HL 85: Poster Session II

Time: Thursday 18:00–21:00 Location: P4

HL 85.1 Thu 18:00 P4

Quasiparticle wave functions in alloys — •Alexander Müller, Marko Stölzel, Gabriele Benndorf, and Marius Grundmann — Universität Leipzig, Institut für Exp. Physik II, Abteilung Halbleiterphysik, Linnéstr. 5, 04103 Leipzig

The effective mass approximation is a powerful tool to understand many effects in semiconductors such as the transport properties of electrons and holes, bound states at impurities as well as multi-particle complexes such as excitons. However, up to now this model has mainly been applied to elemental/compound semiconductors or virtual crystals. For alloys, there exist a number of methods to estimate the band gap or effective carrier masses such as the virtual crystal approximation or local density approximations on supercells. However, the applicability to very large cells to investigate localization effects is limited.

In this contribution we investigate the suitability of the effective mass approximation for alloys to include localization effects in this theory. Calculated envelopes of electron and hole wave functions are compared to wave functions determined using a 1D Kronig–Penney-like model. Indeed, we observe a good agreement between both models. The effective mass model is applied to excitons and the numerical accuracy of the found energy states is discussed.

HL 85.2 Thu 18:00 P4

Empirical band gap corrected local density approximation study — •Roby Cherian and Gabriel Bester — Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany.

We have developed empirical pseudopotentials directly from ab-initio methods, in the local density approximation (LDA), keeping the empiricism at the lowest possible level. Major problems of the LDA calculation for the electronic band structure is the severe underestimation of the electron band gap and the electron effective mass. We have implemented and tested different empirical schemes such as different modifications of the semi-local and the local potentials. We discuss limitations of this approach, e.g., the band gap and the effective mass cannot be corrected simultaneously. On the other hand we demonstrate the quality of the obtained potential by comparing deformation potentials for valence and conduction band with experiment and density functional theory.

HL 85.3 Thu 18:00 P4

Modelling Hertzian Point Dipoles Using the Fourier Modal Method — •Benjamin Lutz, Thomas Zebrowski, Sabine Essig, and Kurt Busch — Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

The experimental realizations of quantum dots, e.g., in photonic crystal waveguides and cavities, motivate the incorporation of Hertzian point dipoles in computational methods such as the Fourier Modal Method (FMM) that are capable of dealing with periodic structures. Since periodicity is broken by a single source it is necessary to isolate the unit cell with perfectly matched layers (PMLs). Thus we present the results of an implementation that isolates sources with PMLs in the lateral plane of the three-dimensional computational domain. We optimized the parameters of the PMLs by comparing the analytical field distribution of a Hertzian point dipole with the simulations. In addition we investigated the influence of adaptive coordinates on the convergence behavior in such a setup.

HL 85.4 Thu 18:00 P4

Few-photon transport in low-dimensional waveguides with a quantum-impurity — •Christoph Martens, Jean-Christophe Blancon, Paolo Longo, and Kurt Busch — Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

We present our recent results on the dynamics of few-photon quantum transport in waveguiding systems in the presence of a quantum impurity. Based on a multimode Jaynes-Cummings model, recent studies show interesting transport properties [1,2,3,4], for instance, effective photon-photon interactions [1,3] and interaction-induced radiation trapping [3]. By monitoring the time evolution of few-photon pulses we investigate the transmission characteristics and the conditions under which atom-photon bound states can be excited. Furthermore, we analyze functional elements which are important for possible experimental realizations.

[1] J. T. Shen and S. Fan, Phys. Rev. Lett. 98, 153003 (2007)
[2] P. Longo et al., J. Opt. A: Pure Appl. Opt. 11, 114009 (2009)
[3] P. Longo et al., Phys. Rev. Lett. 104, 023602 (2010)
[4] D. Witthaut et al., New Journal of Physics 12, 043052 (2010)

HL 85.5 Thu 18:00 P4

New features about angle-resolved fluorescence microscopy in Photonic Crystals — •Lars Heerklotz, Rebecca Wagner, and Frank Cichos — University of Leipzig, Leipzig, Germany

Periodical spatial variations of a materials properties lead, via the Bloch condition, to the formation of bands, causing partial and total band gaps. That holds for electrons in a semiconductor, where the core potential is periodic, as well as for photons in a Photonic Crystal (PC), where the dielectric constant is periodic. In the photonic case this means, that light can not propagate in the band gap regions. To observe these features we produced face-centered cubic (fcc) PCs by evaporation from a solution of fluorescent dye beads and polystyrene beads, which form the PC. In the past conventional wide field or confocal setups have been used intensively to study the behavior of light sent from many dyes in three dimensional PCs. We are using our home-build novel confocal setup to investigate the behavior of light emitted from single dye beads inside the PC. Advantage, compared to former setups, is the acquisition of spectra for several angles in one measurement. This method, angle resolved fluorescence microscopy, is applied to measure the fractional local density of states for different depths of dyes inside the crystal and to observe the threefold structure in the first Brillouin-zone of the fcc-lattice.

HL 85.6 Thu 18:00 P4

Coupling of Quantum Dots to Strongly Interacting Photonic Resonator Systems — •Stefan Declair, Torsten Meier, and Jens Förstner — University of Paderborn, Department of Physics and CeOPP, Warburger Str. 100, D-33098 Paderborn, Germany

We numerically investigate the coupling between semiconductor heterostructures like quantum dots and strongly interacting photonic resonators like coupled photonic crystal cavities or microdisks using a Finite-Difference Time-Domain method. The light-matter Hamiltonian is used to calculate the macroscopic polarisation via dynamic equations for the interband coherence of the semiconductor heterostructure [1].

For photonic systems of multiple coupled one-dimensional cavities and quantum dots, clear anticrossing behavior is observed when the quantum dot gap frequency is tuned through the resonances of the coupled cavity system. Also, strong coupling is shown for a system of two coupled two-dimensional high-Q nanocavities [2] with an embedded quantum dot.

[1] C. Dineen et al., Electromagnetic field structure and normal mode splitting in photonic crystal nanocavities, Optics Express 13, 4980 (2005).
[2] Y. Akahane et al., High-Q photonic nanocavity in a twodimensional photonic crystal, Nature 425, 944 (2003).

HL 85.7 Thu 18:00 P4

Crossed Photonic Crystal Waveguides for Quantum Dots Signal Detection — •Xiaohong Song, Torsten Meier, and Jens Förstner — Department Physik and Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Separation of typically very weak quantum dot signals from the exciting laser light is important for the investigation of the excitation dynamics of quantum dots. Using a combined Maxwell-Bloch approach[1], we theoretically investigate a crossed perpendicular photonic crystal waveguide structure to achieve this aim[2]. The waveguides are designed so that the light can only propagate along one direction and is forbidden in the other directions. When the quantum dots are embedded in this structure, the nearly pure quantum dot signal can be detected in the transverse direction.

[1] C. Dineen, J. Förstner, A.R. Zakharian, J.V. Moloney, S.W. Ko-

chOptics Express 13, 4980 (2005).
[2] S. G. Johnson, C. Manolatou, S. Fan, P. R. Villeneuve, J. D. Joannopoulos, H. A. Haus, Opt. Lett. 23, 1855 (1998).

HL 85.8 Thu 18:00 P4

Tunable Transmission in Rolled-Up Three Dimensional Metamaterials — •Aune Koitmäe, Stephan Schwaiger, Matthias Klingbeil, Markus Broell, Jochen Kerbst, Ricardo Costa, Andrea Stemmann, Yuliya Stark, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Hamburg, Deutschland

Metamaterials are artificial materials with tuneable permittivity and permeability. Alternating layers of metal/dielectric films are rolled up with multiple rotations into three-dimensional microtubes. The walls of these tubes represent three dimensional metamaterials with a well defined lattice constant and a tuneable anisotropic permittivity [1]. By integrating quantum wells as optical amplifiers into the walls of the microtube we can modify the transmission through the tube walls. Transmission measurements are performed using a tapered optical fibre which illuminates the tube from the inside. A microscope objective collects the light transmitted through the tube walls. The same objective is used to focus a pumping laser on the tube. By comparing measurements with and without laser pumping we obtain a characteristic modification of the transmission through the tube walls.

We gratefully acknowledge support by the DFG through GrK 1286.

[1] S. Schwaiger et al., Phys. Rev. Lett. 102, 163903 (2009)

HL 85.9 Thu 18:00 P4

Numerical Simulation of Exciton Dynamics at Ultra Low Temperature — •Sunipa Som[1] and Heinrich Stolz[2] — [1]Institut für Physik, Universität Rostock, Rostock, Germany — [2]Institut für Physik, Universität Rostock, Rostock, Germany

The possibility of Bose-Einstein condensation of excitons in cuprous oxide has been actively pursued for many years, because in the low density limit excitons are bosons, and therefore obey Bose-Einstein statistics. Cuprous oxide is of high interest due to its long exciton lifetime. We have studied theoretically the relaxation behaviour of excitons at ultra low temperatures below 1K, by solving the Boltzmann equation [1,2], while the excitons are confined within a parabolic potential trap. We have included deformation potential phonon scattering but not collision of excitons.

The Boltzmann equation has been solved by finite difference method and the method of lines using MATLAB. Using initial condition representative for actual experimental studies, we are getting the exciton occupation numbers as a function of momentum, space and time. From these we have calculated the effective temperature and studied how it is changing with time. For temperatures above 1K, the effective temperature is coming down to bath temperature within ten nanoseconds. This is different for temperatures below 1K, where the effective temperature is coming down to bath temperature very slowly within hundreds of nanoseconds only.

[1] Ashcroft and Mermin, Solid State Physics (Harcourt Brace, Fortworth, 1976). [2] A. L. Ivanov et al., Phys. Rev. E 55, 6363 (1997)

HL 85.10 Thu 18:00 P4

Magneto-Optical Ellipsometry of Ferromagnetic Thin Films — •Tobias Herzig, Tammo Böntgen, Rüdiger Schmidt-Grund, Michael Lorenz, and Marius Grundmann — Universtät Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5

We have investigated the optical properties of ferromagnetic thin films by means of spectroscopic ellipsometry. From the Müller Matrix (MM) obtained through these measurements one can derive the optical constants as well as the magneto-optical properties of the sample. The diagonal MM elements are a measure for the optical constants (refraction index, absorption). They were modeled using tabulated reference for the refractive index and absorption from the literature. The off-diagonal MM elements on the other hand contain information about the energy conversion between polarization modes. Thus modeling these elements gives inside into the magneto-optical properties of the sample. We determined these properties for Cobalt and magnetite thin films as model systems. The method proved to be a reliable tool to measure important optical properties and magneto-optical effects simultaneously.

HL 85.11 Thu 18:00 P4

Optical properties of crystalline and amorphous TiO2 modifications — •Marc Landmann[1], Thomas Köhler[2], Eva Rauls[1], Thomas Frauenheim[2], and Wolf Gero Schmidt[1] — [1]Lehrstuhl für Theoretische Physik, Universität Paderborn, Germany — [2]Bremen Center for Computational Materials Science, Germany

In its crystalline form TiO2, is traditionally used as a pigment in industrial applications. Moreover, TiO2 surfaces are among the most studied substrates in catalysis and used as a template for crystalline organic film growth for both light-emitting diodes and field-effect transistor applications [1]. TiO2 also offers the possibility of low cost dye-sensitized solar cells based on optically transparent films of nanocrystalline TiO2. To fully exploit the technological potential of TiO2, a detailed understanding of the bulk and surface optical properties is required. Here, we have calculated the optical response of ordered rutile, anatase and brookite bulk material as well as of the the rutile (110)(1x1) surface. The calculations have been done on the density-functional theory (RPA), quasiparticle (GW) and Bethe-Salpeter equation (BSE) level of theory [2]. The results are interpreted in terms of self-energy and excitonic contributions to the optical spectra and compared with the available experimental data and previous calculations [3]. We find characteristic differences between the various bulk phases as well as between the crystalline and amorphous material.

[1] G. Koller et al. Adv. Mater. 16, 2159 (2004).
[2] W. G. Schmidt et al. Phys. Rev. B 67, 085307 (2003).
[3] H. Sano et al. Phys. Rev. B 70, 125411 (2004)

HL 85.12 Thu 18:00 P4

Investigation of the effect of plasmonic metal nanostructures on nanocrystalline TiO_2:Eu^{3+} nanoparticles — cahit benel[1], •barat kurbanjan[1], ulrich herr[1], manuel goncalves[2], othmar marti[2], johannes boneberg[3], and paul leiderer[3] — [1]Inst. of Micro and Nanomaterials, University of Ulm, Germany — [2]Inst. of Experimental Physics, University of Ulm, Germany — [3]Dept. of Physics, University of Konstanz, Germany

Rare-earth-doped materials are used in a variety of photonic applications such as phosphors, X-ray imaging, scintillators, display panels and photonic band gap materials. In this work, Eu^{3+} doped TiO_2 nanoparticles have been produced via chemical vapor synthesis (CVS). Samples with different Eu^{3+} ion concentration ranging from 0.05 at% to 1.51 at% were prepared. XRD results show that the samples primarily consist of the anatase phase. However, with increasing dopant level, an increasing amount of the rutile phase is found. Luminescence lifetime measurements monitoring $^5D_0$-$^7F_2$ transition of Eu^{3+} ions were performed at different excitation wavelengths for both as-prepared and annealed samples. We find two different lifetime components, which are attributed to contributions from surfaces and possibly other defects. The nanoparticles have been deposited on Ag nanostructures, which were prepared by nanosphere lithography on glass substrates. Different sizes of spheres have been used. The samples have been characterized by laser scanning confocal microscopy. Local photoluminescence spectra are used to search for possible luminescence enhancements due to plasmonic effects.

HL 85.13 Thu 18:00 P4

Statistical properties of photon modes in random arrays of ZnO nano-needles — •Christoph Minz, David Leipold, and Erich Runge — Technische Universität Ilmenau, 98693 Ilmenau, Germany

Localization of electromagnetic waves in random media received renewed interest in the last years. Recent ultrafast optical experiments [1] indicate the existence of highly localized photon modes in a system of homogeneous, randomly distributed, vertically aligned ZnO nanoneedles. In particular, hot spots in the spatial distribution of the second harmonic generation (SHG) were found.

In this work, we discuss the optical near field, which we obtain from full 3D solutions of Maxwell's equations of a model system in time domain. The spatial distribution of the electric near-field and the squared electric near-field intensity are investigated with statistical methods. The results are compared to the experimental findings.

[1] We thank Manfred Maschek, Slawa Schmidt, Martin Silies and Christoph Lienau from the Carl von Ossietzky Universität Oldenburg as well as Takashi Yatsui, Kokoro Kitamura and Motoichi Ohtsu from the University of Tokyo for sharing their experimental data with us prior to publication.

HL 85.14 Thu 18:00 P4

Heavy *n*-doping: Wannier-Mott and Mahan excitons in ZnO — •André Schleife, Claudia Rödl, Karsten Hannewald, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik

and European Theoretical Spectroscopy Facility, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Transparent conductive oxides such as ZnO are highly interesting within the modern field of optoelectronics since they have large fundamental band gaps while intentional as well as unintentional n-doping renders them conductive. However, the free electrons in the material form a degenerate electron gas which occupies the lowest conduction-band states and whose effect on the optical properties is unknown.

In addition to the Pauli blocking of the lowest optical transitions, the degenerate electron gas significantly influences the screening of the electron-hole interaction. We generalize the solution of the Bethe-Salpeter equation for the polarization function to investigate both of these aspects as well as their interplay with the excitonic effects for n-ZnO. We introduce **k**-dependent occupation numbers to account for the Pauli blocking. The additional screening due to the free electrons is taken into account by means of a Thomas-Fermi approach.

Our approach essentially captures the involved physics, hence, we observe a Mahan exciton at the absorption edge – in perfect agreement with a measured result. We show that due to the strong decrease of the binding energy and the oscillator strength with an increasing free-electron concentration in the material an excitonic Mott transition is barely observable.

HL 85.15 Thu 18:00 P4

Optical properties of as-grown and ion implanted Cu2O thin films — •Christian Müller[1], Sebastian Geburt[1], Andreas Laufer[2], Bruno K. Meyer[2], and Carsten Ronning[1] — [1]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

Copper(I) oxide is a promising material for future photovoltaic applications, especially due to its environmental friendly and cheap preparation process. The properties of copper(I) oxide are still a hot topic of research and especially n-doping is difficult. But similar problems could be solved in the past at materials like CIS, CGS and CIGS [1].

Copper(I) oxide thin filmes on glas substrates were prepared by reactive oxygen sputtering. The crystal quality and band edge properties were examined using UV-VIS transmission and reflectivity measurements combined with XRD. The layers were annealed in different atmospheres to investigate the effects on the quality of the films in term of phase transformation and the influence on the energy gap. Temperature and power dependent cathodo- and photoluminescence measurements on intrinsic samples were performed to investigate the emission properties with regard to excitonic effects and donator/acceptor behavior. Ion implanted samples were examined to discover extrinsic donor- and acceptor species and optical active impurities.

[1] Biccari F.: Defects and Doping in Cu2O. University of Rome, Diss., 2009

HL 85.16 Thu 18:00 P4

UV photoluminescence spectroscopy of AlGaN alloys with different Al-contents — •Christoph Reich, Jessica Schlegel, Joachim Stellmach, Patrick Vogt, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

AlGaN alloys are very promissing materials for ultraviolet (UV) light emitting diodes and lasers in the spectral range between 360 nm and 200 nm. However, for high efficiency devices further improvement of material quality and better understanding of the optical properties is needed. In order to investigate the influence of the composition and defect density on the emission characteristics we have characterized AlGaN layers with different Al-content using temperature dependent and excitation power dependent UV photoluminescence (PL) spectroscopy. The samples were grown by metalorganic vapor phase epitaxy either on (0001) GaN/sapphire or on (0001) AlN/sapphire to minimize lattice mismatch within the entire composition range. We observe a decrease in the PL intensity and an increase in the full width at half maximum with higher Al-content, which can be attributed to a reduction of the crystal quality as well as an increase in composition fluctuation. The emission characteristics and the temperature dependence of the bandgap energy for different AlGaN compositions will be discussed.

HL 85.17 Thu 18:00 P4

Disorder Effects in Ga(AsBi) — •Christian Wagner[1], Sebastian Imhof[1], Alexej Chernikov[2], Martin Koch[2], Nico S. Köster[2], Kolja Kolata[2], Sangam Chatterjee[2], Stefan W. Koch[2], Xianfeng Lu[3], Shane R. Johnson[3], Daniel A. Beaton[4], Thomas Tiedje[5], Oleg Rubel[6,7], and Angela Thränhardt[1] — [1]Institut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [2]Fachbereich Physik, Philipps-Universität Marburg, 35032 Marburg, Germany — [3]Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-6206, USA — [4]Department of Physics and Astronomy, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada — [5]Department of Electrical and Computer Engineering, University of Victoria, Victoria, British Columbia V8W 3P6, Canada — [6]Thunder Bay Regional Research Institute, Thunder Bay, Ontario P7A 7T1, Canada — [7]Department of Physics, Lakehead University, Thunder Bay, Ontario P7B 5E1, Canada

In recent years, Ga(AsBi) has been shown to be an interesting material for laser applications since its band gap can be varied over wide frequency range. The growth process, however, is still challenging and carrier dynamics remains governed by hopping processes. We show that emission spectra are well described by a two-scale disorder model (S.Imhof et al., Appl.Phys.Lett. 96, 131115 (2010)) and discuss time-dependent simulations and measurements. Theory and experiment show a good agreement in all cases.

