstrate the complementary information obtained by KPFM and SCM measurements, we used the pn junction in a static random access memory integrated circuit device where the n-well with a donor concentration of 2*10^{17} cm^{-3} has been fabricated by implanting the p-epi with a nominal acceptor concentration of 2*10^{16} cm^{-3} with P^+ ions of energy 900 keV and a fluence of 1.7*10^{13} cm^{-2} [1]. As expected, KPFM yields a smooth variation of the CPD between the p-epi and the n-well amounting to 230 meV. SCM clearly shows the boxlike doping profile of this pn junction. The CPD variation can be modelled by assuming a partially compensated donor concentration in the n-well. [1] M.W. Nelson et al., Electrochemical and Solid-State Letters 2 (1999) 475.

HL 48.89 Thu 15:00 P2

Work Function and Electron affinity of Some Layered Transition Metal Dichalcogenide Materials — •Mohamed Moustafa, Alexander Paulheim, Michael Niehle, Karl Mildner-Spindler, Christoph Janowitz, and Recardo Manzke — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin.

Work function and electron affinity values of various semiconducting and metallic layered transition metal dichalcogenides (TMDCs) which might be suitable for the photovoltaic applications (such as ZrS_xSe_{2-x} where $0 \leq x \leq 2$, $HfSe_2$, HfS_2, $TiTe_2$, $NbTe_2$, TaS_2) have been measured using photoemission spectroscopy and vibrating capacitor Kelvin probe techniques [1, 2]. All samples were single crystals grown by the chemical vapour transport method with iodine as a transport agent. The measured values are compared to the previously reported empirical and calculated values based on various band models, and proved good agreement for most of the materials.

[1] G. Ertl and J. Küppers, Low Energy Electrons and Surface Chemistry. Verlag. Chemie, Weinheim, (1985).

[2] P.P. Craig and V. Redeka, Rev. Sci. Instrum. 41,(1970).

HL 48.90 Thu 15:00 P2

Electronic contacts to nanostructures by FIB-deposited metals — •Sebastian Thunich, Leonhard Prechtel, and Alexander Holleitner — Technische Universität München, Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

Focused ion beam (FIB) lithography is a field of growing interest, as it allows etching as well as the deposition of insulating and conducting films on a submicron scale. We show that nanostructures, such as carbon nanotubes, can be electronically contacted using ion beam induced deposition (IBID) and we provide a systematic characterization of the obtained deposits. For our work, we used a 30kV Ga^+ FIB system (NVision40, Zeiss) together with tungsten hexacarbonyl [W(CO)6], a common precursor for conductive deposits. Generally, the yield of the presented method strongly depends on several beam and scanning parameters, such as beam current, pixel size and dwell time, as well as substrate composition. For the purpose of electric contacts to nanostructures, a low resistivity and a low contact resistance also to gold electrodes is required. We have found resistivity of tungsten deposits to be $\sim 5\ \Omega\ \mu$m, and the contact resistance to vary between 30 Ω and 100 Ω.

HL 48.91 Thu 15:00 P2

Barrier height measurements of $In_xAl_{1-x}N$ — •Christian Barth, Mareike Trunk, and Daniel M. Schaadt — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

InN - metal contacts show no Schottky barrier due to Fermi level pinning in the conduction band. AlN - metal contacts however form Schottky barriers. By changing the In to Al ratio, the barrier height could be adjusted over a large range. However, it also known that InAlN shows the tendency to demix into InN and AlN and that it is therefore difficult to obtain high quality films. The defects will likely decrease the ideality of the contact. Therefore barrier height measurements require a robust setup which can cope with non ideal diodes. By performing capacitance - voltage measurements at different frequencies, we can obtain the series resistance (spreading resistance) and parallel resistance (due to leakage paths along defects) for non-ideal diodes. Incorporating these parameters in a combined model, reliable barrier height extraction with little temperature dependence is possible. The setup consists of a LCR-meter and a linear power supply which are controlled from a measurement program. This program allows voltage and frequency dependant measurements and directly calculates the barrier height. A verification of this method with measurements on known barrier heights of Au on Si and GaAs as well as results for $In_xAl_{1-x}N$ is presented

HL 49: Quantum dots: preparation and characterization

Time: Friday 10:15–12:45 Location: BEY 81

HL 49.1 Fri 10:15 BEY 81

Growth and characterization of InP quantum dots deposited on InAs seed layer — •Daniel Richter, Robert Rossbach, Wolfang-Michael Schulz, Matthias Reischle, Claus Hermannstädter, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3 70569 Stuttgart, Germany

As current single-photon detectors have their highest photon detection efficiency in the red spectral range it is preferable to fabricate single quantum dots (QD) with luminescence at such wavelengths.

Self assembled InP QDs emitting at around 670nm exhibit high densities up to $1 * 10^{10} cm^{-2}$. For single QD applications this density has to be reduced drastically. To achieve a low density of optical active InP QDs we used low density InAs islands as a seed layer.

We focus on the MOVPE growth of low density InAs quantum dots in the Stranski-Krastanow (SK) growth mode. An extensive characterization has been accomplished. Scanning electron microscopy measurements confirmed a QD density less than $1 * 10^7 cm^{-2}$ and atomic force microscopy was used to measure the height distribution. To complete the characterization optical measurements, like microphotoluminescence (μ-PL) and ensemble PL have been performed. Equipped with the control over the InAs QD growth it is possible to use InAs QD-layers as seeds for the growth of InP QDs with a reduced density. Here we present the influence of the InAs seed layer on the InP QD density and their optical properties.

HL 49.2 Fri 10:30 BEY 81

Growth of InAs Quantum Dots on Silicon substrates: Formation and Characterization — •Tariq Al-Zoubi, Emil-Mihai

Pavelescu, and Johann Peter Reithmaier — Universität Kassel, Technische Physik, Institute of Nanotechnologies and Analytics (INA)

Self-assembled InAs quantum dots (QDs) were grown by solid source molecular beam epitaxy on different Si substrate orientations (100) and (111) using Stranski-Krastanov growth mode. The grown QDs were characterized using atomic force microscopy .The evolution of size and shape of quantum dots with InAs coverage was examined after ex-situ surface preparation (oxide desorption) of the Si wafers with (NH4)HF etchant and in-situ with temperature between 730°C-750°C (pyrometer). Dashed-like InAs dots of high density (9*10 to the 10th cm-2) were observed on (111) orientation compared to circular shaped QDs with a lower density (3.8*10 to the 10th cm-2) on (100) Si orientation. The dot size and density grew with increasing InAs coverage and growth temperature up to 425°C. A narrow dots size distribution was observed for 1.7 ML InAs coverage at a growth temperature of 400°C.