HL 85.18 Thu 18:00 P4

Photoluminescence of Ga(AsBi) — •Nils Rosemann[1], Alexej Chernikov[1], Verena Bornwasser[1], Niko S. Köster[1], Martin Koch[1], Kolja Kolata[1], Sangam Chetterjee[1], Stephan W. Koch[1], Sebastian Imhof[2], Christian Wagner[2], Angela Tränhardt[2], Xianfeng Lu[3], Shane R. Johnson[3], Dan A. Beaton[4], Thomas Tiedje[5], and Oleg Rubel[6,7] — [1]Fachbereich Physik, Philipps-Universität Marburg, 35032 Marburg, Germany — [2]Institut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [3]Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-6206, USA — [4]Department of Physics and Astronomy, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada — [5]Department of Electrical and Computer Engineering, University of Victoria, Victoria, British Columbia V8W 3P6, Canada — [6]Thunder Bay Regional Research Institute, Thunder Bay, Ontario P7A 7T1, Canada — [7]Department of Physics, Lakehead University, Thunder Bay, Ontario P7B 5E1, Canada

Ga(AsBi) is a promising candidate for GaAs-based near-infrared emitters at telecommunication wavelength. To evaluate the potential of this material system we study the photoluminescence from such a bulk sample as function of pump power and lattice temperature. Strong disorder-related features are observed. To better quantify the experiments we analyze the data using a Monte Carlo approach. A two-scale model is introduced to account for both cluster localization and alloy disorder.

HL 85.19 Thu 18:00 P4

Optical properties of positioned InAs-based nanowire arrays — •Andreas Brenneis, Simon Hertenberger, Sonja Matich, Gerhard Abstreiter, Alexander Holleitner, and Gregor Koblmüller — Walter Schottky Institut and Physik Department, TUM Garching, Germany

Small bandgap semiconducting nanowires allow fabricating nanoscale light-sensitive devices like broadband solar cells or mid-infrared (mir) photodetectors. We discuss the optical properties of positioned InAs-based nanowires. To this end, p-Si(111) substrates with a top layer of SiO_2 are structured via e-beam lithography by holes with a diameter of approximately 80 nm. The nanowires are then grown vertically on the substrates by solid-source molecular beam epitaxy. The optical properties of the nanowires are characterized by FTIR transmission and angle dependent reflection measurements. To fabricate optoelectronic devices, we subsequently embed the nanowires in an insulator (SiO_2 by PECVD and PVD; SOG). After an etch back step, the nanowires are then contacted by depositing a thin conducting layer on top. The p-Si substrate provides the second electronic contact of the optoelectronic two-terminal devices.

HL 85.20 Thu 18:00 P4

Optical investigation on a monolithic planar microcavity containing InP quantum dots as active medium — •Marcus Müller[1], Alexander Franke[1], Thomas Hempel[1], Jürgen Christen[1], Wolfgang-Michael Schulz[2], Marcus Eichfelder[2], Robert Rossbach[2], Michael Jetter[2], and Peter Michler[2] — [1]Otto-von-Guericke-University Magdeburg, Institut of Experimental Physics, Germany — [2]Universität Stuttgart, Institut Für Halbleit-

eroptik und Funktionelle Grenzflächen, Germany

The change of the spontaneous emission properties by the resonator of a planar VCSEL structure was analyzed using spatially resolved photoluminescence (PL). The samples consists of a λ GaInP cavity embedding InP quantum dots (QDs) as active medium grown on top of an 45 layer AlAs/$Al_{0.5}$GaAs bottom distributed Bragg reflector (DBR). For comparison samples without, 10 AlAs/$Al_{0.5}$GaAs and 34 $Al_{0.5}$GaAs/$Al_{0.95}$GaAs layer pairs were grown. Integral PL spectra taken at each sample show a dominant QD emission in the red spectral range at 1.84 eV.

To achieve a stronger carrier confinement the InP-QDs were embedded inside an AlGaInP cavity, too. PL spectra taken at the structure without top DBR show again QD emission at 1.84 eV. In addition a second emission line at 1.63 eV arises from the formation of different type of QDs.

The optical and structural behavior of both QD species was investigated using excitation and temperature dependent PL as well as scanning electron and atomic force microscopy.

HL 85.21 Thu 18:00 P4

Polariton lasing from a GaAs microcavity: a temperature dependent analysis in the spectral and temporal domain — •Jean-Sebastian Tempel[1], Franziska Veit[1], Marc Assmann[1], Lars Erik Kreilkamp[1], Manfred Bayer[1], Arash Rahimi-Iman[2], Andreas Löffler[2], Sven Höfling[2], Stephan Reitzenstein[2], Lukas Worschech[2], and Alfred Forchel[2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany

We present a spectral and temporal analysis of the emission from a strongly coupled GaAs/GaAlAs microcavity in the temperature range 10-110K. Two distinct transitions in the ground state emission from the lower polariton branch are observed up to 70K; thereby, we evidence polariton lasing in the pump power regime between the thresholds. In particular, we show that the two transitions are clearly evidenced in the emission pulse duration and in the photon statistics based on the second-order correlation function. With further increasing temperature up to 110K changes in the spectral as well as in the temporal domain are observed.

HL 85.22 Thu 18:00 P4

Solitary pulse propagation through quantum dot media — •Matthias-René Dachner, Maria Schuld, Harald Engel, and Andreas Knorr — Institut für Theoretische Physik, Technische Universität Berlin, Germany

The propagation of optical pulses through quantum dot media is investigated. We concentrate on solitary solutions in the conservative and the gradual transition to the dissipative regime. The influence of dissipation and pumping on the solutions is taken into account microscopically, by means of phonon assisted quantum dot–wetting layer interaction. We present numerical studies which are carried out by solving the Maxwell-Bloch equations using the finite difference time domain (FDTD) approach and compare the results to solutions of a microscopically derived Ginzburg-Landau equation.

HL 85.23 Thu 18:00 P4

Ultrafast X-Ray Diffraction on Photoexcited Superlattices: Simulation and Experiment — •Marc Herzog[1], Daniel Schick[1], Ionela Vrejoiu[2], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

Ultrafast x-ray diffraction (XRD) is a well-suited method to monitor and hence understand the details of atomic motions in a solid-state material on its intrinsic timescales. However, the interpretation is not always straightforward. This presentation focuses on time-resolved XRD on superlattices (SL) in which photoexcited coherent acoustic phonons modulate the x-ray structure factor of various SL Bragg reflections [1]. The resulting time-dependent strain field manifests itself in transient changes of diffraction efficiencies and shifts of the Bragg angles. From the observation of transient rocking curves we can deduce the structural dynamics initiated by an optical pump pulse and thereby gain knowledge of material properties as well as excitation and coupling mechanisms. We analyze a linear-chain model to simulate the strain field and use dynamical x-ray diffraction theory to calculate the corresponding rocking curves. We identify general features of the transient x-ray reflections of such optically excited SLs and compare the predictions to experimental results. We find almost perfect agreements for a large range of linear and non-linear phenomena and different samples.

[1] Herzog et al., Appl. Phys. Lett. 96, 161906 (2010).

HL 85.24 Thu 18:00 P4

Ultrafast X-Ray Diffraction on a STO/SRO Superlattice — •Daniel Schick[1], Marc Herzog[1], Clemens von Korff Schmising[2], Peter Gaal[1], and Matias Bargheer[1] — [1]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Atomic Physics Division, Department of Physics, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden

Ultrafast x-ray diffraction is capable of probing atomic motions on the fs-timescale. With the new laser-driven table-top plasma x-ray source at the University of Potsdam we are able to generate ≈ 100 fs pulses of Cu K_α radiation with a repetition rate of 1 kHz and a total flux of 5×10^5 ph/s on the sample.

Here we compare ultrafast optical reflectivity changes and ultrafast x-ray diffraction data of a $SrTiO_3$/$SrRuO_3$ superlattice (SL) in order to highlight the relative phase of oscillations in all-optical pump-probe data to the phase of the atomic motion. For high pump fluences we observed for the first time that on longer time scales (15 ps) the Bragg-peaks not only shift due to the lattice expansion but rather split into two separate Bragg-peaks, which can accurately be predicted by simulations of the phonon dynamics in a linear chain model and dynamical x-ray diffraction theory.

HL 85.25 Thu 18:00 P4

Ultrafast optical spectroscopy of layered hole-doped manganites — •Lena Maerten, Marc Herzog, and Matias Bargheer — Institut für Physik und Astronomie, Universität Potsdam

Sr-doped perovskite oxide $LaMnO_3$ is widely studied for its ferromagnet to paramagnet and concomitant metal to insulator phase transition. Inserting a monolayer of SrO following each n unit cells of (LaSr)MnO_3 (Ruddlesden-Popper Series) introduces an intrinsic superlattice structure with strongly anisotropic properties such as a reduced dimensionality of the electron gas. Alternatively, artificial superlattices with dielectric oxides as interlayers can be prepared. Ultrafast optical spectroscopy reveals on which timescales the coupled electronic, lattice and spin degrees of freedom interact. Using IR pump / white-light probe and NOPA-based pump-probe techniques we measure transient reflectivity curves of bulk ($n \to \infty$) and layered ($n = 2$, $n = 3$) $SrO(La_{0.65}Sr_{0.35}MnO_3)_n$ for temperatures above and below the ferromagnetic transition. Fast electronic heating, consecutive electron-phonon coupling and a slow transfer of energy into the magnetic system can be observed. We discuss transient spectral changes and the build-up of zone-folded coherent acoustic phonons in the layered samples.

HL 85.26 Thu 18:00 P4

Pump-Probe Spectroscopy on Superlattices: Experiment and Simulation — •Andre Bojahr, Marc Herzog, Lena Maerten und Matias Bargheer — Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany

We present an experimental setup for highly-sensitive pump-probe measurements using a mode-locked Ti:Sa oscillator at 80 MHz in the weak excitation regime (20 μJ/cm^2). To reach a sensitivity on the order of $\Delta R/R_0 = 10^{-9}$, we rapidly scan the delay line. This setup enables us to conduct high-precision optical experiments with a time-resolution of about 100 fs. In particular, we show transient reflectivity measurements on weakly excited oxide superlattices which exhibit modulations due to the generation of coherent acoustic phonons resulting in standing and propagating strain waves. The results are compared to strong-excitation experiments with kHz amplifier systems in which the observed reflectivity oscillations are phase-shifted. In order to gain understanding, we propose a model that allows the calculation of the transient reflectivity from the modulation of optical properties by the time-dependent strain field within the sample.

HL 85.27 Thu 18:00 P4

Photocurrents in Semiconductor Carbon Nanotubes with Spin-Orbit Interaction — Hong Liu[1,2], Huynh Thanh Duc[1], Stefan Schumacher[1], and •Torsten Meier[1] — [1]Department Physik and CeOPP, Universität Paderborn, D-33098 Paderborn, Ger-

many — [2]Physics Department, Nanjing Normal University, Nanjing 210046, China

In recent years, single-walled carbon nanotubes (SWCNTs) have received widespread attention due to their perfect quasi-one-dimensional structure and unique physical properties, as well as their potential for applications. In the present work, we calculate the band structure of SWCNTs using an atomistic tight-binding model including spin-orbit interaction[1]. We combine this approach with a many-particle calculation of the nonlinear optical response using multi-band semiconductor Bloch equations[2]. We show that, for SWCNTs lacking inversion symmetry, the intrinsic spin-orbit interaction can give rise to single-color photoinduced charge and spin currents. In particular, we study the influence of excitonic effects on these photoinduced currents and draw the analogy to recent investigations on single-color injection of photocurrents in semiconductor quantum wells[2].

[1]Hong Liu, Physica B **406**, 104-107 (2011)
[2]Huynh Thanh Duc, Jens Förstner, and Torsten Meier, Phys. Rev. B **82**, 115316 (2010).

HL 85.28 Thu 18:00 P4

Analysis of Multidimensional Fourier Transform Spectroscopy for Semiconductors with a Phenomenological Level Model — •Christian Wiebeler, Matthias Reichelt, and Torsten Meier — Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Optical two-dimensional Fourier transform spectroscopy has been used to study the properties of semiconductor nanostructures in four-wave-mixing like experiments. [1] Applying a phenomenological level model, we numerically and analytically analyze the main features of excitonic and biexcitonic contributions [2] in a semiconductor quantum well by solving the optical Bloch equations. The method is extended to three-dimensional Fourier transform spectroscopy [3] to investigate a recent experiment. [4].

[1] K. W. Stone et al. Science **324**, 1169 - 1173 (2009).
[2] T. Zhang et al. Proc. Nat. Acad. Sci. **104**, 14227 (2007).
[3] C. Wiebeler, *Modellrechnungen zur mehrdimensionalen Spektroskopie exzitonischer Resonanzen in Halbleiter-Nanostrukturen*, Bachelor Thesis, University of Paderborn (2010).
[4] S. Cundiff, private communication.

HL 85.29 Thu 18:00 P4

Numerical analysis of strong coupling in an absorber-cavity system with two-dimensional Fourier-transform spectroscopy — •Peter Kölling, Matthias Reichelt, and Torsten Meier — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

Strongly coupled absorber-cavity systems have become an important research topic in optics and solid state physics[1]. In this work, we present different simulations of a Four-Wave-Mixing experiment on the basis of a self-consistent Finite-Difference-Time-Domain method in combination with two-dimensional Fourier-transform spectroscopy[2].

[1] Reithmaier et al., Nature 432, 197 (2004)
[2] T. Zhang et al., Proceedings of the National Academy of Sciences of the USA 104, 14227-14232 (2007)

HL 85.30 Thu 18:00 P4

Anisotropic and spin polarization dependent spin dephasing in a 110-grown high-mobility AlGaAs/GaAs quantum well measured by resonant spin amplification technique — •M. Griesbeck[1], V. Lechner[1], I. Caspers[1], M. Glazov[3], T. Korn[1], D. Schuh[1], W. Wegscheider[1,2], and C. Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]present adress: ETH Zürich, 8093 Zürich, Switzerland — [3]A.F. Ioffe Physical-Technical Institute, 194021 St. Petersburg, Russia

The spin dynamics in zincblende-based two-dimensional electron systems (2DESs) are dominated in many cases by the D'yakonov-Perel spin dephasing mechanism and the underlying spin orbit (SO) fields. One exception can be found in symmetrically grown and doped AlGaAs/GaAs quantum wells with the growth axis along the 110-direction, where the Rashba contribution is neglectable and the effective Dresselhaus type SO field is perpendicular to the sample plane. In such a system, consisting of a 30 nm-wide double-sided δ-doped single quantum well with a very high mobility of about 3 million cm^2/Vs, we observed the expected strongly anisotropic spin lifetimes for in- and out-of-plane spin orientations by resonant spin amplification (RSA) measurements. In our experiments, the ratio of in-plane and out-of-plane spin lifetimes is strongly dependent on the sample temperature, the excitation density and also the initial spin polarization of the 2DES. The shape of the RSA traces is modeled using an analytical expression, from which the SDTs are extracted.

HL 85.31 Thu 18:00 P4

Spin dephasing anisotropy in two-dimensional electron systems: dependence on temperature and quantum well width — •Michael Griesbeck[1], Dominik Waller[1], Gerd Plechinger[1], Elisabeth Leierseder[1], Tobias Korn[1], Dieter Schuh[1], Werner Wegscheider[1,2], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]present adress: Laboratorium für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland

The spin dynamics in most AlGaAs/GaAs-based two-dimensional electron systems are governed by the D'yakonov-Perel spin dephasing mechanism, which results from the underlying spin-orbit (SO) fields. In samples with an asymmetric growth profile, there are contributions to the effective internal SO fields mainly due to the lack of inversion symmetry of the crystal structure, as well as the built-in electric field caused by the asymmetric band profile. The different symmetries of the Dresselhaus and Rashba SO fields lead to the well-known spin dephasing anisotropy (SDA), where the spin dephasing time strongly depends on the spin orientation. In this study we have investigated the temperature dependence of the SDA in samples with different quantum well width, ranging from 10 nm to 25 nm. By means of time-resolved Kerr rotation technique we were able to determine the relative strengths of Dresselhaus and Rashba SO fields from liquid Helium temperature up to 130 K, including the interesting case, where the two contributions have the same strength. Such a system could be a working base of the proposed non-ballistic spin-FET.

HL 85.32 Thu 18:00 P4

Generation of coherent and incoherent LO phonons by optical excitation of electrically biased quantum wells — •Thomas Papenkort[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany

Coherent phonons in solids can be generated by optical excitation in a number of different ways, which depend on the material, its structure and the excitation conditions. Although it is the electronic subsystem which the light field predominantly couples to, its detailed characteristics and dynamics can often be left out when explaining the mechanism of phonon generation. In this contribution we will focus on the opposite case where the dynamics of the electronic subsystem plays a vital role to the generation of coherent phonons. An example is the resonant generation of coherent phonons in quantum wells as observed in recent experiments by Mizoguchi et al. [Appl. Phys. Lett. 94, 171105 (2009)], in which a strong coherent phonon amplitude has been achieved by tuning an electronic quantum beat to the LO phonon frequency. We show quantum kinetic calculations of the electronic and phononic dynamics in an optically driven quantum well. We find that the resonant mechanism is very efficient in generating coherent phonons when compared to other mechanisms, but still most of the energy goes into incoherent phonons. Our model also reproduces the limiting cases of phonon generation in which an effective direct coupling of phonons and light field can be assumed.

HL 85.33 Thu 18:00 P4

Squeezing of lattice displacement due to anharmonic decay of phonons in a semiconductor quantum dot — •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

Squeezed states of light have attracted large interest due to a possible reduction in the noise limit of quantum measurements. A standard tool for the generation of squeezed light is parametric down conversion. In many semiconductor materials similar processes exist for phonons, e.g., the anharmonic decay of a longitudinal optic (LO) phonon into a pair of longitudinal acoustic (LA) phonons. Here we study theoretically the fluctuation properties of the lattice displacement and the lattice momentum connected to the LA phonons generated by this de-

cay process. We consider the impulsive creation of an exciton in a semiconductor quantum dot structure. This is accompanied by the generation of LO phonons, which then may decay into entangled pairs of LA phonons. We perform quantum kinetic calculations to analyze the lattice fluctuations related to these LA phonons. We find that a squeezing of the lattice fluctuations occurs, which is confined within the dot area, although LA phonon wave packets travel out of the dot. The strength and the localization of the squeezing effect can be manipulated by an external electric field which strongly affects the coupling of the exciton to the LO phonons and thus the generation process of the LO phonons.

HL 85.34 Thu 18:00 P4

Output control by quantum focusing in multiterminal billiards — •Christian Morfonios[1], Daniel Buchholz[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Germany

By exploring the four-terminal transmission of a half-elliptic open quantum billiard in dependence of its geometry and an applied magnetic field, the possibility to construct a controllable quantum cross-junction between its terminals is demonstrated. Depending on the eccentricity of the half-ellipse and the width and placement of the leads, high transmittivity at zero magnetic field is reached through states guided along the curved boundary or focused onto the straight boundary of the billiard. For small eccentricity, attachment of leads at the ellipse foci can yield optimized corresponding transmission, while depart from this condition demonstrates the inapplicability of purely classical considerations in the deep quantum regime. The geometrically achieved high transmittivity is altered by the phase-modulating and deflecting effect of the magnetic field, which switches the pairs of efficiently connected leads. At higher field strengths edge states form and the multiterminal transmission coefficients are determined by the topology of the system. The combination of magnetotransport with geometrically controlled transmission leads to an efficient control of pathways for a charged particle through the multiterminal structure, which is of advantage in designing transport through nanoelectronic devices.

HL 85.35 Thu 18:00 P4

Linear and non-linear properties of ballistic electron-focusing devices — •Arkadius Ganczarczyk[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Experimental Physics and CeNIDE, Universität Duisburg-Essen — [2]Chair of Applied Solid State Physics, Ruhr-Universität Bochum

Ballistic electron focusing in nanostructured, two-dimensional electron gases was first demonstrated more than 20 years ago [1]. While the linear transport characteristics of such devices were examined in detail, possible nonlinear effects of the device were investigated to a lesser extent so far. However, non-linear transport may be of great interest for possible functional devices such as ballistic rectifiers and transistors.
In this work detailed studies of non-linear (and linear) transport properties of ballistic electron focusing devices are presented. For increasing negative injection bias (emission of electrons above the Fermi energy E_F), we observe an increase in the resonant magnetic field in agreement with the increased velocity of the injected electrons. For small positive bias, a similar electron focusing pattern is observed as for negative bias, which can be understood in the framework of electron-hole-symmetry. For increasing positive bias, however, the resonances are shifted towards smaller magnetic fields, indicating that the transport can also be probed for (missing) carriers below E_F [2].
[1] C.W.J. Beenakker *et al.*, Europhys. Lett. **7**, 359 (1988).
[2] J.G. Williamson *et al.*, Phys. Rev. B **41**, 1207 (1990); Surf. Sci. **229**, 303 (1990).

HL 85.36 Thu 18:00 P4

Boltzmann equation approach to rectification at a potential step — •Stephan Rojek, Daniel Urban, Fred Hucht, and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CeNIDE, 47048 Duisburg, Germany

Ref. [1, 2] shows an experimental analysis of a two-dimensional electron gas with two regions separated by a potential step. The difference in the potential originates from two parallel gates on top of the two-dimensional electron gas.

A bias voltage parallel to the potential step leads to a transverse voltage proportional to the square of the applied bias voltage. This effect can be exploited for rectification, since the transverse voltage does not depend on the bias polarity.

We model the system by means of the Boltzmann equation in the relaxation time approximation. We allow the scattering times to be energy dependent and consider different relaxation times for scattering processes with energy transfer larger and lower than k_BT. In order to study the rectification effects, the distribution function has to be calculated to second order in the applied electric field. We discuss the relevance of the determined transverse voltage for the measurements in Ref. [1, 2].
[1] A. Ganczarczyk *et al.*, arXiv:0804.0689v3 (2009).
[2] A. Ganczarczyk *et al.*, AIP Conf. Proc. **1199**, 143 (2009).

HL 85.37 Thu 18:00 P4

Transport properties of ferromagnet-semiconductor hybrids — •Lakshmy Ravindran[1], Rasmus Ballmer[1], Sven Buchholz[1], Saskia F. Fischer[2], Ulrich Kunze[1], Arne Ludwig[3], Dirk Reuter[3], and Andreas Wieck[3] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Neue Materialien, Humboldt Universität zu Berlin, D-12489 Berlin, Germany — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Ferromagnet-semiconductor hybrid devices integrate nanoscale magnets with semiconductor nanostructures leading to magnetoelectronic devices with high storage density and reduced energy dissipation. In a ferromagnet-semiconductor hybrid device the resistivity of the semiconductor could be controlled by the ferromagnetic element [1]. Our devices consist of GaAS/AlGaAs heterostructure field effect transistor(HFET) with a ferromagnetic Permalloy(Py) nanogate only 35 nm apart from the GaAs channel. The nanostructuring is done with electron beam lithography and the GaAs channel is patterned by shallow wet etching. The 20 nm thick Py gate is fabricated by electron beam lithography, metal evaporation and lift-off process. The angle-dependent magnetoresistance measurements in external low magnetic fields of the order of 150 mT are done with lock-in technology. The measurements infer a positive magnetoresistance for an external magnetic field applied in the longitudinal direction which is due to the magnetic fringing fields emanating from the Py gate.
[1] J.P.Bird, et al., IEEE Trans, Magn, 44, 4707(2008)

HL 85.38 Thu 18:00 P4

Concept of a ballistic transfer device in a GaAs/AlGaAs 4-terminal structure using electron refraction — •Michael Szelong[1], Daniel Salloch[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum

We present a concept of a ballistic four-terminal device based on electron trajectory refraction, resembling a directional coupler. The device structure consists of a straight stem (1 μm wide and 2 μm long) while two branches merge at each end of the stem under an angle of 45° (27°) with the stem's longer axis of symmetry. Devices with different angles and injector widths are processed on a high-mobility GaAs/AlGaAs heterostructure with a two-dimensional electron density and mobility of $n_{2D} = 2 \cdot 10^{11}\text{cm}^{-2}$ and $\mu = 2.4 \cdot 10^6\text{cm}^2/\text{Vs}$, respectively, resulting in a mean free path of 18 μm at $T = 4.2$ K. A mix-and-match process is used which combines the advantages of nano-scale electron beam lithography with time-saving UV-lithography. The resist pattern is transferred into the heterostructure by wet etching in a citric acid solution. After contact alloying a local Schottky-gate is deposited onto the stem. Electron trajectories, starting at one branch, will be refracted at the boundary of the gate-controlled region according to Snell's law of electron refraction [1]. Depending on the direction of refraction electrons will be reflected more or less often at the stem's boundaries and finally hit one of the opposite branches.
[1] Spector *et al.*, Appl. Phys. Lett. **56**, 2433 (1990)

HL 85.39 Thu 18:00 P4

Preparation of quantum transport in GaAs/AlGaAs core/shell nanowires — •Pascal Heintzmann, Stephan Wirths, Christian Blömers, Karl Weis, Kamil Sladek, Andreas Penz, Hilde Hardtdegen, Stefan Trellenkamp, Thomas Schäpers, and Detlef Grützmacher — Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich, 52425 Jülich, Germany

One of the key advantages of the growth of self assembled nanowires is the possibility to fabricate axial and radial heterostructures in a single growth step. Here we focus on GaAs/AlGaAs core/shell structures in order to achieve one-dimensional electron confinement in the GaAs

core. These core/shell heterostructure nanowires are promising for improved electron mobility due to reduced surface impurity scattering.

The GaAs/AlGaAs nanowires used for our investigations were grown by selective area metal organic vapor phase epitaxy on a GaAs (111) substrate. Our wires consist of a GaAs core surrounded by an intrinsic AlGaAs layer, an n-doped AlGaAs layer, an intrinsic AlGaAs layer and finally a thin GaAs cap layer. For electrical characterization the wires were removed mechanically from the original substrate and subsequently placed on a prepattered SiO_2-covered Si (100) substrate. Each wire was contacted individually with Ni/AuGe/Ni/Au electrodes using electron beam lithography. In order to optimize the contact resistance the nanowires were annealed in a rapid thermal processing furnace for different times and temperatures. By performing 2-terminal and 4-terminal transport measurements information on the contact resistance and nanowire conductivity is obtained.

HL 85.40 Thu 18:00 P4

Effect of the interface structure on the cross-plane thermoelectric transport in laterally microstructured ZnO-based stripe structures — •Steve Petznick, Gerd Homm, Martin Eickhoff, Bruno K. Meyer, and Peter J. Klar — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Deutschland

As a starting material MBE-grown ZnO was used, into which stripe structures perpendicular to the direction of the heat gradient or external electric field, and thus the current, were microstructured using photolithography, followed by wet-chemical etching. After the etching ZnO:Ga was sputtered into the grooves between the host material.

As the current must flow through the interfaces, all interface parameters will effect the transport behavior significantly. The shape of the interfaces of different samples is varied systematically to simulate different surface roughnesses. Temperature dependent measurements of the Seebeck coefficient and the electric conductivity will be performed in the temperature range from 80 K to 300 K. The results will be compared with a theoretical simulation based on a network model and other measurement series.

HL 85.41 Thu 18:00 P4

Electrical transport properties of TiO_2 single nanotube — •Tuhin Subhra Maity[1], José Quiquia[1], Winfried Böhlmann[1], Pablo Esquinazi[1], Tobias Ruff[2], and Patrik Schmuki[2] — [1]Division of Superconductivity and Magnetism, Institute for Experimental Physics II,University of Leipzig — [2]Department of Materials Science and Engineering, University of Erlangen Nüremberg

In the present work we investigate the electrical conductivity of single TiO_2 nanotubes. TiO_2 nanotubes were synthesized by anodization of Ti in fluoride containing electrolytes. For the characterization of the sample morphology scanning electron microscope and EDX-detector was used. The structural property was determined by XRD. Electron lithography method was used to make the gold contact on the nanotubes. The electrical properties of single nanotubes were measured at different temperatures and magnetic fields. Resistivity values at room temperature were found of the order of $\sim 10^{-2}$ Ωcm. Furthermore, we explored the effects of atmospheric conditions and light irradiation on conductivity of single TiO_2 nanotubes.

HL 85.42 Thu 18:00 P4

Temperature dependent transport measurements in quasi-freestanding graphene on SiC(0001) — •Epaminondas Karaissaridis[1], Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Florian Speck[2], and Thomas Seyller[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Technische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg

We report on magneto- and ballistic transport measurements in 2D Hall bars and 1D orthogonal cross junctions fabricated from quasi-freestanding monolayer graphene on SiC(0001).
The investigated films are produced by conversion of the $(6\sqrt{3} \times 6\sqrt{3})$R30° reconstruction into graphene via hydrogen intercalation [1]. The hole concentration of $6 \cdot 10^{12}\,\mathrm{cm}^{-2}$ and a mobility of $1900\,\mathrm{cm}^2(\mathrm{Vs})^{-1}$ are derived from Hall effect measurements at 2D structures. These values are constant in a temperature range of $1.4\,\mathrm{K} \leq T \leq 300\,\mathrm{K}$ and correspond to a constant mean free path of $l_e \approx 50\,\mathrm{nm}$. At $T = 1.4\,\mathrm{K}$ the bend resistance characteristic of the 1D orthogonal cross junctions ($w = 50\,\mathrm{nm}$) shows magnetic field dependent negative peaks indicating ballistic transport. As temperature is increased to $T = 50\,\mathrm{K}$ a transition from the ballistic into the diffusive transport regime is observed. These results demonstrate that additional scattering in 1D systems plays an important role.

[1] F. Speck, *et al.*, Mat. Sci. Forum **645-648**, 629 (2010).

HL 85.43 Thu 18:00 P4

Transport Measurements on Bilayer Graphene Systems — •Alexander W. Heine, Hennrik Schmidt, Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We analyse electronic transport properties of coupled bilayer graphene sheets. Similar to monolayer graphene, bilayer graphene samples show a strong field effect but exhibit a different Berry's phase in Shubnikov-de Haas oscillations. Our samples are prepared by micromechanical exfoliation and placed on top of a silicon wafer with a 330 nm thick layer of silicon dioxide. After that they are contacted using electron beam lithography and structured by plasma etching. Low temperature measurements were performed at temperatures down to 1.5 K in a liquid helium cryostat. The conductivity of the samples shows a strong dependence to an applied backgate voltage. By applying a magnetic field up to 13 T we observed Shubnikov-de Haas oscillations. As expected, the bilayer samples show a Berry's phase different to the one of monolayer graphene. In the vertical resistance plateaus according to the minima of the oscillations are observed with a double step around filling factor zero which is typical for graphene bilayer systems.

HL 85.44 Thu 18:00 P4

Terahertz-Photoleitungsmessungen an Graphen-basierten Strukturen — •Markus Golla[1], Majdi Salman[1,2], Fathi Gouider[1], Yuri.B Vasilyev[3], Hennrik Schmidt[2,4], Rolf. J. Haug[2,4] und Georg Nachtwei[1,2] — [1]Institut für Angewandte Physik, Technische Universität Braunschweig, D-38106 Braunschweig, Germany — [2]Niedersächsische Technische Hochschule, D-38106 Braunschweig, D-38678 Clausthal-Zellerfeld, D-30167 Hannover, Germany — [3]A.F. Ioffe Physical Technical Institute, RUS-194021 St. Petersburg, Russia — [4]Institut für Festkörperphysik, Abt. Nanostrukturen, Leibniz Universität Hannover, D-30167 Hannover, Germany

Wir haben die Photoleitung im THz-Spektralbereich an Graphen-basierten Strukturen gemessen. Um die hier untersuchten Graphen-Proben zu charakterisieren, wurden Messungen des Shubnikov-de Haas-Effekts bei einer Temperatur von $T \approx 4$K und im Bereich der Magnetfelder von $0 \leq B \leq 10$T durchgeführt. Aus diesen Messungen lässt sich die Elektronendichte im Graphen bestimmen. Bei der anschließenden Messung der Photoleitung an den verwendeten Graphenproben wurde zur Erzeugung der THz-Wellen ein p-Ge-Laser verwendet. Dieser ist im Wellenlängenbereich von $120\mu\mathrm{m} \leq \lambda \leq 180\mu\mathrm{m}$ kontinuierlich durchstimmbar. Die monochromatische THz-Strahlung wurde durch einen Wellenleiter, der in flüssigem Helium eingetaucht war, auf unsere Graphen-Probe übertragen.

HL 85.45 Thu 18:00 P4

Thermally activated Transport in Quantum Hall Systems — •Martina Flöser[1], Serge Florens[1], and Thierry Champel[2] — [1]Institut Néel, CNRS-Université Joseph Fourier, Grenoble — [2]LPMMC, CNRS-Université Joseph Fourier, Grenoble

We study the thermally activated charge transport in the regime of the quantum Hall effect, where temperature is smaller than the Landau level spacing, but large compared to the onset of quantum tunneling. We show, using diagrammatic methods within a local conductivity model, that smooth disorder leads to slow fluctuations in the Hall components, and provides a small dissipative conductance. Our results demonstrate a microscopic connection between the macroscopic longitudinal and transverse resistance and the disorder distribution, which can be tested experimentally by simultaneous transport and local spectroscopy measurements.

HL 85.46 Thu 18:00 P4

Transport properties of InAs spin-filter cascades in magnetic fields of different directions and strengths — •Hauke Lehmann, Till Benter, Alexander Buhr, and Jan Jacob — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

We present a three-terminal all-semiconductor nanostructure fabricated from an InAs heterostructure, which separates an unpolarized current into two oppositely spin-polarized currents of equal magnitude by the intrinsic spin Hall effect. If this device is fed with an already spin-polarized current, the conductances of its two outputs are different enabling all-electrical detection of the spin polarization in two-stage

spin-filter cascades [1]. The transport measurements are conducted at millikelvin temperatures in a DC-biased lock-in technique. Magnetic fields perpendicular to the two-dimensional electron system introduce a Lorenz force that allows inference on the strength of the intrinsic spin Hall effect. In-plane fields normal to the direction of the electrons' motion change the spin-orbit coupling. If the field is applied normal to the center wire that connects the two filter stages, the spin precession length is changed leading to oscillations in the conductance fractions of the second filter's outputs [2]. By applying the field normal to the input wire the separation of spin-up and spin-down electrons in this wire can be tuned.

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

[2] P. Brusheim and H. Q. Xu, arXiv: 0810.2186v2 (2009).

HL 85.47 Thu 18:00 P4

Room-temperature nanosecond spin-lifetimes in bulk cubic GaN — Jan Heye Buss[1], Jörg Rudolph[1], •Jeanette Gorewoda[1], Thorsten Schupp[2], Donat As[2], and Daniel Hägele[1] — [1]AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany — [2]Universität Paderborn, Department Physik, Warburger Str. 100, 33095 Paderborn, Germany

The metastable zincblende phase of GaN is a highly interesting material system for semiconductor spintronics due to its small spin-orbit coupling. Systematic investigations of the electron spin dynamics are, however, missing so far. We present time-resolved Kerr-rotation measurements of the temperature and magnetic field dependence of electron spin relaxation in moderately n-doped cubic GaN samples and compare the results with the electron spin dynamics in wurtzite GaN. The higher cubic symmetry of the zincblende phase is shown to lead to significantly slower spin relaxation than in the wurtzite phase with hexagonal symmetry. The room-temperature spin-lifetimes of > 2 ns exceed all values reported for III-V bulk materials so far.

HL 85.48 Thu 18:00 P4

Basic design of a three-terminal semiconductor structure for electrical spin-storage and read-out — •Johannes Zeller, Rouven Diehm, Pablo Asshoff, Andreas Merz, Heinz Kalt, and Michael Hetterich — Karlsruhe Institute of Technology (KIT)

In recent years, spin light-emitting diodes have become well-established devices in the spintronics community. In this contribution, we discuss a novel structure design allowing for spin-injection, prolonged spin-storage and spin-readout with all of these processes controlled individually and all-electrically. This structure consists of a diluted magnetic semiconductor as spin-injector and quantum dots which are selectively loaded with either electrons or holes.

HL 85.49 Thu 18:00 P4

Silicon pin solar cells investigated by multi-frequency EDMR — •Christoph Meier[1], Christian Teutloff[1], Jan Behrends[1], Matthias Fehr[2], Alexander Schnegg[2], Klaus Lips[2], and Robert Bittl[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Silizium-Photovoltaik, Helmholtz-Zentrum Berlin für Materialien und Energie, Kekuléstr. 5, 12489 Berlin, Germany

Electrically detected magnetic resonance (EDMR) can be used to investigate paramagnetic centres influencing charge transport in semiconductors even at concentrations well below the sensitivity threshold of conventional electron paramagnetic resonance (EPR). This technique measures conductivity changes in the sample that occur when spin transitions cause an enhancement or a quenching of currents. EDMR was e.g. successfully employed to microcrystalline Si pin solar cells in X-band (9.7 GHz). We present the application of EDMR to Si pin solar cells at Q-band frequency (34 GHz). We could demonstrate a gain of spectral resolution. With multi-frequency EDMR we distinguished between field-dependent and field-independent interactions. Further, we realized EDMR in a non-resonant setup at 94 GHz (W-band) and will show first results.

HL 85.50 Thu 18:00 P4

Low-temperature processed Schottky-gated field-effect transistors based on amorphous oxide channel material — •Michael Lorenz[1], Alexander Lajn[1], Heiko Frenzel[1], Holger von Wenckstern[1], Marius Grundmann[1], Pedro Barquinha[2], Elvira Fortunato[2], and Rodrigo Martins[2] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]CENIMAT/I3N, Departamento de Ciência dos Materiais, Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa and CEMOP-UNINOVA, 2829-516 Caparica, Portugal

We demonstrate metal-semiconductor field-effect transistors based on room temperature deposited indium-zinc-oxide and gallium-indium-zinc-oxide channel material on Corning 1737 glass substrates by radio-frequency magnetron sputtering. The devices were processed by standard photolithography using lift-off technique and metalization of the electrodes was accomplished by dc-magnetron sputtering. The best devices exhibit a subthreshold swing of S = 69 mV/decade and gate sweep voltages of 1.6 V, reach field-effect mobilities up to 15 cm^2/Vs and on-off-current ratios over 8 orders of magnitude [1]. The influence of a low temperature annealing step ($T = 150°C$) for the thin-films is furthermore investigated.