HL 49.3 Fri 10:45 BEY 81

Strain and critical thickness of the 2D→3D transition during GaSb/GaAs quantum dot growth — •Holger Eisele[1,2], Rainer Timm[1], Andrea Lenz[1], Lena Ivanova[1], and Mario Dähne[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenberstr. 36, D-10623 Berlin — [2]The University of Texas at Austin, Austin, TX 78712, USA

While for InAs/GaAs the critical thickness of 2D→3D transition is independent of the growth conditions within a small range of 1.5 – 1.8 monolayer (ML), for the GaSb/GaAs system extremely different values are reported up to now, ranging from about 0.5 ML to 4.0 ML. Therefore, we investigated differently grown GaSb/GaAs samples using cross-sectional scanning tunneling microscopy to study the amount of GaSb material in the wetting layer and the quantum dots. For these samples we found a critical thickness in the range of 1.0 ML to 1.5 ML of accumulated GaSb on the GaAs (001) surface. To support this experimental finding we calculated the strain energies of 1 ML InAs and GaSb on GaAs. Even if the lattice mismatch increases only from 7.2% (for InAs/GaAs) to 7.8% (for GaSb/GaAs), the strain energy is about 34% higher in the latter system due to the differences of the elastic moduli. Assuming similar surface energies for both systems, the critical thickness for the 2D→3D transition gets theoretically reduced by the same factor from about 1.65±0.15 ML for InAs to 1.2±0.1 ML for GaSb on GaAs.

HL 49.4 Fri 11:00 BEY 81

Electric field control of vertically tunnel coupled InP quantum dots — •Elisabeth Koroknay, Wolfgang-Michael Schulz, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Stuttgart, Deutschland

Controllable interactions between coupled quantum dots (QD) are of great interest with regard to quantum information technology. Based on previous research on self organized QD single layers on (Al,Ga)InP barriers the self organized vertical alignment is investigated. The QDs grown by metalorganic vapour phase epitaxy are separated by a spacer layer of the corresponding barrier material. The first QD layer induces a strain field which has influences on the QD growth of the second layer. This influence was investigated by transmission elecron microscopy, atomic force microscopy and photoluminescence measurements. By controlling properly the amount of deposited material, asymmetric QD molecules can be grown, where the high energetic smaller sized QD is located above the low energetic larger sized QD. The electronic coupling between these QDs is achieved by a tunneling process of charge carriers. The influence of the barrier thickness on the tunneling probability can already be seen in ensemble PL measurements. In order to realize controllable interactions between the quantum dot layers, the tunnel coupling is varied by an electric field along the molecule axis. A n-i-schottky structure with the QD molecules in the intrinsic region is used to tilt the overall potential by applying an electric field. In this way the energy levels of the QDs can be tuned in and out of resonance.

HL 49.5 Fri 11:15 BEY 81

Structure of InAs/InGaAsP/InP Quantum Dots/Dashes — •Florian Genz[1], Andrea Lenz[1], Lena Ivanova[1], Rainer Timm[1], Udo W. Pohl[1], Dieter Franke[2], Harald Künzel[2], Holger Eisele[1], and Mario Dähne[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Germany — [2]Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, Germany

Quantum dots or dashes in the InAs/InGaAsP/InP heterostructure system with emission wavelengths matching the absorption minimum of silica fibers (1.55 μm) are promising for semiconductor optical amplifiers for optical data transmission. To improve the device design and the preparation method, a detailed knowledge of the capped nanostructures is of high importance.

The size, shape, and density of InAs/InGaAsP quantum dots/dashes grown by metal organic vapor phase epitaxy were investigated with cross-sectional scanning tunneling microscopy (XSTM). We will present atomically resolved XSTM images of both the $(\bar{1}10)$ and the (110) cleavage surface showing a lateral decomposition of the quaternary InGaAsP matrix which may affect quantum dash development. The evolved nanostructures have lateral sizes of 14 to 33 nm base length along $[\bar{1}10]$ and of 7 to 17 nm along [110] while their heights are about 1.7 nm for the specific growth conditions applied. These structural results will be discussed under consideration of the growth conditions.

This work was supported by Sfb 787 TP A3 and A4 of the DFG.

15 min. break

HL 49.6 Fri 11:45 BEY 81

High and low density quantum dot arrays grown on prepatterned surfaces — •Tino Pfau, Aleksander Gushterov, and Johann-Peter Reithmaier — Technische Physik, INA, Universität Kassel, Heinrich–Plett-Str. 40, 34132 Kassel

Surface templates with nanoscale dimensions are developed for GaAs substrates based on electron beam lithography and wet-chemical etching in order to control the quantum dot position and to reduce the statistical size distribution of the dots in a self-assembled dot formation process. In comparison to dry etching, wet chemical etching avoids crystal damage and defect related non-radiative recombination processes should play a much smaller role. GaAs-templates with a hole density from 10^7 to 10^{10} cm^{-2} were overgrown by InAs to form quantum dots at the hole positions and characterized by scanning electron microscopy(SEM), atomic force microscopy(AFM) and photoluminescence measurements.

HL 49.7 Fri 12:00 BEY 81

Shape of InN quantum dots and nanostructures grown by MOVPE — •S. Ploch[1], Ch. Meissner[1,2], M. Pristovsek[1], and M. Kneissl[1] — [1]TU Berlin, Institut für Festkörperphysik, EW 6-1, Hardenbergstr. 36, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

We report on the shape of InN quantum dots (QDs) grown on GaN/sapphire by MOVPE (metal organic vapour phase epitaxy) investigated by atomic force microscopy (AFM). The InN QDs were grown in a 100 mbar N_2 atmosphere, with a TMIn partial pressure of 0.17 Pa, a V/III ratio of 15,000 and a growth temperature between 480°C and 590 °C for 60 s. X-ray diffraction suggested pure relaxed InN. Only single large nanostructures and a low density are suitable for AFM investigations due to convolution with the AFM tip. Mesa shaped and cone like structures are observed. With increasing growth temperatures the cone type structures prevail. The mean height varies between 15 nm and 40 nm for mesa and 70 nm for conic structures. The mean diameter increases with increasing temperature from 70 nm at 550°C to 230 nm at 590°C for both structure types. The density is $2{\cdot}10^8$/cm^2 over 560°C. The mesa type structures exhibit a hexagonal footprint, the cone's footprint is more distorted. The different structure types have different side facets. For both structures $\{1\bar{1}02\}$ and $\{\bar{1}102\}$ side facets dominate. No preferred facet polarity was observed for any facet. Two different explanations are possible for the different structures basing on a different growth rate caused by dislocations or a polarity inversion.

HL 49.8 Fri 12:15 BEY 81

Volmer-Weber growth of InN quantum dots by MOVPE — •Christian Meissner[1,2], Simon Ploch[1], Markus Pristovsek[1], and Michael Kneissl[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

We have investigated the growth of uncapped InN quantum dots (QDs) on GaN. The indium nitride QDs were grown on GaN/sapphire templates in a horizontal metal-organic vapour phase epitaxy reactor (MOVPE) at 100 mbar in a N_2 atmosphere. At a temperature of 520°C the growth time was varied between 5 s and 60 s. The precursor partial pressures were 0.5 Pa trimetylindium (TMIn) and 2500 Pa

ammonia respectively. The InN material deposition during growth was investigated with in-situ spectroscopic ellipsometry (SE) and ex-situ with atomic force microscopy (AFM) as well as X-ray diffraction (XRD).
A linear increase of the effective layer thickness, i. e. a constant growth rate of InN, was observed. At smallest growth time the surface is covered by only 0.9 ML of InN but still exhibits quantum dots with a density of $7 \cdot 10^{10}\,\mathrm{cm}^{-2}$ indicating Volmer-Weber growth mode. Further growth shows coalescence at a growth time beyond 20 s, with 50 nm in diameter and 4.9 nm high nanostructures. This diameter is consistent with the calculated coalescence diameter of 51 nm for the observed density of $7 \cdot 10^{10}\,\mathrm{cm}^{-2}$.