[1] M. Lorenz et al., Appl. Phys. Lett., *in press* (2010)

HL 85.51 Thu 18:00 P4

First Principles Investigation of La incorporation in high-κ Dielectric Film of the Field Effect Transistors — •Ebrahim Nadimi[1], Rolf Öttking[2], Philipp Plänitz[2], Martin Trentzsch[3], Torben Kelwing[3], Rick Carter[3], Christian Radehaus[2], and Michael Schreiber[1] — [1]Institut für Physik, Technische Universität Chemnitz — [2]GWT TU Dresden GmbH, Geschäftsstelle Chemnitz — [3]Global Foundries, Dresden

The introduction of high-k dielectric and metal gate in silicon field effect transistors (FETs) has involved many challenges. The key requirements are threshold voltage adjustment, reliability of the gate dielectric, low leakage and high channel mobility. Incorporation of metals such as La, Sr, Nb and Mg into thin HfO2 film has been shown to improve the device in terms of threshold voltage, reliability and leakage current. In this work La doping into the HfO2 were investigated on microscopic level using first principles method. Our calculations show that the doped La atoms are energetically favorable when they replace Hf atoms in the first neighboring lattice site of an oxygen vacancy. Furthermore, their interaction with oxygen vacancy leads to the passivation of O-vacancy defect states. Further calculations in multilayer system (Si/SiO2/HfO2) reveal that La atoms tend to migrate into the SiO2/HfO2 interface. This leads to an induced dipole at the interface, which is responsible for the desirable shift in the band alignment. This work was supported by the German ministry of education and research BMBF under SIMKON project Grant No. 01M3138A. The authors are responsible for the content of this paper.

HL 85.52 Thu 18:00 P4

Transverse thermoelectric devices — •Christina Reitmaier and Hans Lengfellner — University of Regensburg, 93053 Regensburg, Germany

Multilayer structures A−B−A... consisting of alternating layers of a metal A and a semiconductor B can show large anisotropy in their transport properties, depending on the properties of the constituents. Multilayer stacks, prepared of alternating layers of Pb and n-type Bi_2Te_3, were obtained by a heating procedure. Depending on thickness ratio $p = d_{BiTe}/d_{Pb}$, where d_{BiTe} and d_{Pb} are the thicknesses of Bi_2Te_3 and Pb layers, respectively, a large thermoelectric anisotropy up to $\Delta S \approx 200\mu V/K$ was observed. In tilted multilayer structures, where layer planes and sample surface include a nonzero tilt angle, non-vanishing off-diagonal elements in the sample's transport tensors lead to transverse Seebeck- and Peltier effects. Achievable temperature differences and figures of merit for transverse Peltier cooling are discussed and compared with experiments, coefficients of performance for transverse power generation are calculated.

HL 85.53 Thu 18:00 P4

Cascading enables ultrafast gain recovery dynamics of quantum dot semiconductor optical amplifiers — •Niels Majer, Kathy Lüdge, and Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Optoelectronic devices based on semiconductor quantum dots are promising candidates for future high speed telecom applications with low operation currents, high temperature stability, low chirp and ultrafast gain recovery dynamics and hence pattern effect free amplification at high bit rates. In this work [1] the ultrafast gain recovery dynamics of a quantum dot semiconductor optical amplifier is investigated on the basis of semiconductor Bloch equations including microscopically calculated carrier-carrier scattering rates between the 2D carrier reser-

voir and the confined quantum dot ground and first excited state. By analyzing the different scattering contributions we show that the cascading process makes a major contribution to the ultrafast recovery dynamics.
[1] N. Majer, K. Lüdge, and E. Schöll, Phys. Rev. B **82** (2010), in print.

HL 85.54 Thu 18:00 P4

Influence of interface roughness on relaxation rates and optical gain in a quantum cascade laser — •Milan Žeželj[1], Vitomir Milanović[2], Jelena Radovanović[2], and Igor Stanković[1] — [1]Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia — [2]Faculty of Electrical Engineering, University of Belgrade, Bul. kralja Aleksandara 73, 11020 Belgrade, Serbia

We present a model for calculating the optical gain in a midinfrared GaAs/AlGaAs quantum cascade laser in a magnetic field, based on solving the set of rate equations that describe the carrier density in each level, accounting for the optical-phonon and interface roughness scattering processes. The confinement caused by the magnetic field strongly modifies the lifetimes of electrons in the excited state and results in pronounced oscillations of the optical gain as a function of the field. Numerical results are presented for the structure designed to emit at 11.4μm, with the magnetic field varying in the range of 10-60T, mean height of roughness is 0.15nm and correlation length 6nm. The effects of band nonparabolicity are also included. The conclusion of presented work is that influence of interface roughness scattering is not negligible and it gives a very important contribution in calculating optical gain of quantum cascade laser.

HL 85.55 Thu 18:00 P4

Optical Characteristics of an InP/AlGaInP quantum dot laser emitting at 660 nm — •Jan Wagner, Wolfgang-Michael Schulz, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Semiconductor quantum dot (QD) laser diodes have gained much interest in recent years due to their superiority in many properties over regular quantum well (QW) lasers. Especially in the visible red spectral range (630-710 nm) QD laser would enhance applications like data storage, medical applications e.g. photodynamic therapy (PDT), pumping solid state lasers or display applications e.g. laser projection. Theory predicts better properties compared to standard quantum well (QW) lasers due to the zero-dimensional character of the structure. For example lower threshold current density, higher differential gain, and higher temperature stability are expected. We characterized electrically pulsed InP/AlGaInP quantum dot lasers with different length at different operating parameters, which are pulse width, frequency and temperature. We achieved lasing operation at room temperature with a relatively low threshold current density of 792 A/cm^2 and a lasing wavelength of 660 nm with an optical output power of more than 41 mW per facet.

HL 85.56 Thu 18:00 P4

1550 nm quantum dot lasers with high modal gain — Christian Gilfert, •Vitalii Ivanov, and Johann Peter Reithmaier — Technische Physik, Institute of Nanostructure Technologies and Analytics, University of Kassel, Heinrich-Plett Str. 40, D-34132 Kassel, Germany

In the last years a strong effort was made in the development of InP based quantum dot (QD) structures to obtain high performance 1550 nm lasers. However, most of the work is related to QDash active materials. In this work the conditions for the formation of InAs QDs and QDashes on the quaternary InAlGaAs surfaces, lattice-matched to n-type InP (100) were investigated. It could be shown that the supply of different types of As molecules allow to switch between QDs and QDashes growth modes. A formation of rather round-shaped dots was observed under As2 atmosphere. These new type of QD layers exhibited a significantly reduced height distribution, which reduces the inhomogeneous linewidth to about 23 meV (see APL 96, 191903 (2010)). Based on these QD structures diode lasers with an SCH design were realized. The laser structure consists of 6 QD layers embedded in an InGaAlAs core waveguide and 1700 nm InP top cladding layer. The QD lasers exhibit a low internal absorption of 8 cm-1 and a rather high modal gain of about 60 cm-1, which is nearly a factor of two higher than for any other reported comparable InP based QD laser. We attribute this strong improvement to a much higher spectral gain, which is consistent with the observed very narrow photoluminescence linewidth.

HL 85.57 Thu 18:00 P4

Gain and reflectance measurements of a 1050nm VECSEL chip — •Sebastian Haupt[1,2], Michael Furitsch[1], Hans Lindberg[1], Ines Pietzonka[1], Uwe Strauss[1], and Gerd Bacher[2] — [1]Osram Opto Semiconductors GmbH , Leibnitzstrasse 4, 93055 Regensburg — [2]WET Universität Duisburg-Essen , 47057 Duisburg

Optically pumped Vertical External Cavity Surface Emitting Lasers (VECSELs) have a wide range of applications due to a combination of output power, high efficiency and a good beam quality in the infrared spectral range. Furthermore the visible spectrum is accessible with intra cavity frequency-doubling.

We will present a method to measure the gain of a 1050 nm VECSEL chip based on a resonant periodic gain (RPG) structure with a reflectance measurement. In the case of a VECSEL the reflectance is determined by the Bragg mirror reflectance and the quantum wells. The reflectance is less than one for carrier densities below transparency and more than one above transparency. In this latter we have an amplification of the light and hence a net gain.

This method has enabled us to measure the gain for a wide spectral, pumping power and temperature range. Additionally we study the influence of different VECSEL Chip anti reflection coatings. The measured gain curves are to be found in good agreement with experiments in laser operation.

HL 85.58 Thu 18:00 P4

Biofunctionalization of ZnO nanowires for DNA sensory applications — Ulrich Christian Schröder[1], •Martin Gnauck[1], Robert Möller[2], Bettina Rudolph[2], Wolfgang Fritzsche[2], and Carsten Ronning[1] — [1]Institute of Solid State Physics, University of Jena, Max-Wien-Platz 1, D-07743 Jena — [2]Institut für Photonische Technologien e.V., Albert-Einstein-Straße 9, D-07745 Jena

In recent years, DNA detecting systems have received a growing interest due to promising fields of application like DNA diagnostics, gene analysis, virus detection or forensic applications[1]. Nanowire-based DNA biosensor allows both miniaturization and easy continuous monitoring of a detection signal by electrical means. The label free detection scheme based on electrochemical changes of the surface potential during immobilization of specific DNA probes was heretofore mainly studied for silicon [2]. In this work a surface decoration process with bifunctional molecules known as silanization was applied to VLS-grown ZnO nanowires which both feature a large sensitivity for surface modification, are biocompatible and easy to synthesize as well. Successfully bound DNA was proved by fluorescence microscopy. Dielectrophoresis (DEP) was chosen and optimized for quickly contacting the ZnO nanowires. Furthermore, electrical signal characterization was performed in preparation for DNA sensory applications.

[1] Sassolas, A.; Leca-Bouvier, B. D. & Blum, L. J., Chemical Reviews, Amer Chemical Soc, 2008, 108, 109-139; [2] Corso, C. D.; Dickherber, A. & Hunt, W. D., Elsevier Advanced Technology, 2008, 24, 805-811

HL 85.59 Thu 18:00 P4

Preparation and immobilization of noble metal nanoparticles for plasmonic solar cells — •Ruoli Wang[1,2], Martin Pitzer[1,2], DongZhi Hu[1,2], Daniel M. Schaadt[1,2], and Ljiljana Fruk[2] — [1]Institut für Angewandte Physik,Karlsruhe Institut für Technologie (KIT),76131 Karlsruhe — [2]DFG Centrum für Funktionelle Nanostrukturen (CFN), KIT

Thin-film solar cells are of high interest due to good electrical properties and low material consumption. Traditional thin-film cells, however, have considerable transmission losses because of the reduced absorption volume. A promising way to enhance absorption in the active layer is the light-trapping by plasmonic nanostructures. Metallic nanoparticles have in particular shown large enhancement of the photocurrent in thin-film devices. In this poster, we present preparation of Au,Ag and Pt nanoparticles by polyol method and seed mediated methods for use in plasmonic solar cells. Polyol method typically uses ethylene glycol as the solvent and reducing agent,and in seed-mediated synthesis small nanoparticle seeds are first prepared and then used to promote the growth of different shapes of nanoparticles. We particulary focus on the use of nanocubes and nanospheres for solar cell design. Following the nanoparticle preparation, a new method to immobilize particles on GaAs surfaces via covalent chemical bonds has been developed which prevents agglomerations and allows control of

the surface density. Photocurrent spectra of GaAs pin solar cells with and without particles have been recorded. These measurements show the dependence of the photocurrent enhancement on particle material, shape and density.

HL 85.60 Thu 18:00 P4

Semiconductor-Insulator-Semiconductor solar cells on wet-chemically etched silicon nanowire carpets using different tunnel barrier materials — •Martin Schreivogel[1], Björn Hoffmann[1], Gerald Brönstrup[1], Vladimir Sivakov[1], and Silke Christiansen[1,2] — [1]Institut für Photonische Technologien, Jena — [2]Max-Planck-Institut für die Physik des Lichts, Erlangen

Nanostructured semiconductor substrates are an intensively investigated possibility to improve solar cell performance. For this purpose we prepare chemically etched silicon nanowire carpets with adjustable geometrical structure. The etching process is cheap and easily scalable, is performed at room temperature and uses no photolithography-step. The produced nanowire carpets show high absorption over a broad spectral range. The nanowires are used as substrate for semiconductor-insulator-semiconductor (SIS) solar cells. Therefore we generate a very thin layer of an insulating oxide on the nanowires and deposit a transparent conductive oxide (TCO) as top electrode. The insulating tunnel barrier is prepared either by chemically oxidizing the substrate material receiving silicon oxide or by depositing aluminium oxide by atomic layer deposition (ALD). Sputtered or ALD-Aluminum-doped zinc oxide (AZO) is used as TCO. We characterize the solar cells by I-V-curve measurements and calculation of the pseudo efficiency, which is reproducibly more than 8%. The structure of the produced devices is investigated by SEM and FIB. To prove the electrical contribution of the nanowires we performed electron beam induced current (EBIC) measurements on solar cell cross sections.

HL 85.61 Thu 18:00 P4

Crystallographic structure and grain size of polycrystalline Cu_2ZnSnS_4 nanoparticles and thin films studied with XRD and SEM — •Folker Zutz, Christine Chory, Ingo Riedel, and Jürgen Parisi — Thin Film Photovoltaics, Energy and Semiconductor Research Laboratory, University of Oldenburg, D-26111 Oldenburg

Cu_2ZnSnS_4 (CZTS) is a compound semiconductor with an absorption coefficient of $>10^4 cm^{-1}$ and energy gap of about 1.5 eV. Because CZTS is comprised of abundant and non-toxic precursor elements the semiconductor represents an attractive material for low-cost thin film solar cells. CZTS nanoparticles (NP) were prepared in a low-temperature colloidal synthesis yielding high amounts per synthesis cycle. For thin film deposition the NPs were converted to an ink which can be processed to thin films via printing techniques. Finally, the thin films were annealed in argon atmosphere at different temperatures in order to control the growth of microcrystallites. The photoelectrical quality of the semiconductor sensitively depends on the relative concentrations of the precursor elements (band gap, crystallographic phases) and the average grain size (charge transport). We report on structural investigations (X-ray diffraction, electron microscopy) of CZTS dried powders and thin films processed from inks with varying chemical compositions. Further, the evolution of the grain size was studied as function of the annealing temperature.

HL 85.62 Thu 18:00 P4

Spatially resolved photoluminescence and AFM measurements on Cu(In,Ga)Se_2-based thin film absorbers prepared with different throughput speeds — •Max Meessen[1], Oliver Neumann[1], Stephan J. Heise[1], Rudolf Brüggemann[1], Wolfram Witte[2], Dimitrios Hariskos[2], and Gottfried H. Bauer[1] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany

We study the behavior and interdependence of quantities such as photoluminescence (PL) yield, quasi-Fermi level splitting and AFM-determined surface roughness on CIGS thin-film absorbers with different thicknesses between 0.25 and 3 μm achieved by varying the throughput speed in an in-line physical vapor deposition (PVD) process. These quantities are studied on the macroscopic as well as on the microscopic scale with a resolution of approximately 1 μm. It is shown that the structural sizes of the inhomogeneities of the absorber layer itself and its lateral photoluminescence properties decrease with decreasing absorber thickness. These results are compared to those on samples thinned by bromine-methanol etching.

Furthermore, we show that varying the thickness of the CdS buffer layer on top of the absorber influences surface recombination and thereby PL yield and quasi-Fermi level splitting. A decrease in surface recombination at higher buffer thicknesses has to be weighed against the increase in absorption in the buffer layer, which in turn decreases carrier generation in the absorber layer.

HL 85.63 Thu 18:00 P4

Variation of sulfur content in Cu(In,Ga)(S,Se)2 thin film solar cells — •Martin Knipper, Robin Knecht, Ingo Riedel, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany

Chalcopyrite thin film solar cells made of the compound semiconductor Cu(In,Ga)$(S,Se)_2$ (CIGSSe) have a strong potential for achieving high efficiencies at low production costs. Volume production of CIGSSe-modules has already started to exploit their favorable attributes such as low cost processing and reasonable module efficiency. In this study we studied industrially produced CIGSSe modules obtained from rapid thermal processing (RTP) for sulfurization. In detail, we investigated the effect of sulfur offer and RTP temperature (500°C to 580°C) on the photoelectric characteristics of small-area solar cells cut from the modules. Current-voltage profiling under standard test conditions revealed a strong influence of the particular process recipe on the open circuit voltage whereas significant variations of the maximum quantum efficiency can be observed. X-ray diffraction was employed to relate these effects to the crystallographic structure of the actual CIGSSe films. Lock-in thermographic imaging was employed to link apparent film inhomogeneities and disruptions to the specific process recipe.

HL 85.64 Thu 18:00 P4

Series resistance mapping of Cu(In,Ga)Se_2 solar cells by voltage dependent electroluminescence — •Felix Daume[1,2], Christian Scheit[1], Stefan Puttnins[1,2], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, 04288 Leipzig, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 5, 04103 Leipzig, Germany

Cu(In,Ga)Se_2 (CIGSe) thin film solar cells deposited on flexible polyimide foil promising innovative applications and a fabrication in continuous roll-to-roll processes currently reach efficiencies up to 17.6 %.

The optimization of the solar cell efficiency requires the reduction of inherent losses in the cell. In order to achieve this goal preferably spatially resolved access to parameters characterizing ohmic losses like series and shunt resistances are indispensable.

We will apply an interpretation method for electroluminescence (EL) images taken at different voltages which is known for solar cells made of crystalline silicon from literature to solar cells made of polycrystalline CIGSe. The theory of this method to obtain a mapping of the series resistance and the EL imaging process as well as the data interpretation will be reviewed and demonstrated on an example. Furthermore, the benefit of this method for the characterization of solar cells under accelerated aging conditions (damp heat) which is important for the estimation of the long-term stability will be shown.

HL 85.65 Thu 18:00 P4

A theoretical investigation on the Cd doping of $CuIn_5Se_8$ — •Janos Kiss, Thomas Gruhn, and Claudia Felser — Institut für Anorganische Chemie und Analytische Chemie, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

Due to its attractive optical, electrical, and chemical properties the ternary $CuInSe_2$ (CIS) chalcopyrite-type semiconductor is widely employed as absorber layer in thin film photovoltaic devices. In the industrial fabrication of thin film solar cells on top of the CIS layer a CdS films is deposited as buffer layer. Despite the exhaustive experimental and theoretical research, the atomic and electronic structure of the CIS–CdS interface is not well understood due to its complex nature. In the contemporary literature it is well accepted that the CIS surface regions are Cu-depleted and doped with Cd through the diffusion of Cd atoms from the buffer layer. Still, the concentration of the Cd dopant atoms and their arrangement in the Cu-depleted CIS is not yet unambiguously determined. To gain new insights on the doping of Cu-depleted CIS phases, we have investigated the Cd doping of bulk $CuIn_5Se_8$ via performing density functional theory (DFT) calculations on large supercells. We found that bulk $CuIn_5Se_8$ can be doped with Cd up to a Cd concentration of about 0.6–0.8%. Moreover, our calculations show that energetically it is favorable for Cd dopant atoms to occupy Cu antisites in $CuIn_5Se_8$.

HL 85.66 Thu 18:00 P4

Preparation and characterization of Bi_2S_3 thin films grown with the hot-wall deposition method — •Sebastian ten Haaf and Gerhard Jakob — Institut für Physik, Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany

As a first step in the search for new absorbing materials in inorganic thin film photovoltaics with the benefit of reduced costs in comparison to currently used CIGS, polycrystalline Bi_2S_3 was deposited in vacuum and examined for its suitability for solar cells.

The bismuth sulfide thin films were grown in a recently designed ultra high vacuum chamber with the hot-wall deposition method under conditions close to thermodynamic equilibrium on ITO coated glass substrates with variation of substrate, wall and source temperature.

For further structural characterization, Bi_2S_3 was additionally deposited on epitaxial $LaAlO_3$ and $SrTiO_3$ substrates in order to enhance directional growth of the thin films.

HL 85.67 Thu 18:00 P4

Optical and Electrical Characterization of InP-based Low Bandgap Multijunction Solar Cells — •Anja Dobrich, Nadine Szabó, Klaus Schwarzburg, and Thomas Hannappel — Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin, Germany

At present, III-V triple junction (3J) solar cells are achieving the highest conversion efficiencies (η=41.6%) worldwide. The current record multi junction solar cell grown on germanium, having Ge, Ga(In)As and GaInP as subcells, but still considerably higher efficiencies can be achieved with a four junction (4J) 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 have grown InGaAsP/InGaAs tandem solar cells lattice-matched to InP by MOVPE.

The lifetime of minority charge carriers affects strongly the performance of solar cells, hence it is one of the most important properties of photovoltaic absorbers. Results of minority carrier lifetime measurements for the IR-bandgap compounds InGaAsP (1.03 eV) / InGaAs (0.73 eV) are presented. This technique is sensitive for both, the quality of the bulk material within the double hetero structure (DHS) as well as the interface preparation between barrier and bulk. Furthermore, by scanning the sample, spatial inhomogeneities in the lifetime can be detected. We show the effect of different interface preparation routines on the minority charge carrier lifetime.

HL 85.68 Thu 18:00 P4

Herstellung, Kontaktierung und Charakterisierung von GaAs Mikro-Photovoltaikzellen — •Michael Kwiatek, Arne Ludwig, Rüdiger Schott und Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

In den letzten Jahren hat die Bedeutung von alternativen und regenerativen Energiequellen für den zentralen Energiebedarf immer weiter zugenommen. Doch besonders auch für dezentrale Energieversorgungslösungen eignet sich die Photovoltaikzelle als möglicher Weg.

In der Informationstechnologie werden derzeit die Weichen zur stärkeren Einbindung optischer Übertragungswege gestellt. So können größere Distanzen mit höherer Bandbreite zurückgelegt werden. Ein Problem stellt sich hier jedoch in der Energieversorgung der angeschlossenen Endgeräte.

Dieser Beitrag zeigt die ersten Ergebnisse der hergestellten Mikro-Photovoltaikzellen auf GaAs Basis. Im Speziellen wird auch die Möglichkeit erörtert, kleinere Chipsysteme, wie Flashspeicher, über eine optische Faser mit genügend Energie zu versorgen um ihre Funktionalität unabhängig von stark längenbeschränkten Kupferzuleitungen zu gewährleisten. Außerdem ergibt sich durch die vollständige galvanische Trennung von Sender und optisch angesteuertem Endgerät eine höhere Unanfälligkeit beziehungsweise Unempfindlichkeit gegenüber Störungen und Potentialschwankungen.

HL 85.69 Thu 18:00 P4

Electroluminescence of Thin Film Silicon Solar Cells — •Viola Mönkemöller[1], Matthias Niederkrüger[2], Helmut Stiebig[2], and Ulrich Heinzmann[1] — [1]Molecular and Surface Physics, Bielefeld University — [2]Malibu GmbH & Co. KG, Bielefeld

Electroluminescence (EL) and Dark-Lock-In-Thermography (DLIT) are commonly used methods to characterize crystalline silicon solar modules.

We have applied these methods to analyze thin-film silicon-PV-mini-modules based on amorphous silicon (a-Si) and microcrystalline silicon (μc-Si).

DLIT shows the heat dissipation of the solar cell which originates mainly from the ohmic losses in the Transparent Conductive Oxide (TCO). Defects e.g. electrical short cuts of the cell (shunts) provide a large DLIT signal, due to the high temperature caused by the increased current. In contrast EL shows effects of the semiconductor material. Shunts caused by dust particles in the thin film appear as dark lateral spots since less luminescent recombination takes place.

Furthermore EL allows the distinguishing between a-Si and μc-Si. The different semiconductor band gaps lead to different emission spectra ($\lambda_{\mu c-Si} > \lambda_{a-Si}$). Using adequate filters this behavior leads to the analysis of the individual diodes of tandem modules.

In general EL and DLIT show a similar image of a systematic signal distribution. This effect results from the inhomogeneous voltage and current distribution across the cells in the semiconductor and TCO which is caused by the integrated series connection.

HL 85.70 Thu 18:00 P4

Metal-assisted Chemical Etching of Multicrystalline Silicon Wafers for Solar Cell Application — •Xiaopeng Li[1,2], Stefan L. Schweizer[2], and Ralf B. Wehrspohn[2,3] — [1]Max-Planck Institute of Microstructure Physics — [2]Martin-Luther-Universität Halle-Wittenberg — [3]Fraunhofer Institute for Mechanics of Materials

Metal-assisted Chemical Etching (MaCE) has been proved as a cost-effective route to create semiconductor nanostructures. In this study, MaCE was employed to texturize different kinds of multicrystalline silicon (mc-Si). Noble nanoparticles were firstly deposited on the non-polished mc-Si by a galvanic displacement reaction, and then further acted as catalysts for silicon etching in a solution containing HF and DI water. By using different metal nanoparticles (Ag, Au, Pt and Pd), we obtained various nano/micro structures on the mc-Si surface, including nanoporous layer, nanowire, and cone-shaped microstructures. These silicon structures are formed independent of crystal orientation and uniform in the wafer size, which exhibited strong light-trap capabilities. This has the potential to allow three dimensional p-n junction to achieve more efficient mc-Si solar cell.

HL 85.71 Thu 18:00 P4

Semi-coherent optical modelling of thin film silicon solar cells — •Cordula Walder, Jürgen Lacombe, Karsten von Maydell, and Carsten Agert — NEXT ENERGY, EWE-Forschungszentrum für Energietechnologie e.V., Carl-von-Ossietzky-Straße 15, 26129 Oldenburg, Germany

At NEXT ENERGY the experimental investigation of thin film silicon solar cells is combined with numerical simulations using the software Sentaurus TCAD from Synopsys. We present the results of optical modelling with Sentaurus TCAD based on the one-dimensional semi-coherent optical model by Janez Krč [1]. The idea of this model is that after interacting with a rough interface the incident light is split into a direct coherent part treated as electromagnetic waves and in a diffuse incoherent part treated as light beams. The proportion of either direct or diffuse part is determined by the haze parameter which can be obtained from spectrometer data. In order to describe the scattering effects at rough interfaces the intensities of the diffuse light are scaled with angular distribution functions. These functions are obtained from angle resolved scattering measurements.

The optical model will be verified by experimental data and compared to the Raytracer and the Transfer Matrix Model. Furthermore the influence of different angles of incidence and of the spectral dependency on the solar cell performance will be investigated.

[1] J. Krč, F. Smole, M. Topič. One-dimensional semi-coherent optical model for thin-film solar cells with rough interfaces. Informacije MIDEM 2002; 32(1): 6-13.

HL 85.72 Thu 18:00 P4

Texturing transparent conductive oxide (TCO) and use of antireflective (AR) coating to optimize light-trapping in amorphous silicon thin film solar cells (a-Si:H) for high stabilized efficiencies: A simulative Approach — •Kambulakwao Chakanga — NEXT ENERGY, EWE-Forschungszentrum für Energietechnologie e.V.

The advantages of the a-Si:H technology range from low material consumption, less manufacturing energy required, possibility of efficient rapid mass production to the abundance of the raw material silicon. One major drawback of the a-Si:H pin structure is the light induced

degradation (Staebler-Wronski effect) which causes a reduction in the efficiency. The effect is profound in cells with thick intrinsic layers. Thus thinner layers are desirable which however constraints the short-circuit current density. The required light-trapping can be achieved by implementing AR, textured TCO and back contact (BC).

This study aims to reduce the intrinsic layer by implementing an effective light coupling using a simulative approach. The software Sentaurus TCAD is used to model the optical behavior of the a-Si:H pin cell consisting of AR/glass/TCO/pin/BC using numerical models. Successful simulation can illustrate the behavior of fictitious structures and permit a better understanding of the physical processes. Hence it would be possible to predict the ideal system that would provide an effective light trapping for a given absorber thickness. Emphasis is put on light scattering effect of various TCO surface structures and AR on the performance of the cell.

HL 85.73 Thu 18:00 P4

Epitaktische Kristallisation von Silicium mit einem Diodenlaser — •Thomas Schmidt, Gudrun Andrä und Fritz Falk — Institut für Photonische Technologien e.V., Jena, Deutschland

Dünnschichtsolarzellen aus kristallinem Silicium sind eine günstige Alternative zu Waferzellen. Multikristalline Dünnschichtzellen aus Silicium auf einem Substrat aus Borosilikat–Glas können mit Hilfe eines laserinduzierten Epitaxieprozesses hergestellt werden.

Es werden Ergebnisse präsentiert, bei denen durch Diodenlaserbestrahlung von amorphem Silicium sowohl auf einkristallinen Substraten als auch auf polykristallinen Schichten (Korngrößen $> 100\,\mu$m) epitaktisches Wachstum erreicht werden konnte. Die Epitaxie fand dabei durch Erstarren der geschmolzenen Phase oder durch direkte Festphasenumwandlung des amorphen Materials im ms– bis s–Bereich statt. Durch Messung der Reflektivität während der Bestrahlung zusammen mit numerischen Simulationen konnte dabei der Kristallisationsvorgang zeitaufgelöst verfolgt werden.

HL 85.74 Thu 18:00 P4

Epitaxie auf kristallinem Silizium durch Excimer-Laser Bestrahlung — •Ingo Sill, Gudrun Andrä und Fritz Falk — Institut für Photonische Technologien e.V., Jena

Dünnschichtsolarzellen aus kristallinem Silizium sind eine günstige Alternative zu Waferzellen. Multikristalline Dünnschichtzellen aus Silizium auf einem Substrat aus Borosilicat-Glas können mit Hilfe des LLC Prozesses (Layered Laser Crystallization) hergestellt werden. In diesem Prozess wird eine hoch Bor-dotierte a-Si Schicht durch einen cw-Diodenlaser kristallisiert, sodass Kristallite in der Größenordnung von 100 μm entstehen. Diese Keimschicht wird anschließend epitaktisch verdickt, indem darauf Bor-dotiertes a-Si durch Elektronenstrahlverdampfen abgeschieden und gleichzeitig das a-Si durch wiederholtes Bestrahlen mit dem Puls eines Excimer-Lasers epitaktisch kristallisiert wird. Um den Prozess hinsichtlich der Abscheidung großer a-Si Schichtdicken zwischen den einzelnen Laserpulsen und geringer Substrattemperatur optimieren zu können, wurde ein einzelner Kristallisationsschritt untersucht. Dabei wurde die Keimschichtdicke, die a-Si Dicke, die Substrattemperatur und die Fluenz des Excimer-Lasers variiert, um die Abhängigkeit des Epitaxieintervalls von diesen Parametern zu messen und zu verstehen. Experimentelle Ergebnisse werden mit Simulationsrechnungen verglichen.

HL 85.75 Thu 18:00 P4

Thickening of polycrystalline silicon layers by solid phase epitaxy — •Ingmar Höger, Annett Gawlik, and Fritz Falk — Institut für Photonische Technologien, Albert-Einstein-Str. 9, D-07745 Jena, Germany

Crystalline silicon solar cells on glass substrates are considered to be an alternative to well established wafer-based concepts due to their potentials for cost reduction. This work deals with a seed-layer approach to obtain thin silicon films. First of all an amorphous silicon layer is deposited on bare glass substrates. Diode-laser crystallization by means of continuous-wave irradiation results in grain diameters of 100 μm. Next, the absorber gets deposited by high rate electron beam evaporation which needs to be crystallized via solid phase epitaxy in a tube furnace at temperatures around 600 °C. In this way the crystallographic information of the seed-layer can be transferred to absorbers up to 1,5 μm in thickness. The maximum thickness is limited by the onset of nucleation in the amorphous material beginning after a certain retardation time and leading to crystallites several micrometers in seize. The kinetics of the solid phase epitaxy strongly depends on crystallographic orientation, doping concentrations and the a-Si preparation conditions. In order to prevent the formation of defects the interface between seed and absorber layer needs to be clean as well.

HL 85.76 Thu 18:00 P4

Time-resolved photoluminescence imaging of silicon wafers using a CCD camera — •David Kiliani, Gabriel Micard, Bernd Raabe, and Giso Hahn — Abteilung Photovoltaik, Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

A method to record and evaluate time-resolved photoluminescence images of crystalline silicon wafers using a standard silicon-CCD camera was developed. The use of a fast rotating shutter wheel decouples the obtained temporal resolution from the camera exposure time, making it possible to record the decay curve of free minority charge carriers. The transient curve for each pixel is determined from a set of photoluminescence images, making the method calibration-free and much faster than measurements of microwave-detected photoconductance. Lifetime maps for different injection levels can be calculated and show good agreement with steady-state photoluminescence images and quasi-steady-state photoconductance measurements. Compared with dynamic methods using a CMOS camera, a high spatial resolution at much lower equipment cost can be obtained.

HL 85.77 Thu 18:00 P4

Transmission Electron Microscopy for thin film solar cells — •Nies Reininghaus[1], Vitalij Schmidt[1], Wiebke Hachmann[1], Stefan Gruss[2], Helmut Stiebig[2], and Ulrich Heinzmann[1] — [1]Molecular and Surface Physics, Bielefeld University — [2]Malibu GmbH & Co. KG, Bielefeld

Thin-film amorphous and microcrystalline silicon are promising materials for photovoltaics as they have the potential to reduce the solar cell costs. In case of microcrystalline silicon the crystalline volume fraction is related to the efficiency factor of solar cells because it provides information about the microstructure of the material and the defect density. With Transmission Electron Microscopy of cross-sections it is possible to show the microstructure of the cells. However to determine the structure of the bulk it is necessary to analyse the diffraction of the electron beam. For the purpose of imaging diffraction patterns and displaying dark fields a new camera system has been installed in the Phillips CM200. With much higher sensitivity and a larger photoactive area it is possible to take images of the low-intensity diffraction and the dark field patterns.

HL 85.78 Thu 18:00 P4

Lasing in ZnO and CdS Nanowires — •Andreas Thielmann, Sebastian Geburt, Michael Kozlik, Julian Kühnel, Christian Borschel, and Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

The development of nanoscaled semiconductor lasers could be the key resolution to the still persistent size mismatch between integrated microelectronic devices and semiconductor optoelectronic devices[1]. Semiconductor nanowires offer an elegant path to the development of nanoscaled lasers as their geometry with two planar end facets naturally combines a fiber-like waveguide with an optical resonator. The possible stimulation of the material's emission processes enables lasing of resonant optical modes[2].

ZnO and CdS nanowires of different aspect ratios have been synthesized via the VLS mechanism and were characterized by SEM, EDX and ensemble PL measurements. Power dependent PL measurements on single nanowires excited with pulsed laser light at 355 nm have been performed between 10 K and room temperature and were set in correlation to the nanowires' respective morpholgy. Sharp emission lines which show characteristics of Fabry-Pérot modes could be observed above a power threshold. The measured power dependencies reveal amplified stimulated emission and lasing at high excitation densities.

[1] Ning, C. Z. (2010), physica status solidi (b), 247: 774-788.
[2] M. A. Zimmler et al (2010), Semicond. Sci. Technol., 25: 024001

HL 85.79 Thu 18:00 P4

Atomic and electronic structure of non-planar Si/SiO_2 interfaces — •Kaori Seino[1], Friedhelm Bechstedt[1], and Peter Kroll[2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Jena, Germany — [2]Department of Chemistry and Biochemistry, University of Texas at Arlington, Arlington, TX, USA

Silicon (Si) nanocrystals (NCs) are promising objects for quantum and photovoltaic devices. However, there are open questions concerning the

influence of the embedding amorphous SiO_2 matrix and the NC-matrix interface. In contrast to the planar Si/SiO_2 interfaces with defined crystallographic orientation in layered heterostructures, the NCs are surrounded by almost spherical interfaces with various facets. Here we study the interfacial electronic and bonding properties of Si NCs embedded in SiO_2 by large-scale first-principles calculations. They are based on the density functional theory (DFT) implemented in the VASP code. In our simulations Si NCs with nominal diameters up to 1.6 nm, i.e. systems with more than 1000 atoms, are treated. The atomic geometries are optimized within full quantum-mechanical calculations. The fundamental gap of the NC depends significantly on the matrix. The Si−Si bonds in the NC core are stretched while in the interface regions both types of bonds, stretched and compressed ones, occur. We compute the spatial variation of the electronic structure. The local band edge profiles exhibit different band gaps in the Si NCs and in the matrix region. Significant differences are found comparing embedded Si NCs and planar Si/SiO_2 interfaces.

HL 85.80 Thu 18:00 P4

Dopant-induced morphology evolution of silicon via wet chemical etching — •Guodong Yuan[1,2] and Saskia F. Fischer[1,2] — [1]Institute of physics, Humboldt-Universität zu Berlin, D-12489 Berlin, Germany — [2]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Silicon nanowires (SiNWs), as promising building blocks for future nanoelectronic devices, have been the intensive research focus in past decade due to their unique 1-D morphology and related properties. A lot of methods have been developed to fabricate SiNWs, for example, vapour-liquid-solid (VLS), reactive ion etching and electroless etching [1-2]. Among all these methods, the electroless etching approach for SiNWs is rather fascinating with respect to the traditional chemical vapour deposition (CVD) method, which always needs high temperature, hazardous precursors, long duration, expensive source materials and complex vacuum furnace systems. We found that the doping level of silicon wafer can influence morphology of the final etched structures. In low doped silicon wafer, the etching process produced the solid SiNWs, while in the case of highly doped silicon wafer, the wet chemical etching resulted in porous SiNWs or porous silicon due to the interaction between the dopants and aqueous chemical. The morphology evolution with the dopants is discussed in this work.

[1] K. Q. Peng, Y. Wu, H. Fang, X. Y. Zhang, Y. Xu, J. Zhu, Angew. Chem., Int. Ed. 2005, 44, 2737. [2] G. D. Yuan, Y. B. Zhou, C. S. Guo, W. J. Zhang, Y. B. Tang, Y. Q. Li, et al, ACS Nano, 2010, 4, 3045.

HL 85.81 Thu 18:00 P4

Low temperature Coulomb anomaly in CMOS compatible silicon quantum dots — •Stefan Jauerneck[1], Matthias Ruoff[1], Dharmraj Kotekar-Patil[1], David Wharam[1], Dieter Kern[1], Marc Sanquer[2], and Maud Vinet[3] — [1]Eberhard Karls Universität, Tübingen — [2]CEA INAC, Grenoble, France — [3]CEA LETI, Grenoble, France

Due to the ever decreasing sizes in CMOS technology, it has become possible to investigate transport in small geometries, where both Coulomb charging and quantum-mechanical effects play an important role. Furthermore fluctuations in the number of dopants in the active region of transistors are important and such dopants may act as an ultimate quantum dot with huge charging energies as compared to artificial silicon islands and lead to high temperature operation.

We report on transport measurements of nanoscale enhancement mode nanowire SOI-FETs, which clearly show Coulomb blockade behaviour. The size of the Coulomb diamonds is modulated in source-drain direction with an enveloping diamond structure, which may be explained by Coulomb charging effects due to a dopant in or near the barrier. Additionally the measurements feature regularly spaced lines with a slope $dV_{sd}/dV_g > 1$. We have investigated these features with respect to the symmetry of the measurement setup and show that they become independent of source-drain bias when the dot is symmetrically biased. Alternative explanations for this behaviour are considered.