HL 49.9 Fri 12:30 BEY 81

The role of the spin-orbit interaction on the exchange coupling in lateral coupled quantum dots — •Fabio Baruffa[1], Peter Stano[2], and Jaroslav Fabian[1] — [1]Institute for Theoretical Physics - University of Regensburg — [2]Research Center of Quantum Information - Slovak Academy of Science, Bratislava

Direct exchange in coupled quantum dots is proposed as a means to manipulate spin qubits. In the presence of spin-orbit coupling the exchange is qualitatively changed: the total spin is no longer a good quantum number and chirality of the spins emerges. This is described by a new term in the Hamiltonian, the so called anisotropic exchange (proportional to the vector product of the two spins). We report systematic numerical and analytical calculations of both the direct and anisotropic exchange interactions, for realistic GaAs quantum dots, demonstrating the role of the Bychkov-Rashba and Dresselhaus spin-orbit coupling on the important two-electron interactions.

This work is supported by the GK638.

HL 50: Ultra fast phenomena

Time: Friday 10:15–12:45 Location: BEY 118

HL 50.1 Fri 10:15 BEY 118

Femtosecond Pump-Probe Spectroscopy of ZnO Thin Films — •Sumedha Chouthe[1], Chris Sturm[2], Gerhard Seifert[1], Rüdiger Schmidt-Grund[2], Marius Grundmann[2], and Heinrich Graener[1] — [1]Optics Group, Institute for Physics, Martin-Luther-University Halle-Wittenberg, Hoher Weg 8, D-06129 Halle, Germany — [2]Institute for Experimental Physics-II, University of Leipzig, Linnestraße 5, D-04103 Leipzig, Germany

ZnO being a direct n-type semiconductor with a large energy gap of ˜3.4eV has several applications such as in short wavelength light emitting devices. In this work, the ultrafast carrier dynamics in ZnO film are investigated using femtosecond time resolved transmission pump probe spectroscopy. The ZnO thin film with thickness of 500nm was grown on sapphire substrate by means of pulsed laser deposition. Complete dielectric function of the sample was determined from detailed analysis of ellipsometric and transmission measurements. In the pump-probe set up, frequency doubled Ti:Sa laser pulses at λ=400nm were used as pump (Epump=46μJ, pulse width=150fs) to excite the sample, and femtosecond supercontinuum light (320-560nm) probed the transmission changes in the sample. A complicated time evolution of the spectral changes is observed. Four contributions are needed to understand the time resolved results. Analysis of temporal evolution of different processes allows detailed insight into the electron dynamics in ZnO film initiated by the λ=400nm femtosecond laser pulse.

HL 50.2 Fri 10:30 BEY 118

Terahertz wave emission from an InGaAsN large area emitter — •Falk Peter[1], Stephan Winnerl[1], Harald Schneider[1], Manfred Helm[1], and Klaus Köhler[2] — [1]Forschungszentrum Dresden-Rossendorf — [2]Fraunhofer-Institute for Applied Solid State Physics, Freiburg

We present large-area emitters [1] based on InGaAsN which show efficient THz emission for excitation wavelengths up to 1.35 μm [2]. The substrate material consists of a 1000 nm thick Ga(y)In(1-y)As(1-x)N(x) (y=0.11 and x=0.04) layer grown by molecular-beam epitaxy on semi-insulating GaAs. On top there is an additional GaAs/Al(0.3)Ga(0.7)As heterostructure with thicknesses of 5 nm for the GaAs and 60 nm for the AlGaAs layer, respectively. Transmission measurements with a Fourier spectrometer reveal a bandgap corresponding to a wavelength of 1.5 μm. The resistance of a complete device with an active area of 1 mm˜2 is 0.3 MΩ. For excitation an optical parametric oscillator (OPO), tunable between 1.1 μm and 1.5 μm, is used. The THz signal is detected using electro-optical sampling with ZnTe crystal. The gating beam ($\lambda = 820$ nm) for detection is split off from a Ti:sapphire oscillator which pumps the OPO. In contrast to conventional dipole antennas no saturation was observed within the available range of average power (up to 50 mW).

[1] A. Dreyhaupt, et al., Appl. Phys. Lett. 86, 121114 (2005).
[2] F. Peter et al., Appl. Phys. Lett. 93, 101102 (2008).

HL 50.3 Fri 10:45 BEY 118

All-optically induced ultrafast currents in GaAs quantum wells: Excitonic effects and dependence on quantum well width — •Shekhar Priyadarshi[1], Ana Maria Racu[1], Klaus Pierz[1], Uwe Siegner[1], Mark Bieler[1], and Philip Dawson[2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany — [2]School of Physics and Astronomy, University of Manchester, Manchester, M60 1QD, England

We have studied the influence of excitonic effects on ultrafast current transients that are induced in unbiased GaAs quantum wells by all-optical excitation. The ultrafast current transients result from second-order nonlinear optical effects and were detected by measuring the simultaneously emitted THz radiation. Experiments were performed on (110)-oriented GaAs/AlGaAs quantum well samples with different well widths and with 150 fs excitation laser pulses at room temperature. By studying the dependence of the current amplitude and phase on excitation photon energy in the different samples, we find that Coulomb effects and the quantum well width substantially affect the properties of these ultrafast currents. This becomes most prominently visible when exciting light-hole exciton transitions. The phase data shows that for excitation of light-hole-type transitions a current reversal occurs as compared to excitation of heavy-hole-type transitions. The amplitude dependence of the current transients on excitation photon energy is influenced by the reversed current contribution from heavy- and light-hole-type transitions, the complex bandstructure, and non-instantaneous effects contributing to the current dynamics.

HL 50.4 Fri 11:00 BEY 118

Quantum dynamical study of the amplitude collapse and revival of coherent A1g phonons in bismuth: A classical phenomenon? — •Momar S. Diakhate, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretische Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany.

We parametrize the potential energy surface of bismuth after intense laser excitation using accurate full-potential linearized augmented plane wave calculations.Anharmonic contributions up to the fifth power in the A1g phonon coordinate are given as a function of the absorbed laser energy. Using a previously described model including effects of electron-phonon coupling and carrier diffusion [S. L. Johnson et al.: Phys.Rev. Lett. 100, 155501 (2008)] we obtain the time-dependent potential energy surface for any given laser pulse shape and duration. On the basis of this parametrization we perform quantum dynamical simulations to study the experimentally observed amplitude collapse and revival of coherent A1g phonons in bismuth [O. V. Misochko et al.: Phys.Rev. Lett. 92, 197401 (2004)]. Our results strongly indicate that the observed beatings are not related to quantum effects and are most probably of classical origin.