HL 85.82 Thu 18:00 P4

Ivestigation of an InGaN - GaN nanowire heterstructure — •Friederich Limbach[1], Tobias Gotschke[1], Toma Stoica[1], Raffaella Calarco[1], Eli Sutter[2], Jim Ciston[2], Ramon Cusco[3], Luis Artus[3], Stefan Kremling[4], Sven Höfling[4], Lukas Worschech[4], and Detlev Grützmacher[1] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Center Jülich GmbH, D-52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology — [2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York 11973, USA — [3]Institut Jaume Almera, Consell Superior d'Investigacions Científiques (CSIC), 08028 Barcelona, Catalonia, Spain — [4]University Wurzburg, Wilhelm Conrad Rontgen Research Centre Complex Matter Systems, D-97070 Wurzburg, Germany

InGaN/GaN nanowire (NW) heterostructures grown by molecular beam epitaxy were studied in comparison to their GaN and InGaN counterparts. The InGaN/GaN heterostructure NWs are composed of a GaN NW, a thin InGaN shell, and a multi-faceted InGaN cap wrapping the top part of the GaN NW. Transmission electron microscopy images taken from different parts of a InGaN/GaN nanowire show a wurtzite structure of the GaN core and the epitaxial InGaN shell around it. Photoluminescence spectra of these heterostructure NW ensembles show an emission peak at 2.1 eV. However, μ-PL spectra measured on single nanowires reveal much sharper luminescence peaks. A Raman analysis reveals a variation of the In content between 20 % and 30 %, in agreement with PL and TEM investigations.

HL 85.83 Thu 18:00 P4

Influence of the nanowire interdistance on growth conditions and crystal structure of self-catalyzed GaAs nanowires grown via MBE — Joachim Hubmann[1], •Benedikt Bauer[1], Andreas Rudolph[1], Anna Fontcuberta i Morral[2], Dieter Schuh[1], Dominique Bougeard[1], Josef Zweck[1], and Elisabeth Reiger[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Laboratoire des Matériaux Semiconducteurs, EPFL Lausanne, Switzerland

Nanowires grown in bottom-up processes are considered as possible building blocks for future electronic devices. For this use it is necessary to gain control over the growth position of single nanowires. By nanopatterning the SiO_2/GaAs substrate with e-beam lithography we could restrict nanowire growth to predefined sites using the self-catalyzed, Ga-assisted growth technique[1]. We found that there is a correlation between the interdistance of the predefined growth sites and the probability of nanowire growth. This indicates that the effective growth conditions that are seen by a single nanowire are influenced by its local surrounding, in particular by the distance to its neighbours. We attribute the difference of the effective growth conditions to be caused by different diffusion lengths for Ga and As atoms on the SiO_2 surface. As the nanowire crystal structure can be tuned via the growth parameters we further examine how the change of the effective growth conditions affects the crystal structure of the grown nanowires.

[1]Bauer *et al.*, Nanotechnology 21 (2010), 435601.

HL 85.84 Thu 18:00 P4

Voltage-dependent excited state spectroscopy of single lateral InGaAs quantum dot molecules — •Meike Seible[1], Matthias Heldmaier[1], Jie Peng[2], Gabriel Bester[2], Lijuan Wang[2], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [3]Institut für Integrative Nanowissenschaften IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

We investigate single laterally coupled quantum dot molecules (QDMs) which are grown using a combination of molecular beam epitaxy and in situ atomic-layer precise etching. Each QDM consists of two individual quantum dots (QDs) which are coupled along the [1-10] crystal direction via electron tunneling, while the holes are strongly localized in either of the QDs. The electronic coupling can be influenced by applying an electric field along the molecular coupling axis. This leads to a shift between the intensities of the excitonic emission lines of the respective dots. For the investigation of the behaviour of the excited states in this system under different coupling conditions, detailed photoluminescence excitation (PLE) spectroscopy measurements have been carried out, using a wideband tunable Ti:Sapphire laser source under systematic variation of the applied lateral electric field. We compare these results with theoretical calculations of absorption spectra, using an empirical many-body pseudo-potential approach with random composition of the QDMs.

HL 85.85 Thu 18:00 P4

Time-dependent measurements of single In(Ga)As quantum dots embedded in GaAs reversed pyramid cavities — •Christoph Reinheimer, Daniel Rülke, Daniel Schaadt, Heinz

Kalt, and Michael Hetterich — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

We have investigated the exciton decay in single In(Ga)As quantum dots (QD) embedded in GaAs reversed micropyramids by means of time-correlated single photon counting (TCSPC). Pyramids with square and octagonal shape are manufactured by a wet-chemical etching process utilizing an AlAs sacrificial layer. The slope angle can be tailored by the composition of the etching solution. A layer of In(Ga)As QDs is situated close to the pyramid tip (25 nm distance). This ensures an extremely low number of dots in the cavity which is important for potential applications like single photon sources. Since light emitted by the QDs is mainly radiated through the top of the reversed pyramid due to reflection at the facets, this type of cavity is useful to efficiently detect the emission of single QDs. To investigate the exciton lifetime, we have studied the emission of single QDs under pulsed laser excitation. Furthermore, we have studied the temporal auto-correlation of subsequent photons emitted by the excitonic decay of a single QD using a Hanbury-Brown and Twiss setup in order to investigate the suitability of this approach as single photon emitter.

HL 85.86 Thu 18:00 P4

Optical properties of terbium doped ZnS nanowires — •Franziska Riedel, Sebastian Geburt, and Carsten Ronning — Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Jena

Semiconductor nanowires have the potential for fundamental future application in optoelectronic devices to act as nanoscaled light emitters (LED), waveguides or nanolasers. Doping of the nanowires with optical active elements (e.g. rare earth) could offer new optical properties, as it combines the features from well known material with the quasi-1D-structure. Terbium doped ZnS is a promising candidate as it shows strong green emission in thin-film electroluminescence devices, but there are no investigations on 1-D Tb doped ZnS nanostructures yet.

ZnS nanowires were synthesized via the VLS mechanism with diameters between 150-400 nm and lengths of about 60 μm. The doping with Tb was realized using ion beam implantation and annealing for the recovery of the implantation damage. The structural and morphological properties were analyzed using SEM and TEM. The optical properties were investigated using spatial resolved cathodoluminescence. The Tb doped ZnS nanowires show a strong intra-4f-luminescence. Several transitions could be identified and the luminescence properties of samples with Tb concentrations between $2{\cdot}10^{-3}$ and 2 at.% were examined at different temperatures and excitation powers.

HL 85.87 Thu 18:00 P4

Optical Spectroscopy on Single Charge-Tunable InGaAs/GaAs Quantum Dots — •Jan Kettler[1], Sven M. Ulrich[1], Matthias Heldmaier[1], Daniel Richter[1], Wolfgang-Michael Schulz[1], Robert Rossbach[1], Michael Jetter[1], Lijuan Wang[2], Armando Rastelli[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany — [2]Institut für Integrative Nanowissenschaften IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

We investigate the optical properties of self-assembled InGaAs/GaAs quantum dots (QDs) embedded into a n-i-Schottky diode structure which is placed on top of a distributed Bragg reflector in order to increase the photoluminescence (PL) extraction efficiency. The application of a bias voltage enables to control the charge state of the QDs. The ability to deterministically prepare a negative trion and its excited states is a preliminary requirement for future optical spin pumping experiments. Two similar sample structures are spectroscopically analyzed, one with QDs grown in molecular beam epitaxy and a second with QDs grown in metal organic vapor phase epitaxy. Micro-PL measurements in combination with photon cross-correlation measurements demonstrate the preparation of a negative trion ground state (X^-). Polarization resolved micro-photoluminescence excitation spectroscopy is applied to reveal the excited negative trion states (X^{-*}).

HL 85.88 Thu 18:00 P4

Influence of the inhomogeneous broadening of quantum dots in microcavity lasers — •Alexander Foerster and Jan Wiersig — Institut für Theoretische Physik, Universität Magdeburg

Microcavity lasers have recently attracted a considerable interest in semiconductor physics. Previous models [1] ignored the inhomogeneous broadening of quantum dots, i.e. they used the assumptions of identical quantum dots in resonance with the laser mode. Here we present a microscopic theory, which accounts for the energetic detuning of the different quantum dots. We use a four level laser model based on the cluster expansion method.

The impact of inhomogeneous broadened quantum dots on various properties of the laser is studied. The contribution of each quantum dot in the system is analysed. With increasing detuning a shift in the Input-Output characteristics becomes visible.

[1] C. Gies, J. Wiersig, M. Lorke, and F. Jahnke, Phys. Rev. A 75, 013803 (2007)

HL 85.89 Thu 18:00 P4

Optical properties of GaAs quantum dots fabricated by filling of self-assembled nanoholes — •Andreas Graf[1], David Sonnenberg[1], Christian Heyn[1], Andrei Schliwa[2], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Local droplet etching (LDE) is a technique to fabricate self-assembled patterning of semiconductor surfaces. Using LDE, we drill nanoholes (depth ≥ 7 nm) with Al droplets on the AlGaAs substrate and partially fill these with GaAs. This results in strain-free GaAs quantum dots (QDs) [1]. By control of the filling level a very narrow size distribution is achieved within the QD ensemble. We study photoluminescence spectra of QD ensembles as well as of single QDs and discuss the observations in view of QD size dependence, the shell structure, and the excited states in the QDs. In particular, the fine-structure splitting of neutral exciton and biexciton peaks of single QDs is studied. Furthermore, a model using the eight-band k·p theory and configuration interaction [2] is used to interpret the experimental results.

[1] Heyn et al., Appl. Phys. Let. **94**, 183113 (2009)
[2] Schliwa et al., Phys. Rev. B **80**, 161307 (2009)

HL 85.90 Thu 18:00 P4

Towards site controlled growth of InAs quantum dots on patterned GaAs by microsphere photolithography — •Ulrich Rengstl, Elisabeth Koroknay, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

To use quantum dots (QDs) in single photon applications, like quantum information processing, we are working on separate addressable, site controlled QDs. For this, we generate surface potential modulations by patterning the GaAs surface before the overgrowth in a metal-organic vapor-phase epitaxy system (MOVPE). Conventional patterning techniques, such as electron beam lithography or site controlled surface oxidation using scanning tunneling microscopy, have the disadvantage of high time consumption. A faster method for prepatterning a large surface uses microsphere photolithography [1]. For partial exposure of UV-sensitive photoresist, we use a hexagonal close-packed microsphere monolayer as an array of microlenses to focus UV-light. We obtained structures with controllable diameters of 300 to 700 nm in the photoresist, which can be used as an etching mask for wet chemical etching to generate holes in the GaAs surface. After this, various steps of post etch cleaning and oxide removal are necessary to obtain a GaAs buffer with low defect density and high optical quality after the following overgrowth. The prepatterning also leads to an increased accumulation of deposited InAs inside the holes, which supports island growth.

[1] W. Wu et al, Nanotechnology 18, 485302 (2007)

HL 85.91 Thu 18:00 P4

Transport spectroscopy of many-particle hole states in InAs quantum dots coupled to a two-dimensional hole gas — •Andreas Beckel[1], Bastian Marquardt[1], Martin Geller[1], Axel Lorke[1], Tobias Nowozin[2], Andreas Marent[2], and Dieter Bimberg[2] — [1]Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Interactions between self-organized InAs quantum dots (QD) and a two-dimensional hole gas (2DHG) can be used to probe the charge state in future memory applications [1]. We demonstrate that the conductance of the 2DHG is a very sensitive tool, also for time-resolved

measurements. This enables us to measure the tunneling dynamics between the 2DHG and the QDs [2] for very weakly coupled QDs exhibiting tunneling times in the order of several seconds. The time-resolved spectroscopy makes it possible to measure the density of states in the QD ensemble with single charge resolution up to 75 K. These results demonstrate the feasibility of high temperature read-out of the quantum states in self-assembled QDs using a 2DHG.

[1] A. Marent et al., Appl. Phys. Lett. **95**, 242114 (2009).
[2] B. Marquardt et al., Appl. Phys. Lett. **95**, 22113, (2009).

HL 85.92 Thu 18:00 P4

Mobility and carrier density in nanoporous indium tin oxide films — •Jaqueline Weissbon[1], Andreas Gondorf[1], Martin Geller[1], Axel Lorke[1], Martina Inhester[2], Anna Prodi-Schwab[2], and Dieter Adam[2] — [1]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen, D-47048 Duisburg — [2]Evonik Degussa GmbH, D-45772 Marl, Germany

Indium tin oxide (ITO) has become an indispensable material for a range of electronic devices. It is transparent in the entire visible range and electrically conducting, hence, a well suited material for transpar- ent electrodes. An interesting possibility to realize transparent, con- ducting films without the use of vacuum techniques is the printing of dispersions containing ITO nanoparticles[1]. We study here the charge carrier concentration and mobility of various nanoporous in- dium tin oxide (ITO) films, using Hall measurements and optical spectroscopy[2]. For the carrier density inside the particles ($2 - 4 \cdot 10^{20}\mathrm{cm}^{-3}$), the results of these complementary measurement techniques are in good agreement with each other and suggest that even in highly porous materials the common equations for the Hall resistance can be applied. However, for the mobilities in these layers the results differ very strongly: from 50 $\frac{\mathrm{cm}^2}{\mathrm{Vs}}$ in optical spectroscopy (which is comparable to bulk ITO) to 0.4 $\frac{\mathrm{cm}^2}{\mathrm{Vs}}$ in Hall measurements.This suggests that the mobility for electrical transport in nanoporous ITO films is strongly suppressed by scattering at interparticle boundaries.

[1] Ederth et al. Phys. Rev. B **68**, 155410 (2003).
[2] Gondorf et al. Phys. Rev. B., submitted (2010).

HL 85.93 Thu 18:00 P4

Electronic properties of GaN nanowires with different doping concentrations — •Markus Schaefer[1], Pascal Hille[1], Florian Furtmayr[1,2], and Martin Eickhoff[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universitaet Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — [2]Walter Schottky Institut, Technische Universitaet Muenchen, Am Coulombwall 3, D-85748 Garching, Germany

Semiconductor nanowires (NWs) are promising candidates for future generations of electronic and optoelectronic devices with a high density of integration. For this purpose it is interesting to combine available top-down approaches with bottom-up growth of NWs.

We report on electronic properties of detached GaN NWs with a typical length of about 500 nm placed on a pre-structured substrate. The NWs were grown in a self-assembled process by plasma assisted molecular beam epitaxy, substrate patterning was achieved by optical and electron beam lithography. The NWs were aligned by dielectrophoretic manipulation, which allows us a parallel deposition of several NWs from the fluid to the pre-patterned electrodes. The influence of different doping concentrations and illumination during measurements to the electronic properties of the NWs is reported.

HL 85.94 Thu 18:00 P4

Atomistic tight binding models of semiconductor quantum dots — •Elias Goldmann and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen, 28359 Bremen

In recent years, semiconductor nanostructures such as quantum dots have been the subject of intense theoretical and experimental research due to their large potential for next generation device applications.

We present results of an atomistic empirical tight-binding model (ETB) for the calculation of electronic properties of semiconductor nanostructures. We choose a sp^3s^* basis set localized at each atomic site to correctly reproduce the electronic band structure in the relevant part of the Brillouin-zone and include next-neighbour-interaction as well as spin-orbit-coupling.

A Jacobi-Davidson algorithm in connection with the folded spectrum method is used to compute the eigenstates and eigenenergies of the resulting TB-Hamiltonian of the supercell that contains about $4 \cdot 10^5$ atoms.

Within this ETB model we investigate the electron and hole wavefunctions and confinement energies of semiconductor nanostructures such as spherical- and pyramidal-shaped self-assembled InAs quantum dots in a $In_xGa_{1-x}As$ quantum well, embedded in a GaAs matrix, which are known as dots-in-a-well (DWELL) structures [1,2]. The influences of dot size, shape and Indium-concentration on the confined states are presented.

[1] S. Krishna, J. Phys. D: Appl.Phys.**38** 2142 (2005)
[2] A. Amtout *et al.*, J. Appl. Phys. **96** 3782 (2004)

HL 85.95 Thu 18:00 P4

X-ray characterization of Au-free grown GaAs nanowires on Si — •Andreas Biermanns[1], Steffen Breuer[2], Anton Davydok[1], Lutz Geelhaar[2], and Ullrich Pietsch[1] — [1]Universität Siegen, Festkörperphysik, Germany — [2]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Semiconductor nanowires (NW) are of particular interest due to the ability to synthesize single-crystalline 1D epitaxial structures and heterostructures in the nanometer range. However, many details of the growth mechanism are not well understood. In this contribution we present a x-ray diffraction study of the early stage of Au-free GaAs nanowire growth on Si(111)-substrates with native oxide using the nano-focus setup available at the ID1 beamline of ESRF. The GaAs NWs were grown by molecular beam epitaxy (MBE), and their formation was induced by Ga droplets. Using a nanometer-sized x-ray beam, size and lattice parameters of individual wires were measured separately. Using asymmetric x-ray diffraction on particular zinc-blende (ZB) and wurtzite (W) sensitive reflections, we show that under the used conditions the NW growth starts with predominantly WZ phases and continues mainly in ZB phase. In addition we can show that the WZ segments of the NWs exhibit a different vertical lattice parameter compared to the zinc-blende segments. A combination of x-ray diffraction from single wires and grazing incidence diffraction shows that the base of the NW is compressively strained along the inplane direction. This strain is released within 20nm from the substrate-interface.

HL 85.96 Thu 18:00 P4

Coupled Quantum Dots for Thermopower Measurements — •Holger Thierschmann, Luis Maier, Johannes Knorr, Mathias Mühlbauer, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Germany

A detailed knowledge of the physics of quantum dots is of fundamental importance in modern solid state physics. For this purpose thermoelectric transport measurements are a powerful method since they are known to be more sensitive to details of the electronic structure than conventional conductance measurements. In recent years, thermoelectric transport measurements have revealed additional insight in a number of single quantum dot phenomena [1,2]. However, there are only few experiments that investigate the thermoelectric properties of two coupled quantum dots. To fill this gap, we have designed samples that enable us to perform conductance measurements as well as thermoelectric measurements on two parallel quantum dots. We use gate electrodes on top of a GaAs/AlGaAs interface 2DEG to define lateral quantum dots and to tune their size and coupling strength to their surrounding. The dots are situated adjacent to a heating channel through which a current is passed so that a temperature gradient across the dot can be provided. Detailed potential simulations were run on a number of different gate designs. The designs were realized using optical and e-beam lithography and the performance of the structures was analyzed in a dilution refrigerator at electron temperatures below 100 mK.

[1] R. Scheibner et al,. Phys. Rev. B 75, 041301 (2007)
[2] R. Scheibner et al., Phys. Rev. Lett. 95, 176602, (2005)

HL 85.97 Thu 18:00 P4

Electroluminescence from silicon nanoparticles — •Jens Theis[1], Martin Geller[1], Axel Lorke[1], Hartmut Wiggers[2], and Cedrik Meier[3] — [1]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen — [2]Institut für Verbrennung und Gasdynamik and CeNIDE, Universität Duisburg-Essen — [3]Nanophotonics & Nanomaterials Group, University Paderborn

Si nanoparticles are tuneable light emitters and therefore a promising material for optoelectronic applications. We have fabricated an electroluminescence device based on silicon nanoparticles on a micropatterned semiconductor heterostructure. The Si nanoparticles have been synthesized from the gas phase in a low-pressure microwave plasma using SiH_4 as a precursor. The nanoparticles were dispersed from an aqueous solution onto the patterned substrate. For carrier injection, the particle layer was sandwiched between a transparent ITO layer

and a Si-doped GaAs back contact. A strong EL emission from the Si nanoparticles is observed with the unaided eye[1]. The EL spectra of the devices were investigated in a μ-photoluminescence setup, confirming that the EL in the visible range is indeed caused by the Si nanoparticles. Additionally, we study the influence of the waveform, frequency and amplitude of the driving AC voltage on the electroluminescence.

[1] Theis et al. *Nanotechnology* **21**, 455201 (2009)

HL 85.98 Thu 18:00 P4

Engineering self-assembled SiGe islands for robust electron confinement in Si — •Roman O. Rezaev[1,2], Suwit Kiravittaya[1], Vladimir M. Fomin[1], Armando Rastelli[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW-Dresden, D-01069 Dresden, Germany — [2]Laboratory of Mathematical Physics, Tomsk Polytechnic University, 634050 Tomsk, Russia

The confinement potential and the energy of localized electron states in the Si matrix surrounding self-assembled SiGe/Si(001) islands are evaluated with realistic structural parameters. For homogeneously alloyed islands overgrown with Si at low substrate temperatures, a non-monotonic dependence of the energy levels on size and composition is obtained and conditions to achieve the deepest confinement potential are derived within the framework of the available parameters. Shape changes occurring during Si capping at high substrate temperatures are shown to lead to a substantial reduction in the confinement potential. This work was supported by DAAD, DFG SPP 1386, Grant of President of the Russian Federation SS-871.2008.2, Russian Science and Innovations Federal Agency Contract 02.740.11.0238, and Russian Federal program Kadry Grant P691.

HL 85.99 Thu 18:00 P4

Analysis of squeezed LO phonon states in a QD with the help of the Wigner function — •Daniel Wigger[1], Doris Reiter[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

We study the fluctuation properties of non-classical phonon states within the model of an optically excited semiconductor quantum dot (QD). The QD is modeled in the strong confinement limit as a two level system. An ultrashort laser pulse creates an exciton in the QD which can be manipulated by further pulses. The exciton is coupled to the longitudinal optical (LO) phonons and, thus, lattice vibrations are created by the optical manipulation of the QD. For two pulses with a certain time delay and relative phase we find that the lattice fluctuations are squeezed, i.e., the fluctuations fall below the fluctuations of the phonon vacuum. [Sauer et al. PRL 105, 157401 (2010)] The quantum mechanical characteristics of the phonon states are studied using the Wigner function which allows an instructive interpretation of the phononic system. With the Wigner function we analytically calculate the fluctuation properties of the lattice displacement and momentum caused by the LO phonons and explain the mechanisms leading to squeezing.

HL 85.100 Thu 18:00 P4

Effects of phonon-induced dephasing on Rabi oscillations in GaAs quantum dots — •Sebastian Lüker[1], Doris 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

We discuss the laser-induced Rabi oscillation of the exciton occupation in a GaAs quantum dot (QD). Considering the strong confinement limit we model the QD as a two level system. In principle arbitrary superpositions of these two states can be prepared by using light-induced Rabi oscillations. However, the control of the quantum state is limited by dephasing caused by electron-phonon interaction which reduces the coherence of the system and leads to a damping of the Rabi oscillations. Due to the energy structure only phonon-induced pure dephasing is taken into account. We study the impact of the dephasing on the coherence in the density matrix formalism. The many body nature of the problem leads to an infinite hierarchy of equations of motion which we truncate by a correlation expansion. The resulting closed set of equations is solved numerically. The influence of the different orders of this hierarchy is discussed. Recent experiments on Rabi oscillations in semiconductor QDs have been performed showing damped Rabi oscillations in the occupation of the QD exciton state [Ramsey et al., PRL **105**, 177402 (2010)]. We compare our model with the experimental data and find a very good qualitative and quantitative agreement.

HL 85.101 Thu 18:00 P4

Growth of GaAs-Nanowires on GaAs (111)B substrates induced by focused ion beam — •Rüdiger Schott, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

Semiconductor nanowires are a promising system for applications in the areas of electronics and photonics and also for exploring phenomena at the nanoscale. There are several approaches to grow nanowires at arbitrary sites on the wafer. We report about growing GaAs-nanowires on GaAs (111)B substrates via the vapour-liquid-solid (VLS) mechanism in an ultra-high-vacuum (UHV)-cluster of a molecular beam epitaxy (MBE) and a focused ion beam (FIB) system. Our idea is to implant metal seeds (especially Au) for the nanowire growth by in situ patterning using FIB. Due to the UHV transfer between the FIB and the MBE chamber, no further cleaning step of the substrate surface is necessary. Formations of organized GaAs-nanowires and high aspect ratios are observed.

HL 85.102 Thu 18:00 P4

Geometry effects on Coulomb charging in CMOS-compatible SOI-SETs — •Matthias Ruoff[1], Dharmraj Kotekar-Patil[1], Stefan Jauerneck[1], David Wharam[1], Dieter Kern[1], Marc Sanquer[2], and Maud Vinet[3] — [1]Eberhard Karls Universität, Tübingen — [2]CEA INAC, Grenoble, France — [3]CEA LETI, Grenoble, France

The charging energy of a single electron transistor (SET) and therefore its suitability for high-temperature operation is determined by the effective size of the Coulomb island. Nanowire SOI-FETs with nominally undoped channels of different widths and thicknesses and various gate lengths, fabricated in the FP7 project AFSID with a CMOS compatible process, have been investigated. In this case the Coulomb island may be formed by a small body of undoped silicon, a single stray dopant from source/drain implantation, or one or more dopant atoms in the access regions of the channel. The investigated devices show clear Coulomb blockade oscillations. From their period the gate capacitance can be directly obtained. Gate efficiency and total capacitance can be extracted by fitting theoretical models to conductance peak shapes and from charge stability diagrams. Capacitances resulting from different geometrical models are compared with those obtained from the transport measurements.

HL 85.103 Thu 18:00 P4

Kondo effect in double quantum dots with magnetic field-tuned coupling — Daniel Tutuc[1,3], Rolf Haug[1,3], •Brendan Coughlan[2,3], Lars Musiol[2,3], Sabine Tornow[2,3], and Gertrud Zwicknagl[2,3] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]Institut für Mathematische Physik, Technische Universität Braunschweig, D-38106 Braunschweig — [3]NTH School for Contacts in Nano Systems, Braunschweig-Clausthal-Hannover

We study the variation with magnetic field of the Kondo effect in a double quantum dot system coupled via an open conducting region. The transport measurements [1] indicate a competiton between Kondo singlet formation and magnetic alignment via the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction which has been in the focus of interest in heavy electron systems during the past year. Tuning the coupling by a magnetic field provides insight into the relative importance of the different interactions (excluded volume, RKKY, etc) between Kondo impurities. Novel features originate from the chirality of the coupling in finite magnetic fields. Theoretically we model the double quantum dot system by two Anderson impurities which are both coupled to individual fermionic baths representing the leads as well as to a central fermionic reservoir representing the common source. We calculate equilibrium and transport properties of this model using a variational ansatz for the ground state and discuss the validity of simplified effective coupling models.

[1] Daniel Tutuc et al., arXiv:1010.5692

HL 85.104 Thu 18:00 P4

X-ray characterization Si-doped InAs nanowires grown on GaAs — •Muhammad Saqib[1], Andreas Biermanns[1], Thomas Grap[2], Mihail Lepsa[2], and Ullrich Pietsch[1] — [1]Universität Siegen, Festkörperphysik, Germany — [2]Forschungszentrum Jülich, Institut für Bio- und Nanosysteme (IBN-1),Germany

Semiconductor nanowires (NW) are of particular interest due to the ability to synthesize single-crystalline 1D epitaxial structures and heterostructures in the nanometer range. However, many details of the growth mechanism are not well understood. In particular, understanding and control of doping mechanisms during NW growth are important issues for technological applications. In this contribution we present a x-ray diffraction study of the influence of Si-doping in InAs NWs grown on GaAs (111) substrates using In-assisted MBE growth. With the help of coplanar and asymmetric x-ray diffraction, we monitor the evolution of the lattice constants and structure of the InAs NWs as function of doping concentration. We observe that increasing the nominal doping concentration leads to the appearance of additional diffraction maxima corresponding to material whose vertical lattice parameter is 1% smaller than that of the undoped nanowires. Those lattice parameters can be attributed with alloy formation in the form of island like crystallites.

HL 85.105 Thu 18:00 P4

Electronic transport properties of InAs nanowires — •Önder Gül, Christian Blömers, Hilde Hardtdegen, Mihail Ion Lepsa, Kamil Sladek, Andreas Penz, Thomas Grap, Detlev Grützmacher, and Thomas Schäpers — Institute of Bio- and Nanosystems (IBN-1) and JARA - Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

III-V nanowires have recently attracted a lot of interest, because they are promising building blocks for future nanoscale applications, such as high density field effect transistors, high performance solar cells or sensing devices. In this context, InAs is especially interesting because of its low effective electron mass, its high predicted electron mobility, and its low direct band gap. Additionally ohmic contacts are easy to prepare because of the intrinsic surface electron accumulation. We investigated the transport properties of InAs nanowires, grown by means of molecular beam epitaxy and metal organic vapor phase epitaxy. In a temperature range from 300K down to 4K we determined basic transport parameters such as contact resistance, resistivity, mobility, and carrier concentration. At low temperatures, magnetotransport measurements were carried out in order to observe electron interference effects.

HL 85.106 Thu 18:00 P4

Spin noise spectroscopy of single semiconductor quantum dots — •Ramin Dahbashi[1], Michael Schmidt[1], Klaus Pierz[2], Hans Werner Schuhmacher[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

We demonstrate spin noise spectroscopy [1] as a technique for the nearly perturbation free measurement of the electron spin dynamics in single semiconductor quantum dots charged with one electron or one hole. The investigated sample are InAs quantum dots with a density gradient enclosed in a Bragg mirror cavity. The charge status is determined via the spectral and polarization dependence of the photoluminescence. We present preparatory photoluminescence measurements to ensure that we can detect single quantum dot photoluminescence. The measurements are set up in a self-designed sample rod for ordinary helium bottles to realise an intrinsically stable, low temperature measurement system with direct optical access.

[1] G. M. Müller, M. Oestreich, M. Römer, and J. Hübner, Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges, Physica E 43, 569 (2010).

HL 85.107 Thu 18:00 P4

Magnetotransport on ferromagnetiv (Ga,Mn)As/GaAs core-shell nanowires — •Christian Butschkow[1], Stefan Geissler[1], Andreas Rudolph[1], Marcello Soda[1], Elisabeth Reiger[1], Dieter Schuh[1], Werner Wegscheider[2], and Dieter Weiss[1] — [1]Institute for Experimental and Applied Physics, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg — [2]Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland

We performed magnetotransport measurements on individually contacted GaAs/(Ga,Mn)As nanowires at low temperatures. The core nanowires were grown by MBE using gold as catalyst at a temperature of 530°C. For the (Ga,Mn)As shell growth, the substrate temperature was decreased to 205°C. A Curie-Temperature of 17K to 20K was observed by SQUID measurements on an ensemble of 10^8 nanowires as well as by transport measurements. Investigating the magnetoresistance effects for various field directions we can determine the magnetic anisotropy to be strongly uniaxial with a magnetic easy axis pointing along the nanowire axis. The observed effects are very pronounced when compared to (Ga,Mn)As bulk material with a similar manganese concentration. Also the anisotropy field and coercive fields are significantly larger than for (Ga,Mn)As bulk material.

HL 85.108 Thu 18:00 P4

Triple dot structures from CMOS-compatible SOI-FETs — •Dharmraj Kotekar-Patil[1], Matthias Ruoff[1], Stefan Jauerneck[1], Dieter Kern[1], David Wharam[1], Marc Sanquer[2] und Maud Vinet[3] — [1]Eberhard Karls Universität, Tübingen — [2]CEA INAC, Grenoble, France — [3]CEA LETI, Grenoble, France

We report on electronic transport in triple quantum dots in series created by three closely spaced top gates on the same SOI-nanowire. Each quantum dot is individually characterised as a single electron transistor(SET) exhibiting clear Coulomb blockade oscillations. We also study the electrostatic coupling between 2 dots at a time with the third dot kept at a fixed bias. From charge stability measurements for each combination of gates, interdot capacitances and cross capacitances between dots and gates are extracted and correlated with geometrical models. Device fabrication is compatible with advanced CMOS processes so the devices may serve as building blocks for charge based quantum computes or quantum cellular automata (QCA).

HL 85.109 Thu 18:00 P4

Droplet epitaxy of InGaAs quantum dots on (100) GaAs substrate — •Verena Zuerbig, Aleksandar Gushterov, Mohamed Benyoucef, and Johann Peter Reithmaier — Technische Physik, Institute of Nanostructure Technologies and Analytics, University of Kassel, Heinrich-Plett-Strasse 40, 34132 Kassel, Germany

In 1991 N. Koguchi et al. has proposed an alternative growth technique named droplet epitaxy (DE) for fabrication of self-organized nanostructures. DE offers the fabrication of nanostructures with reduced or without wetting layer on both lattice matched and lattice-mismatched substrates in comparison to the widely used Stranski-Krastanov (SK) growth mode, which is extremely attractive for the growth of lattice-mismatched substrates. Many groups use low temperature QD DE growth to prevent material redistribution. But the low temperature results in poor crystal quality of the QD structures, which needs additional annealing steps at high temperatures. We report on the structural (atomic force microscope) and optical (macro- and micro-photoluminescence) properties of InGaAs QDs grown by DE on undoped (100) GaAs substrates at elevated growth temperatures in the range from 410 °C to 500 °C to preserve the crystal quality of QDs. By using different growth conditions such as substrate temperature, amount and deposition rate of In, As flux and the opening time of the As valve, QDs with small sizes (height: 2-6 nm) and narrow photoluminescence linewidth (30 meV) are fabricated. Sharp and intense luminescence lines obtained by micro-photoluminescence spectroscopy showed good quality of QDs formed by DE.

HL 85.110 Thu 18:00 P4

Optical properties of ZnO/ZnMgO nanowire heterostructures — •Nils Neubauer[1], Bingqiang Cao[2], Marius Grundmann[2], and Frank Cichos[1] — [1]Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig — [2]Semiconductor Physics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

ZnO nanowires are promising candidates for the fabrication of nanoscaled light emitting devices. Due to the large energy bandgap and exciton binding energy of ZnO, it offers the possibility for nanoscale light emitters in the UV spectral region working at room temperature. Pulsed laser deposition (PLD) enables the growth of defined nanowire shapes and nano-heterostructures to modify their optical properties. Due to quantum confinement effects in such heterostructures even single-photon emission is possible, a key requirement for future communication technologies like quantum cryptography. We have investigated ZnO nanowires with a radial and axial ZnO/ZnMgO quantum well heterostructure. These core/shell nanostructures were grown by a two step PLD process, which leads to a low area-density of the nanowires to provide homogeneous growth of the quantum well heterostructures. Optical studies were carried out in a photoluminescence setup. Excitation is done with a frequency quadrupled Nd:YVO_4 laser in a TIRF (Total Internal Reflection Fluorescence) configuration. The emitted light is collected confocally and is detected

in a Hanbury Brown-Twiss setup to study photon correlations.

HL 85.111 Thu 18:00 P4

Control of the carrier density of an inverted GaAs/$Al_xGa_{1-x}As$ high electron mobility transistor (HEMT) heterostructure with embedded quantum dots via a backgate — •Sascha René Valentin, Arne Ludwig, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum

InAs quantumdots coupled to a two-dimensional electron gas (2DEG) are already widely studied but the tuning of the charge of the quantum dots is always accompanied by a change of the carrier density of the 2DES. In this contribution we show a structure with a backgate which is capable of charging the quantum dots independently of the density of the carriers in the 2DEG. Different approaches for such a backgated structure will be discussed.

HL 85.112 Thu 18:00 P4

Asymmetric optical nuclear spin pumping in a single uncharged quantum dot — •Heike Schwager[1], Florian Klotz[2], Vase Jovanov[2], Johannes Kierig[2], Emily C. Clark[2], Gerhard Abstreiter[2], Martin Brandt[2], Geza Giedke[1], and Jonathan Finley[2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Highly asymmetric dynamic nuclear spin pumping is observed in a single self-assembled InGaAs quantum dot subject to resonant optical excitation of the neutral exciton transition. A large maximum polarization of 54% is observed and the effect is found to be much stronger upon pumping of the higher energy Zeeman level. Time-resolved measurements allow us to directly monitor the buildup of the nulcear spin polarization in real time and to quantitatively study the dynamics of the process. A strong dependence of the observed dynamic nuclear polarization on the applied magnetic field is found, with resonances in the pumping efficiency observed for particular magnetic fields. We develop a model that accounts for the observed behaviour, where the pumping of the nuclear spin system is due to hyperfine-mediated spin flip transitions between the states of the neutral exciton manifold.

HL 85.113 Thu 18:00 P4

Investigation of the local electronic structure of Cu-doped GaN by XANES and XLD — •Ralf Schuber[1], Philipp R. Ganz[1], Fabrice Wilhelm[2], Andrei Rogalev[2], and Daniel M. Schaadt[1] — [1]Institute of Applied Physics/DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, Germany — [2]European Synchrotron Radiation Facility (ESRF), Grenoble, France

Cu doped GaN has been reported to exhibit ferromagnetic behavior at room temperature, in implanted films, nanowires and in grown films. However, there are yet many unanswered questions concerning the mechanism of ferromagnetism in this system. Above all, a detailed understanding of the incorporation of Cu in the GaN host is desirable. The local electronic structure of Cu-doped GaN can suitably be probed by the element specific x-ray linear dichroism (XLD) as well as the x-ray absorption near edge structure (XANES) at the K-edges of Cu and Ga. This was done at the ESRF ID12 beamline on a series of GaN:Cu samples grown by plasma assisted MBE with nominal Cu concentrations between 0% and 2.3%. To clarify the role of the surface compounds on the samples and to evaluate the Cu site position in the GaN host, i.e. Cu on Ga sites, N sites or interstitial sites, we performed simulations of the GaN:Cu and the Cu9Ga4 crystals for the Cu and Ga K-edges at different doping levels using the FDMNES code [1]. A comparison with the experimental results shows that the Cu atoms predominantly occupy Ga and interstitial sites. [1] Y. Joly, Phys. Rev. B, 63, 125120 (2001).

HL 85.114 Thu 18:00 P4

Interpretation of photoluminescence decay at the limits of time-resolution — •Markus Göthlich, Torsten Langer, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

Time-resolved photoluminescence spectroscopy using time-correlated single photon counting is a reliable way to measure carrier lifetimes that are long compared to the temporal resolution of the instruments. But problems arise, when carrier lifetimes become comparable or even shorter than that: A convolution of the real intensity decay $I_{\mathrm{true}}(t)$ and the response function of the instruments $h(t)$ leads to a significant broadening of the resulting experimental intensity transients $I_{\mathrm{exp.}}(t) = \int_{-\infty}^{t} h(t-\tau) I_{\mathrm{true}}(\tau) d\tau$. This not only affects the lifetime values obtained from the experiment. There is also an influence on the shape of the transients. In this contribution, we discuss different numerical methods of deconvolving $h(t)$ with the aim to reconstruct the "true" decay transients and to improve the over-all time-resolution of the experimental setup. A possible method is based on Fourier transforms, as deconvolution is simple in Fourier space. Other numerical methods solve a set of linear equations: $I_{\mathrm{exp.},j} = h_{ji} \cdot I_{\mathrm{true},i}$. Both ways are very sensitive to experimentally inevitable noise, making deconvolution a sophisticated task. We test different algorithms by applying them to simulated convolved transients where the true lifetime is known. Furthermore, we demonstrate the application on measured transients of GaInN/GaN quantum well structures.