HL 50.5 Fri 11:15 BEY 118

Elektromagnetisch induzierte Transparenz (EIT) im Intersubbandsystem von Halbleiter Quantum Well (QW) Strukturen — Stefan Hanna[1], •Boris Eichenberg[1], Alois Seilmeier[1], Leonid E. Vorobjev[2], Vadim Yu Panevin[2], Dmitry A. Firsov[2], Vadim A. Shalygin[2], Victor M. Ustinov[3] und Alexey E. Zhukov[3] — [1]Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Deutschland — [2]St. Petersburg State Polytechnic University, St. Petersburg 195251, Russia — [3]Ioffe Physico-Technical Institute, St. Petersburg 194021, Russia

Die Untersuchung von Quanteninterferenzen, wie zum Beispiel EIT, in Festkörpern ist wegen der hier im ps Bereich liegenden Phasenrelaxationszeiten sehr schwierig und bisher nur in Ansätzen gelungen. Als geeignetes System für solche Untersuchungen erweisen sich Intersubband-Übergänge in QWs, da wegen ihres großen Dipolmoments μ die Rabi Frequenzen $\Omega = \mu E/\hbar$ groß genug sind, um mit Intensitäten im MW Bereich kohärente Licht-Materie-Wechselwirkung beobachten zu können. In diesem Beitrag werden experimentelle Ergebnisse zur EIT an einer n-dotierten, asymmetrischen GaAs/AlGaAs QW Probe mit einem drei Niveau Kaskade-System im mittleren Infraroten (MIR) vorgestellt. Koppelt man bei tiefen Temperaturen (T≈20K) die unbesetzten elektronischen Niveaus e_2-e_3, durch einen intensiven ps MIR Pumpimpuls der Wellenlänge λ=10μm, so lässt sich eine deutlich ausgeprägte Transmissionserhöhung des e_1-e_2 Übergangs um etwa 50% nachweisen. Zeit- und frequenzaufgelöste Messungen werden präsentiert und eingehend diskutiert.

15 min. break

HL 50.6 Fri 11:45 BEY 118

Electronic dynamics of semiconductors irradiated with an ultrashort VUV laser pulse — •Nikita Medvedev and Baerbel Rethfeld — Technical University of Kaiserslautern, Erwin Schroedinger Str. 46, 67663 Kaiserslautern, Germany

We investigate theoretically the interaction of an ultrashort high-intensity VUV laser pulses produced in a new light source FLASH (at DESY in Hamburg) with semiconductors. In our contribution we present numerical simulations of excitations of electronic subsystem within a solid silicon target, irradiated with femtosecond laser pulse (total duration of 25 fs, and photon energy $\hbar\omega$ = 38 eV). The Monte Carlo method (ATMC) was extended in order to take into account the electronic band structure and Pauli's principle for electrons excited into the conduction band. Secondary excitation and ionization processes were included and simulated event by event as well.

In the presented work, the temporal distribution of the density of free electrons, the energy of these excited electrons and their energy distribution function were calculated. It is demonstrated that due to the fact that part of the energy is spent to overcome ionization potentials, the final kinetic energy of free electrons at the moment of 25 fs is much less than the total energy provided by the laser pulse. We introduce the concept of an 'effective band gap' for collective electronic excitation, which can be applied to estimate the free electron density after high-intensity VUV laser pulse as an expression: $n_e = \hbar\omega/E_{\rm gap}^{eff}$. Effective band gap depends on properties of material as well as on laser pulse.

HL 50.7 Fri 12:00 BEY 118

High-harmonic generation by a driven mesoscopic ring with a localized impurity — Nicki Hinsche, •Andrey Moskalenko, and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

We investigate theoretically a single-channel semiconductor mesoscopic ring with a localized impurity subjected to half-cycle electromagnetic pulses. We show that the presence of an impurity strongly influences the induced time-dependent charge polarization and for strong excitations leads to the generation of higher harmonics in the terahertz range of the emitted light spectrum.

HL 50.8 Fri 12:15 BEY 118

Nonlinear THz spectroscopy of excitons in optically excited semiconductors — •Johannes T. Steiner, Mackillo Kira, and Stephan W. Koch — Fachbereich Physik, Philipps-Universität, Renthof 5, D-35032 Marburg

We theoretically investigate the interaction of optically-excited semiconductors with strong coherent terahertz (THz) pulses using a fully microscopic many-body theory. In contrast to optical fields, THz fields are resonant with *intra*band transitions and can directly induce internal transitions of the optically-excited quasi-particles [1]. In the past, time-resolved linear THz spectroscopy has been used, e.g., to monitor the build-up of exciton populations. In my talk, I will concentrate on situations where a strong THz pulse induces nonlinear transitions between different exciton states, e.g., between the 1s and 2p exciton states. The THz pulse can interact either with *coherent* excitons, i.e., interband polarization which decays within a few picoseconds after optical excitation or with *incoherent* excitons, i.e., genuinely bound electron-hole pairs. I will discuss the signatures of THz-induced nonlinearities which include Rabi oscillations, ponderomotive effects and extreme-nonlinear dynamics. The nonlinear THz regime is distinguished by the fact that three characteristic energies – the 1s-to-2p transition energy, the Rabi energy and the ponderomotive energy – are of the same order of magnitude. The theory is quantitatively compared to recent experiments in different material systems.
[1] M. Kira and S. W. Koch, Prog. Quantum Electron. **30,** 155 (2006)

HL 50.9 Fri 12:30 BEY 118

First principles molecular dynamics simulations of ultrafast events — •Eeuwe Zijlstra, Alan Kalitsov, Nils Huntemann, and Martin Garcia — Theoretische Physik, Universität Kassel, Kassel, Deutschland

We develop a new computer program (BORON), with which we perform molecular dynamics simulations of large systems based on density functional theory in order to capture the full complexity of laser-induced ultrafast events in a variety of materials. In this presentation, we provide an overview of the present state of this project. Apart from discussing the various approximations that hold the potential to make the code faster, we also discuss our recent work on small efficient basis sets [Modelling Simul. Mater. Eng. (accepted)] that we optimized to be used in combination with accurate, analytical pseudopotentials. We also present a first application of BORON.

HL 51: Photonic crystals II

Time: Friday 10:15–12:45 Location: BEY 154

HL 51.1 Fri 10:15 BEY 154

Thermal emission properties of 2D and 3D silicon photonic crystals — •Benjamin Gesemann, Stefan Schweizer, and Ralf B. Wehrspohn — Martin Luther Universität Halle-Wittenberg

We present measurements of the thermal emission properties of electrochemically etched 2D and 3D silicon photonic crystals heated resistively with and without substrate. The Out-of-plane emission properties were recorded and compared to numerical simulation.

HL 51.2 Fri 10:30 BEY 154

Efficient Calculation of the Optical Properties of Stacked Metamaterials in a Fourier Modal Approach — •Thomas Weiss[1,2], Nikolay Gippius[2,3], Sergei Tikhodeev[3], and Harald Giessen[1] — [1]4th Physics Institute, Stuttgart, Germany — [2]LASMEA, Clermont-Ferrand, France — [3]General Physics Institute, Moscow, Russia

Metallic photonic crystals and metamaterials provide features such as band gaps, negative refractive indices, chirality, and polarization effects that can lead to a number of applications. Nowadays, the theoretical description of these structures is based on simple models as well as numerical methods such as FDTD (finite difference time domain) and FMM (Fourier-modal method).

We are going to present efficient techniques such as adaptive spatial resolution [1] and factorization rules [2] to overcome the restrictions in a Fourier-modal S-matrix (scattering matrix) approach [3] caused by the jump discontinuities in the permittivity function. Thus, we can calculate the spectra, eigenmodes, and near-field distributions of two- and three-dimensional metallic photonic crystals and metamaterials with a high accuracy. In addition, we will show that the scattering matrix provides an easy way to derive ellipticity and Stokes parameters. This allows us to study the polarization effects of stacked and rotated structures such as split ring resonators.

[1] G. Granet, J. Opt. Soc. Am. A 16, 2510 (1999).
[2] L. Li, J. Opt. Soc. Am. A 13, 1870 (1996).
[3] D. M. Whittaker and I. S. Culshaw, Phys. Rev. B 60, 2610 (1999).

HL 51.3 Fri 10:45 BEY 154

Tailoring the second-order nonlinear optical properties of

silicon by application of inhomogeneous strain — •Clemens Schriever, Daniel Pergande, and Ralf B. Wehrspohn — Institut für Physik, Universität Halle-Wittenberg, Halle, Germany

Silicon has become a promising candidate for integrated optics mainly due to its highly optimized CMOS processing technology and its suitable optical properties at telecommunication wavelengths. The difficulty of integrating silicon into active optoelectronics, where electrical and optical functionalities are combined in a monolithic device, is due to its limited active optical properties. Because of the materials centrosymmetric lattice structure silicon does not exhibit a second-order nonlinear susceptibility and is therefore not suitable for higher-order non-linear optical processes. One possibility to overcome this limitation is to break the centrosymmetry of the atomic lattice. We present first numerical studies and analytical approximations on how inhomogeneous strain can be used to create non-linear optical properties. The variation of magnitude and direction of the applied strain using realistic values of e.g. highly strained SiN-layers allows tailoring the nonlinear optical properties of a silicon photonic device.

HL 51.4 Fri 11:00 BEY 154

Photonic crystal cavities with embedded site-controlled quantum dots — •Martin Kamp, Thomas Sünner, Benedikt Friess, Christian Schneider, Micha Strauss, Alexander Huggenberger, Daniel Wiener, Sven Höfling, and Alfred Forchel — Technisch Physik, Am Hubland, 97074 Würzburg

Photonic crystal (PhC) cavities with embedded quantum dots (QDs) have become an attractive model system for the study of cavity quantum electrodynamics (CQED). In order to maximize the coupling between the cavity and a quantum dot, the emission of the latter has to match the resonance wavelength of the cavity. Furthermore, the dot should be located at the maximum of the localized optical mode. We present a scalable method that allows the fabrication of site-controlled quantum dots embedded in photonic crystal cavities, thus addressing this issue of spatial alignment. First, a set of markers is defined on a GaAs sample, followed by patterning of an array of nano-holes which serve as nucleating centers for the growth of InGaAs QDs. After the epitaxy, membranes with PhC cavities are fabricated. The array of nano-holes and the cavities are both aligned to the markers, resulting in an overlay accuracy of better than 50 nm. Charaterization of the structures was performed by low temperature photoluminescence. The spectra show sharp emission lines, which can be attribued to individual quantum dots and the cavity. An enhancement of the spontaneous emission was observed when the dot was brought in resonance with the cavity by temperature tuning.

HL 51.5 Fri 11:15 BEY 154

Hydrogensensor based on a metallic photonic crystal — •Cornelius Grossmann, Todd P. Meyrath, and Harald Giessen — 4. Physics Institute, University of Stuttgart, Germany

Hydrogen has gained substantial amount of interest in recent years and it is considered to be a future carrier of energy. However, hydrogen can mix and ignite with air in a wide concentration range and surveillance is necessary.

Here, we present an optical hydrogen sensor based on a metallic photonic crystal. Our sample consists of a WO3 waveguide layer and metallic nanowires on top. The nanostructuring is done with interference lithography. Due to incorporation of atomic hydrogen into the crystal lattice structure of WO3, the optical properties of the waveguide-plasmon polariton resonance change in presence of hydrogen. The sharpness of the plasmonic resonance increases the accuracy of our sensor significantly in comparison to a bare WO3 layer.

We present the detection mechanism as well as temperature- and time-dependent measurement results. Advantages and disadvantages over the conventional hydrogen sensors are pointed out and the development towards an all-optical hydrogen sensor with full seperation of detection electronics and measurment optics will be shown as well.

15 min. break

HL 51.6 Fri 11:45 BEY 154

Nonlinear Optical Spectroscopy of Metamaterials — •Mathieu Gentile[1], Mario Hentschel[1], Hongcang Guo[2], Harald Giessen[2], and Manfred Fiebig[1] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Germany

Optical metamaterials recently gained considerable attention since they offer genuinely new optical properties with possible negative value for effective electric permittivity, ε, and magnetic permeability, μ.

We measure the first-ever second harmonic generation (SHG) spectra of ⊔-shaped gold structure arrays on a glass substrate. Using a 130 fs OPA-tunable laser source the spectral response was measured in the SHG range from 1.64 eV to 3.00 eV.

Measurements are in perfect agreement with tensor components allowed by sample symmetry. The linear reflection spectrum of these structures displays a resonance for photon energies around 0.83 eV. In contrast, SHG spectra reveal resonances at different photon energies that are determined by the actual geometry of the metamaterial "atoms" while the linear optical properties of the metamaterial and the spectral characteristics of the gold are of minor significance.

HL 51.7 Fri 12:00 BEY 154

Reversed GaAs pyramids as new optical micro-cavities based on total internal reflection — •Daniel Rülke[1], Matthias Karl[1], Dongzhi Hu[1], Daniel M. Schaadt[1], Benjamin Kettner[2], Sven Burger[2], Frank Schmidt[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Zuse Institut Berlin (ZIB), 14195 Berlin, Germany

We investigate the potential of GaAs pyramids standing upside down as a new type of optical micro-cavity based on total internal reflection. The latter are fabricated from molecular-beam epitaxy grown structures utilizing a combination of electron-beam lithography and wet-chemical etching, taking advantage of an AlAs sacrificial layer. Among other things, this approach allows us to realize coupled reversed pyramids or their electrical contacting via small bridges. In the pyramids we place In(Ga)As quantum dot layers as internal light source which emit in the range from 900 to 1050 nm after laser excitation. We identify optical modes in the cavities by their thermal behavior and map their spatial distribution for a better characterization. Due to their easily tunable geometrical dimensions reversed pyramidal resonators can access the intermediate regime between conventional and whispering-gallery-like mode behavior. Therefore, they should be promising candidates to enhance light matter interaction.