HL 85.115 Thu 18:00 P4

Defekterzeugung durch hohe elektrische Stromdichten im III-V-Halbleiter Galliumnitrid — •Christian Karrasch, Thomas Geruschke, Bert Kann und Reiner Vianden — Universität Bonn, Helmholtz-Institut für Strahlen- und Kernphysik, Nußallee 14-16 D-53115 Bonn

Galliumnitrid (GaN) besitzt vielfältige technische Anwendungen in der Halbleiterindustrie, wie z.B. Hochleistungsdioden und -transistoren. Dennoch ist über Schädigungsmechanismen in GaN und die durch elektrischen Strom erzeugten Kristalldefekte noch wenig bekannt. Mit Hilfe der Methode der gestörten Winkelkorrelation (PAC) können Gitterdefekte untersucht und klassifiziert werden. Als PAC Sonde wird ^{111}In in undotiertes GaN implantiert. Die dabei entstehenden Implantationsschäden werden durch thermische Behandlung ausgeheilt. Da Indium isoelektronisch zu Gallium ist und in einer ternären Verbindung in blauen InGaN-LEDs Verwendung findet, eignet es sich sehr gut als Sondenatom zur PAC-Messung. Aufgrund der relativ kurzen Halbwertszeit von ^{111}In ($t_{1/2}$ = 2,83 d) muss die Belastung durch elektrischen Strom mit sehr hoher Stromdichte (über 10^4 A/cm^2) durchgeführt werden. Anschließend wird die Schädigung des GaN Gitters durch den elektrischen Stromfluss untersucht. Zur weiteren Charakterisierung werden Hall-Effekt Messungen durchgeführt.

HL 85.116 Thu 18:00 P4

Properties of quaternary (Al, Ga, In)N layers and MQWs — •Lars Groh, Christoph Hums, Armin Dadgar, Jürgen Bläsing, and Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg

The achievement of efficient green LEDs is at present mostly prohibited by the Quantum Confined Stark-Effect (QCSE), which leads to a low quantum efficiency for longer wavelengths. Responsible for the QCSE are strong polarization fields in growth direction of c-axis oriented group-III-nitride heterostructures, especially within the quantum wells. To reduce or eliminate these polarization fields, mainly two approaches are followed. The first and most popular one is to change the growth direction to semi- or non-polar facets. Our approach is to change the barrier material in order to control the band gap and in particular the polarization field strength. By this the polarization of well and barrier can be nearly matched, with the benefit of the well established growth in c-axis direction which is, e. g., low in stacking fault density. We have grown by MOVPE GaInN/AlGaInN MQWs on silicon and sapphire substrates to investigate the effect of different growth conditions on the composition and luminescence of these structures. PL, (HR)XRD and FE-SEM measurements have been performed. The results from these measurements are compared to the predictions from theory.

HL 85.117 Thu 18:00 P4

Influence of crystal defects on the magnetic properties of Gd-doped GaN — •Stepan Shvarkov[1], Dirk Reuter[1], Andreas D. Wieck[1], Hans-Werner Becker[2], Yvon Cordier[3], Jens Herford[4], and Achim Trampert[4] — [1]Ruhr-Universität Bochum, Lehrstuhl für Angewandte Festkörperphysik, Universitätsstr. 150, 44780 Bochum, Germany — [2]Ruhr-Universität Bochum, RUBION, Universitätsstr. 150, 44780 Bochum, Germany — [3]CNRS-CRHEA, rue Bernard Grégory, 06560 Valbonne, France — [4]Paul Drude Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

Investigations on the role of crystal defects for the magnetic properties of Gd-doped GaN are presented. GaN layers were grown by molecular beam epitaxy (MBE) with Gd atoms incorporated during the growth. Defects were intentionally introduced by performing

N^+ implantation. The magnetization measured by a superconducting quantum interference device (SQUID) increased after the N^+ ions were implanted. In addition, the electrical transport properties of Gd-implanted $Al_xGa_{1-x}N$/GaN high electron mobility transistor (HEMT) structures have been studied. Gd was implanted in the MBE-grown $Al_xGa_{1-x}N$/GaN heterostructures by focused ion beams (FIB). Two sets of the samples were prepared: one set of samples was analyzed as implanted, while the other one was thermally annealed after the Gd implantation so that the number of defects was reduced. Anomalous Hall effect (AHE) was observed for both types of samples. However, AHE measured on the as-implanted samples was found to be much more pronounced than the one of the annealed samples.

HL 85.118 Thu 18:00 P4

Band-to-band Auger recombination in GaInN from first principle calculations — •Markus Heinemann and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392 Giessen, Germany

Recent theoretical work [1] implies that inter-band Auger recombination causes a resonance in the Auger coefficient in the blue to green spectrum and opened a discussion whether this effect may lead to a loss in quantum efficiency of nitrite based light emitters. We investigate the possibility of intra- and inter-band Auger recombination in wurtzite $Ga_{1-x}In_xN$ alloys. Using density functional theory and the local density approximation we compute Auger recombination rates for Indium concentrations x ranging from 0 to 100%.

[1] K. T. Delaney, P. Rinke, and C. G. Van de Walle, Appl. Phys. Lett. **94**, 191109 (2009)

HL 85.119 Thu 18:00 P4

Locally resolved imaging of internal electric fields in GaN/GaInN quantum wells by differential phase contrast microscopy — •Matthias Lohr[1], Johannes Thalmair[1], Michael Jetter[2], Ferdinand Scholz[3], and Josef Zweck[1] — [1]Fakultät für Physik, Universität Regensburg, D-93053 Regensburg — [2]Fakultät für Physik, Universität Stuttgart, D-70569 Stuttgart — [3]Institut für Optoelektronik, Universität Ulm, D-89081 Ulm

InGaN/GaN-based laser diodes emitting in the green spectral range are still difficult to achieve. The efficiency "droop" in the green spectral range is strongly believed to be a consequence of the quantum confined Stark effect (QCSE), due to inner piezoelectric fields in the material, caused by strain at the interfaces.

Attempts are made to reduce the piezoelectric (PE) fields by choosing semi- or non-polar crystal facets for the growth of quantum wells. It is necessary to measure the existing PE fields in order to determine whether the various approaches actually can reduce the QCSE and to foster more efficient light emission.

We present first results using differential phase contrast (DPC) in a (S)TEM, where we measure directly the beam deflection due to the inner PE fields. The specimens contain quantum wells grown on different facets. The DPC images display the PE fields in strong contrast and laterally highly resolved over a large field of view. We observe effects not only in the quantum wells but also adjacent to them in the substrate layer and around stacking faults.

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HL 85.120 Thu 18:00 P4

GaN-ZnO-InGaN/GaN core shell nanorods — •Ingo Tischer[1], Mohamed Fikry[2], Manfred Madel[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institut für Quantenmaterie, Gruppe Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

For sensing application it is desirable to have GaN nanorods with InGaN quantum wells which are standing upright in a well defined pattern. Our approach starts with ordered GaN pyramids on which in a first step ZnO nanopillars were grown. This structure was overgrown with GaN, and subsequently with a radial GaN/InGaN multi quantum well structure.

We report about the structural and optical properties of this nanostructured material which we investigated by spatially resolved cathodoluminescence, photoluminescence, energy dispersive X-ray spectroscopy, and X-ray diffraction.

HL 85.121 Thu 18:00 P4

Optical investigation on the valence band structure of AlGaN with low Al content — •Tobias Meisch[1], Frank Lipski[2], Kamran Forghani[2], Benjamin Neuschl[1], Martin Feneberg[3], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institut of Quantum Matter, Ulm University, 89069 Ulm, Germany — [2]Institut of Optoelectronics, Ulm University, 89069 Ulm, Germany — [3]Institut für Experimentelle Physik, Abt. Materialphysik,Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg

For the binary semiconductors GaN and AlN, the crystal field splitting determining the valence band structure changes from $\approx +20$ meV (GaN) to $\approx$ -200 meV (AlN), whereas the spin orbit splitting should remain constant at $\approx$ 20 meV. Therefore, for unstrained AlGaN ternary layers an interchange of the character of the topmost valence band from Γ_9 to Γ_7 is theoretically expected for an Al content in the range of 5-10%, manifesting itself mainly in a change of polarization of optical transitions. Strain in epitaxial layers alters the situation and shifts this crossing point. Literature reports experimental values ranging from 20% to 75% Al for the crossover. We present results of temperature dependent photoluminescence and reflectivity experiments on AlGaN layers with Al content ranging from 0 to 30%, and find different contributions from free and bound excitons. The Al content and strain were determined from multiple HRXRD reflections, and entered in a 6x6 k·p model calculation. We discuss our experimental spectra on the basis of this calculation.

HL 85.122 Thu 18:00 P4

Scanning near-field optical microscopy on UV emitting GaN/AlGaN quantum well structures — •Peter Clodius, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Technische Universität Braunschweig, Institut für Angewandte Physik, Mendelssohnstr. 2, 30106 Braunschweig

The efficiency of GaN/AlGaN quantum well (QW) structures is quite low compared to GaInN/GaN structures emitting in the blue/violet spectral region which show very high efficiencies despite the high defect density that is commonly observed in such structures. Our explanation for the high efficiency of GaInN/GaN structures is based on the observation that every dislocation in highly efficient c-plane GaInN/GaN structures is decorated with a so-called V-pit, a hexagonal shaped inverted pyramid with $(10\bar{1}1)$ sidewalls. On these sidewalls, thinner quantum wells act as a barrier, suppressing nonradiative recombination at the defects. TEM measurements on high efficiency GaN/AlGaN UV structures have shown that pit formation around defects also takes place in those structures [1]. In this contribution, we will present scanning near-field optical microscope (SNOM) measurements of the luminescence of these high efficiency UV emitting GaN/AlGaN quantum well structures with a spatial resolution below 100 nm. Light emission with a wavelength shorter than that of the c-plane QW, originating from the sidewalls of the pits, which is visible in low temperature measurements, indicates that a similar mechanism is present in UV structures.

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HL 85.123 Thu 18:00 P4

Internal quantum efficiency of high In content GaInN quantum well structures — •Fedor Alexej Ketzer, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig, Germany

The internal quantum efficiency (IQE) of GaN based light emitters shows a strong reduction for emission wavelenghts beyond 500 nm. In order to get LEDs and LDs emitting in the green spectral region the indium content has to be increased. This leads to stronger piezoelectric fields in the quantum wells resulting in a reduced oscillator strength. In addition the low growth temperatures needed for high In contents and the larger strain may lead to an increased defect density and stronger nonradiative recombination. In this contribution we analyze the internal quantum efficiency of GaInN quantum well structures measured by temperature and excitation power dependent photoluminescence. The samples were grown by MOVPE on sapphire or bulk GaN substrates. We investigated single and multiple quantum well structures with indium contents between 18% and 32% and quantum well thickness between 0.8 nm and 2.0 nm. For structures emitting at similar wavelengths the IQE can be optimized using thin quantum wells and high indium contents. Furthermore we studied the influence of subsequent layers on the optical properties of the QWs. The thickness and the growth rate of the GaN barrier directly following the QW turned out to be key parameters for improving the efficiency of our structures.

HL 85.124 Thu 18:00 P4

Dielectric functions of wurtzite GaN at elevated tempera-

tures — •Christian Möller[1], Sviatoslav Shokhovets[1], Gerhard Gobsch[1], Klaus Köhler[2], and Oliver Ambacher[2] — [1]Technische Universität Ilmenau, Weimarer Str. 32, 98693 Ilmenau, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastraße 72, 79108, Freiburg, Germany

Wurtzite GaN is already widely used for production of blue-ultraviolet and white light-emitting devices. In addition, numerous applications in high-power and high-temperature electronics are also possible. The knowledge of optical constants and understanding of optical processes in the vicinity of the excitonic absorption edge at room temperature as well as at elevated temperatures is crucial for the design and optimization of GaN-based devices. We carried out spectroscopic ellipsometry (SE) measurements of undoped and Si-doped c-plane epitaxial films of wurtzite GaN in a temperature range 300-800 K. The determined temperature-dependent dielectric functions (DFs) are analyzed in terms of contributions from discrete exciton states, excitonic continuum, band-to-band transitions, and phonon-assisted optical transitions into exciton-phonon complexes. Effects of Si-doping are discussed and the temperature dependence of band-gap and exciton energies and broadening parameters is presented.

HL 85.125 Thu 18:00 P4

Characterization and simulation of coupled GaInN quantum wells — •Christopher Hein, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig, Germany

Despite the tremendous progress in the field of Group-III-nitrides, new applications and research topics are still emerging. One point of interest is the tunneling transport in nitride heterostructures, which can be realized by coupled quantum wells. In this contribution we present photoluminescence studies of coupled GaInN/GaN multiple quantum wells and the simulation of such structures using Nextnano++. The samples were grown by metal organic vapor phase epitaxy on c-plane sapphire. The In content and the thickness of the GaInN quantum wells determined by X-ray diffraction measurements was 38% and 0.26nm, respectively. The barrier width was varied for each sample between 4.15nm, 3.04nm, 1.3nm and 1.0nm. With decreasing barrier thickness the peak energies observed in photoluminescence decreased from 3.28eV to 3.12eV. In addition the sample structure was simulated by a self-consistent solution of Schrödinger's equation using Nextnano++. The measured PL emission energy was then used to check the results of the simulation and adjust simulation parameters. The decrease of photon energies related to reduced barrier widths can be described by an exponential function in good agreement with theoretical considerations.

HL 85.126 Thu 18:00 P4

Polaritonic effects in wide-gap semiconductors as a function of temperature — •Marie-Elena Kleemann[1], Sviatoslav Shokhovets[1], Gerhard Gobsch[1], and Oliver Ambacher[2] — [1]Technische Universität Ilmenau, Ilmenau, Deutschland — [2]Frauenhofer-Institut für Angewandte Festkörperphysik, Freiburg, Deutschland

Polaritonic effects are regarded as the properties of an excitonic crystal with the spatial dispersion, which is related to the ability of the exciton to move through the lattice.The influence of an increasing temperature on the excitonic polaritons consists in the increasing damping (broadening of optical transitions). In the limiting case of a high damping, the polaritonic effects should become not observable.

In this work we measured polarized reflectance and photoreflectance for high-quality c-plane epitaxial films of wurzite GaN and ZnO as well as of a-and m-plane ZnO crystals in the range from liquid-helium temperatures up to room temperature. In order to reveal the presence of polaritonic effects and their temperature dependence, the data is analyzed using two different models of the dielectric function, which describe the experimental results. While in the first model spatial dispersion is implemented, it is disregarded in the second model.

HL 85.127 Thu 18:00 P4

Optoelectronical properties of InGaN quantum well light emitting diodes on semipolar GaN — •Jens Rass, Marcus Stascheit, Simon Ploch, Tim Wernicke, Patrick Vogt, and Michael Kneissl — Technische Universitaet Berlin, Institute of Solid State Physics, Secretariat EW6-1, Hardenbergstrasse 36, 10623 Berlin, Germany

The performance of GaN-based light emitting diodes (LEDs) is strongly affected by polarization fields along the c-axis of the crystal. Due to the resulting quantum-confined Stark effect the radiative transition rate is reduced and the emission wavelength is blue-shifted when carriers are injected. By growing the structures on semipolar or nonpolar planes the polarization fields can be significantly reduced or even eliminated. In this work, InGaN single quantum well LEDs have been grown by metal-organic vapor phase epitaxy on different semipolar surfaces such as the $(10\bar{1}1)$ and $(20\bar{2}1)$ plane. The optoelectronic properties such as the light output power, the emission wavelength and its shift with injection current as well as the operating voltage have been studied. By employing capacitance-voltage- and current-voltage measurements, the size of the depletion region, the build-in potential, the saturation current and the doping concentrations have been determined. LEDs with emission wavelengths ranging from the violet to the blue and green region are presented and their performance characteristics are compared to LEDs grown on the polar c-plane surface.

HL 85.128 Thu 18:00 P4

Performance characteristic of GaN, InGaN and AlGaN based UV photodetectors with Ti/Al/Mo/Au-contacts — •Bertram Jaeger[1], Jessica Schlegel[1], Patrick Vogt[1], Michael Kneissl[1,2], Sylvia Hagedorn[2], Veit Hoffmann[2], Sven Einfeldt[2], and Markus Weyers[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

We have investigated UV photodetectors with Ti/Al/Mo/Au-contacts on GaN, $Al_{0.2}Ga_{0.8}N$, $In_{0.07}Ga_{0.93}N$ and $In_{0.11}Ga_{0.89}N$ respectively by photocurrent spectroscopy, transmission spectroscopy and I-V measurements. The influence of the different absorber materials on contact properties and device performance will be discussed. The spectral response of each detector has a cut-off wavelength according to the bandgap energy of its absorber material between 317 nm and 416 nm. The AlGaN detector has very low dark current in pA-range for an applied bias up to 100 V indicating a Schottky-like character of the contacts (MSM detector). The GaN and InGaN based detectors however show the behavior of photoconductors with ohmic contacts resulting in dark currents in the mA-range for biases of a few volts. The photocurrent of those detectors is sublinear with incident optical power, which hints at the presence of an internal gain mechanism and may explain the observed high currents. The photocurrent of the AlGaN-based detector is below 1 nA up to 100 V bias and linear with optical power.

HL 85.129 Thu 18:00 P4

Influence of the interdigitated contact geometry on the performance of $Al_{0.2}Ga_{0.8}N$ based MSM photodetectors — •Alexander Wolf[1], Jessica Schlegel[1], Patrick Vogt[1], Sylvia Hagedorn[2], Sven Einfeldt[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

The device properties of metal-semiconductor-metal (MSM) photodetectors strongly depend on the interdigitated finger contact geometry. In order to optimize these parameters for visible-blind UV detectors we have characterized $Al_{0.2}Ga_{0.8}N$ MSM structures with Ti/Al/Mo/Au Schottky-contacts in varying finger geometries. We have analyzed the device properties by photocurrent spectroscopy and I-V measurements. The detectors have a cut-off wavelength of 315 nm. All structures show dark currents below 3 pA for bias voltages up to 100 V and linearity with optical power. Photocurrents up to 0.9 nA at 310 nm and a maximum responsivity of 57 mA/W at 310 nm and a bias voltage of 100 V have been obtained. For fixed bias voltages a smaller finger spacing leads to a higher responsivity due to the higher electric fields and reduced carrier transit times. The finger width is a crucial parameter for the optimization of the external quantum efficiency due to shadowing of the underlying semiconductor absorber layer. The dependence of the device properties on geometrical parameters of the interdigitated finger contacts will be presented and compared.

HL 85.130 Thu 18:00 P4

Study of transport processes in AlGaInN-based light-emitting diodes — •Bastian Galler, Ansgar Laubsch, Andreas Wojcik, Hans-Jürgen Lugauer, Alvaro Gomez-Iglesias, Matthias Sabathil, and Berthold Hahn — OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany

Several experiments investigating the efficiency droop in AlGaInN-based light-emitting diodes (LEDs) point to a loss mechanism resulting from a too high carrier density in the active region causing the decreasing efficiency at high currents [1,2]. Therefore, it is desirable to spread carriers over a larger active volume to achieve good efficiency values at high current densities. As this is difficult to achieve in GaN-based LEDs, a detailed understanding of the transport processes governing the carrier distribution in GaN/InGaN multi-quantum-wells (MQWs) is crucial for further brightness improvements. We study colour-coded LEDs featuring one QW emitting at a longer wavelength to analyze the carrier distribution experimentally. Although the absolute emission from such a high-indium QW is increased due to its more favourable energetic level, valuable insight can be gained analyzing the fraction of the colour-coded emission as a function of temperature and current density.

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