HL 51.8 Fri 12:15 BEY 154

Local Infiltration of Individual Pores with Dyes in Macroporous Silicon Photonic Crystals — •Peter W. Nolte[1], Stefan L. Schweizer[1], Daniel Pergande[1], Ralf B. Wehrspohn[1,3], Markus Geuss[2], Martin Steinhart[2], and Roland Salzer[3] — [1]Institut für Physik, Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Fraunhofer-Institut für Werkstoffmechanik, Halle, Germany

Photonic crystals (PhC) are promising candidates for novel optical components. Passive devices realized with PhC, e.g. complex waveguides, are widely known. However, for many applications active devices are required. One possible way to realize such devices is the functionalization of 2D PhC. This can be done by combining 2D PhC with dyes. We present an experimental technique for the infiltration of individual pores which allows the realization of a broad spectrum of different device designs. For the infiltration of individual pores we use 2D PhC templates made of macroporous silicon, electron beam physical vapor deposition, focused ion beam technique, electrochemical deposition and the wetting assisted templating (WASTE)-process.

HL 51.9 Fri 12:30 BEY 154

Thermal Emission in Photonic Crystals — •Christian Schuler[1], Marian Florescu[2], Christian Wolff[1,3,4], Sabine Essig[1,3,4], Thomas Zebrowski[1,4], and Kurt Busch[1,3,4] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Department of Physics, Princeton University — [3]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [4]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

Photonic crystals (PCs) exhibit great potential for technological applications that are based on the conversion from energy to light, for example energy-efficient light sources or improved devices for thermophotovoltaics. We analyze the spectral and angular dependence of the thermal radiation emitted from a semi-infinite two-dimensional PC into free space. The emitted light originates from thermally excited Bloch modes, which are obtained from the PC's complex bandstructure. The Bloch modes are coupled to the free space plane waves by a scattering matrix approach. Our results are in good agreement with Kirchhoff's law of thermal radiation and obey the black body limit.

HL 52: Organic semiconductors II

Time: Friday 10:15–12:30 Location: POT 51

HL 52.1 Fri 10:15 POT 51

Influence of electrical stress on hole transport in Poly(p-phenylenevinylene) — •Katja Stegmaier, Arne Fleissner, Christian Melzer, and Heinz von Seggern — Electronic Materials Department, Institute of Materials Science, TU Darmstadt, Petersenstraße 23, 64287 Darmstadt, Germany

One of the most prominent class of materials used as organic luminescent layer in large-area applications are derivatives of Poly(p-phenylenevinylene) (PPV). Organic light-emitting diodes (OLEDs) comprising such a polymeric semiconductor still disclose a degradation of the device performance under device operation limiting its applicability. Up to now, the processes taking place during this electrical fatigue are not fully understood. Different approaches to explain the increase of impedance and the loss of luminescence have been proposed.

For the first time the influence of electrical fatigue on the hole transport properties of different derivatives of PPV is investigated on bipolar PPV-based test structures similar to real OLED devices by the optical time-of-flight (TOF) technique. The utilized PPV layer thicknesses are in the order of microns and therewith considerably thicker than those of conventional OLEDs. TOF measurements on these structures before and after electrical treatment reveal a pronounced difference in hole transport. Due to electrical stressing under constant current hole transport becomes dispersive and hole mobility is reduced. The method of thermally stimulated currents (TSC) is employed to determine the trap structure in order to clarify the reasons for the variation in hole transport of the electrically fatigued OLEDs.

HL 52.2 Fri 10:30 POT 51

Growth and Morphology of Three Dimensional Rubrene Single Crystals — •Mira El Helou[1,2], Olaf Medenbach[3], and Gregor Witte[1,2] — [1]Molekulare Festkörperphysik, Philipps-Universität Marburg, Germany — [2]Physikalische Chemie I, Ruhr-Universität Bochum, Ger — [3]Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Germany

In the fast growing field of organic electronics, organic field effect transistors (OFETs) have become a focus of intense research due to their promising potential in flexible electronics, low-cost devices and large-area applications. Among organic semiconductors the highest room temperature charge carrier mobility has been reported for rubrene crystals (Sundar et al. 2004). So far essentially crystalline platelets of a few microns thickness and (001) orientation were grown (de Boer et al. 2004) while the growth of thicker single crystals became a challenge, due to the conformational change from gas into bulk phase but can be overcome by employing hot wall type deposition (Käfer et al. 2005). Here we report a detailed morphological characterization of bulk crystallites with lateral dimensions of up to 150*m. By using SEM and AFM the equilibrium structure and the topography including the step height of the differently oriented surfaces have been analyzed in detail. The availability of such oriented crystallites allows in particular a precise characterization of optoelectronic properties along different crystallographic directions. As a stating point the refractive indices of the three main crystallographic directions a, b and c at wavelength of 589 nm have been determined.

HL 52.3 Fri 10:45 POT 51

Electroluminescence from Single Molecules — •Maximilian Nothaft[1], Aurélien Nicolet[1], Fedor Jelezko[1], Jens Pflaum[2], and Jörg Wrachtrup[1] — [1]3. Phys. Inst., Univ. Stuttgart, D-70550 Stuttgart — [2]Exp. Phys. VI, Univ. Wuerzburg and ZAE Bayern, D-97074 Wuerzburg

Doping of organic host matrices by guest molecules is widely applied in organic light emitting devices to improve their efficiency. Especially in single molecule spectroscopy the individual guest molecules serve as a tool to investigate single quantum emitters for possible application in quantum cryptography.

In our contribution we discuss light emission properties of individual Dibenzoterrylene (DBT) dye molecules inserted into an Anthracene (AC) host crystal at relative concentrations in the order of 10^{-8} mol/mol driven by optical and electronic stimulation.

It will be shown that this system offers key requirements to observe electrically excited single molecules at room temperature such as the possibility to obtain balanced current densities of up to 100mA/cm^2 and single photon emission from the dye (DBT) using laser excitation of 710nm.

The electroluminescence signal was investigated using confocal microscopy and will be compared to images obtained using laser excitation. The detected light was spectrally resolved showing distinct emission peaks of the host and the dye. To quantify the respective emission behavior, photon correlation measurements under optical as well as electrical excitation will be presented.

HL 52.4 Fri 11:00 POT 51

The influence of field- and density- dependent mobility and contact properties on OFETs — •Susanne Scheinert[1] and Gernot Paasch[2] — [1]TU Ilmenau, Germany — [2]IFW Dresden, Germany

The current characteristics of organic field-effect transistors (OFET) show often a disadvantageous non-linearity at low drain voltages. We have already proved (J. Appl. Phys. 102, 054509 (2007)) that in top contact OFETs this effect can be caused by trap recharging, if the contacts are of Schottky type. For bottom contact OFETs, in spite of controversial discussions, the effect is repeatedly attributed to Schottky contacts. We show that such non-linearity does occur in bottom contact OFETs only in the special case with a Schottky contact with large ideality factor as drain and an Ohmic contact at source. However, if the dependence of the mobility on carrier concentration and field is taken into account, Schottky contacts at both source and drain can cause the non-linearity. The effect has been investigated by numerical 2D-simulations incorporating for the mobility the field dependent Pool/Frenkel model and two models, which in addition depend on the carrier concentration, the Limketai model and the Pasveer/Coehoorn model. Analysis of the simulated profiles of concentrations and fields allows us to clarify the mechanism causing the non-linearity, which is particularly effective for the Pasveer/Coehoorn model. Based on the achieved understanding of the mechanism, we discuss strategies to prevent the non-linearity.

15 min. break

HL 52.5 Fri 11:30 POT 51

Ambipolar organic/inorganic field effect transistor — •Maria S Hammer[1], Daniel Rauh[2], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

In order to attain flexible electronic devices, the fabrication of complementary metal-oxide-semiconductor inverters based on soluble semiconductors offers an attractive potential for realizing printable logic circuits. One approach is an organic/inorganic bulk heterojunction system. Using an inorganic material offers the possibility of setting up its transport properties namely mobility, conductivity and charge carrier density via doping and adjusting it to an optimum for the combined performance with the organic material. Therefore we chose aluminium doped zinc oxide nanoparticles as the *n*-type and rr-poly(3-hexylthiophene) (P3HT) as the *p*-type component. Our field effect transistor measurements on the pristine and blended materials allow the determination of charge carrier mobility in dependence of the accumulated charge carrier densities and temperature. We survey the properties of the transport in disordered systems, organic and inorganic, with respect to the morphology of the film. We show that by doping zinc oxide nanoparticles it is possible to adjust a balanced electron and hole transport in the hybrid material which is indispensable for the performance of an ambipolar transistor.

HL 52.6 Fri 11:45 POT 51

Prediction of Dynamical Properties of Organic Field-Effect Transistors from DC Transistor Parameters — •Benedikt Gburek and Veit Wagner — Jacobs University Bremen, School of Engineering and Science, Campus Ring 1, 28759 Bremen, Germany

Dynamical properties of Organic Field-Effect Transistors (OFETs) are of crucial importance for almost any application. However, not direct AC data but DC measurements are usually used to optimize transistor performance. Here we present a systematic study to which extent DC parameters can actually be used to predict AC performance and AC

limits of transistors. The standard FET theory for long channel devices predicts a maximum device bandwidth of $\omega_B = \mu$ V / L^2. However, this holds only for ideal situations, e.g. without parasitic capacitances, and not too high frequencies. Furthermore, as was recently shown [1], contact resistances can pose severe additional high-frequency limits to the AC performance. To check the AC limit of a given transistor directly we perform a frequency scan up to the frequency where the gate current equals the drain current, which defines the true bandwidth of the device. The frequency-scanned AC voltage is applied at the gate while the drain contact is kept at a constant voltage. A model which defines a correction factor to the ideal μ V / L^2 behaviour is proposed in order to predict the measured bandwidth from DC transistor parameters correctly. The model takes into account contact resistances and parasitic capacitances among others.

[1] V. Wagner, P. Wöbkenberg, A. Hoppe, J. Seekamp, Appl. Phys. Lett. 89 (2006) 243515

HL 52.7 Fri 12:00 POT 51

Trapped-space-charge-limited currents: Evaluating analytical approximations by simulation — •Gernot Paasch[1] and Susanne Scheinert[2] — [1]IFW Dresden, Germany — [2]TU Ilmenau, Germany

The well-known analytical approximations for trapped-space-charge-limited currents are widely used in analyzing organic diodes. However, within these approximations, it is not possible to check the validity of the assumptions made in the derivation of the approximations. Besides the neglect of the diffusion current, this concerns especially the relations of the contact work function and of the layer thickness with the doping of the organic semiconductor, the position of the center of the trap distribution and its maximum value, and in the case of a Gaussian trap distribution the approximation for the density of the trapped charge. We present results of full numerical simulations (drift-diffusion model) for a wide range of parameter variation together with the application of the analytical approximations to fit the simulations. From this comparison one can set limits for the parameter ranges in which the approximations can be applied. This is important since other effects can also lead to similar power laws of the current voltage characteristics. In addition, further analytical approximations will be discussed for different combinations of trap distributions and distributions of hopping transport states.

HL 52.8 Fri 12:15 POT 51

Unified Theory of Charge Transport in Wide-Band and Narrow-Band Semiconductors — •Frank Ortmann, Friedhelm Bechstedt, and Karsten Hannewald — IFTO & ETSF, Friedrich-Schiller-Universität Jena, Jena, Germany

The charge carrier mobility is often calculated within one of the two limiting cases: wide bands or narrow bands. In the case of wide-band systems, usually pure band transport is assumed along with a calculated relaxation time. In contrast, for narrow-band materials, hopping is usually considered prevalent and the interaction with lattice vibrations is described within the polaron concept. In this talk, we will present a unified approach to the description of charge transport based upon the Kubo formalism applied to a Holstein Hamiltonian. As a result, we obtain an analytical formula for the temperature dependence and anisotropy of the mobility describing a seamless transition from band transport at low temperatures to hopping transport at high temperatures. The results are illustrated for naphthalene crystals and a comparison to previous approaches [1,2] is made. [1] V.M. Kenkre, Phys. Lett. A 305, 443 (2002) [2] K. Hannewald and P.A. Bobbert, Phys. Rev. B 69, 075212 (2004)

HL 53: Transport properties

Time: Friday 10:15–11:45 Location: POT 151

HL 53.1 Fri 10:15 POT 151

Electronic properties of crystalline phase change materials — •Michael Woda, Peter Jost, Stephan Kremers, Philipp Merkelbach, Theo Siegrist, and Matthias Wuttig — I. Physikalisches Institut (1A), RWTH Aachen, 52056 Aachen, Germany

In phase change materials (PCM) the pronounced contrast between the amorphous and crystalline state in form of optical and electrical properties is combined with a fast phase transition on a ns timescale. This combination opens the possibility of memory applications. PCM are already employed in rewritable optical data storage and are used for the Phase change RAM (PCRAM). This is a promising candidate to become the next generation non-volatile solid state electronic memory. In PCRAMs it is important to have stable and well defined resistance levels. Here we present a comparative study of different PCM alloys in order to determine the origin of different crystalline resistivities upon thermal annealing, which seem not to be governed by grain properties. We investigate different degrees of crystallinity with various techniques including van der Pauw, Hall, ellipsometry, FTIR and XRD measurements.

HL 53.2 Fri 10:30 POT 151

A time dependent approach to obtain transmission coefficients of multi-terminal devices — •Christoph Kreisbeck[1], Viktor Krückl[1], and Tobias Kramer[1,2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We are interested in transport behavior of semiconductor nanostructures, where we particularly focus on multi-terminal devices. The conductivity through these devices can be described theoretically within the Landauer-Büttiker formalism, which connects conductance-voltage characteristics with scattering matrices. To obtain the latter we introduce a time dependent approach, which proves to be a very efficient way to calculate transmission coefficients numerically. Moreover this method can go beyond Landauer-Büttiger. This means that we do not have to restrict ourself to asymptotic channels anymore, but we can study localised electron sources as well.

HL 53.3 Fri 10:45 POT 151

Tuning of decoupled graphene layers by front and backgate — •Thomas Lüdtke, Hennrik Schmidt, Patrick Barthold, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover

We present transport measurements through a heterojunction of decoupled layers of graphene as a function of backgate and topgate voltage as well as magnetic field at temperatures down to 300mK [1]. Folded monolayers on a SiO2 substrate are structured and contacted by using electron beam lithography. A PMMA layer is deposited onto the structured part to be able to fabricate an additional local gate afterwards.

In a four terminal measurement the resistance of the device was obtained by tuning the potential of the backgate and the topgate independently. Charge neutrality points of both regions are clearly visible, separating the different charge configurations (e.g. p-n-p, n-n-n) of the graphene field effect transistor. The magnetic field dependence of the localy gated sample shows four different oscillations in the Shubnikov-de Haas (SdH) measurement. Two of these oscillations are dependent on the potential of the applied backgate, whereas the other two oscillations changes when tuning the local topgate. Calculations of the carrier concentrations from SdH measurements as well as a Berry phase of Pi shows the existence of two decoupled monolayers of graphene that can be tuned by gates independently.

[1] H. Schmidt, T. Lüdtke, P. Barthold, E. McCann, V. I. Fal'ko, and R. J. Haug; Appl. Phys. Lett. 93, 172108 (2008)

HL 53.4 Fri 11:00 POT 151

A tunable self-switching in-plane diode in a 2D-system — •Simone Vossen[1], Arkadius Ganczarczyk[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimental Physics and CeNIDE, Universität Duisburg-Essen — [2]Solid State Physics, Ruhr-Universität Bochum

Patterning on the nanometer scale enables to produce devices with new functionalities that are mainly given by the sample geometry. We fabricated a device geometry in a two-dimensional electron gas (2DEG) that uses the so-called self-switching effect to realize a tunable diode-like structure [1]. The sample consists of a 400nm wide channel in a

2DEG confined by etched insulating trenches. An asymmetric potential profile causes the self-switching effect. The working principle is based on lateral pinch off, which modulates the width of the depletion zones of the narrow etched channel. Depending on the direction of the applied voltage along the channel, the channel opens or closes, resulting in diode-like behavior.

The tunability of the self-switching device (SSD) is achieved by two in-plane side gates, which modulate the depletion zones of the electron channel. We are able to tune the characteristics of the SSD for instance the on-voltage of the diode from 0 V up to 0.7 V in comparison to the fixed on-voltage of a standard p-n diode.

Additionally we examine the frequency operations of the SSD and analyze its behavior in a magnetic field.

[1] A.M. Song, M. Missous, P. Omling, A.R. Peaker, L. Samuelson, and W. Seifert, Appl. Phys. Lett. 83, 1881-1883 (2003)

HL 53.5 Fri 11:15 POT 151

Nonlinear mesoscopic transport in asymmetric quantum wires — •Bettina Brandenstein-Köth, Lukas Worschech, Stefan Lang, Jan Heinrich, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, 97074 Würzburg

The nonlinear transport of asymmetric quantum wires has been studied under the influence of an external magnetic field. The investigated structures were based on a modulation doped GaAs/AlGaAs heterostructures with a two-dimensional electron gas approximately 80nm below the surface. The inplane asymmetry of the quantum wire was realized by two different side walls, one defined via an etched channel and the other by a metal-surface depletion gate. Magnetic fields were applied perpendicular to the sample surface. The conductance of the quantum wires was studied at a temperature of 4.2K. It was found that such asymmetric quantum wires show a pronounced magnetic-field asymmetry, defined as the change in the conductance induced by a change in the magnetic-field sign. The asymmetric conductance increases linearly with the bias voltage up to several hundred millivolts. We explain our findings by a recently proposed magnetic-field asymmetry of nonlinear mesoscopic transport.[1]

[1] D. Sánchez and M. Büttiker, Phys. Rev. Lett. 93, 106802 (2004); B. Spivak and A. Zyuzin, Phys. Rev. Lett. 93, 226801 (2004).

HL 53.6 Fri 11:30 POT 151

Tunable Graphene System with Two Decoupled Monolayers — •Hennrik Schmidt, Thomas Lüdtke, Patrick Barthold, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

Atomically thin sheets of carbon, graphene, can be used as current-carrying components in field-effect transistors. Using micromechanical cleavage of natural graphite, flakes of different thickness are deposited on top of a silicon wafer with a 330 nm thick silicon oxide, including also folded samples. This folding leads to a misorientation and thereby to decoupling of the two stacked layers.

We present measurements on such two layer systems consisting of decoupled monolayers [1]. To distinguish this sample from monolayer and single cystal bilayer graphene, magnetotransport measurements are carried out with temperatures down to 1.5 Kelvin. A backgate voltage between -70 V and 70 V is used to tune the carrier concentration and type. Applying magnetic fields up to 13 Tesla, the longitudinal resistance shows two sets of Shubnikov-de Haas oscillations with a Berry's phase of π for both oscillations, verifying a system of stacked monolayers. From the period of theses oscillations, the charge carrier densities are obtained, showing different values for each layer due to screening effects.

[1] H. Schmidt, T. Lüdtke, P. Barthold, E. McCann, V. I. Fal'ko, and R. J. Haug, Appl. Phys. Lett. 93, 172108 (2008)

HL 54: Invited Talk Hübner

Time: Friday 11:00–11:45 Location: HSZ 01

Invited Talk HL 54.1 Fri 11:00 HSZ 01

Spin Noise Spectroscopy in Semiconductor Nanostructures — •Jens Hübner, Michael Römer, Georg Müller, Hannes Bernien, Tammo Böntgen, Hauke Horn, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany

The aim towards semiconductor spin devices and spin quantum information processing drives the current intense research on semiconductors spintronics. Spin noise spectroscopy in semiconductors (SNS) is a new powerful method to reveal the spin related physical processes of a wealth of semiconductor systems [1]. Known from quantum optics as quantum non-demolition measurement, SNS is in particular capable to unravel the intrinsic spin dynamics without disturbing influences. SNS measurements at low temperatures on weakly n-doped bulk GaAs yield for example spin lifetimes up to 260 ns, which has been masked before by carrier heating and spin relaxation by holes. In two dimensional systems like n-doped 110-GaAs quantum wells, SNS is capable to distinguish between intrinsic and extrinsic spin dephasing mechanisms like, e.g., pure dephasing and time of flight broadening resulting from the electron motion [2]. SNS can be as well applied to zero dimensional systems like quantum dots or impurity bound carriers.

[1] M. Oestreich, M. Römer, R. J. Haug, and D. Hägele, Phys. Rev. Lett. **95**, 216603 (2005).

[2] G. Müller, M. Römer, D. Schuh, W. Wegscheider, J. Hübner, and M. Oestreich, Phys. Rev. Lett. **101**, 206601 (2008).