Method — Modelling Hertzian Point Dipoles Using the Fourier Modal

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.

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.

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 crystals 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 unit 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.

Few-photon transport in low-dimensional waveguides with a quantum-imurity — CHRISTOPH MARTENS, JEAN-CHRISTOPHE BLANCON, PAULO 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 imurity. 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.


The experimental realizations of quantum dots, e.g., in photonic crystals and strongly interacting photonic resonators 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.

C. Dineen et al., Electromagnetic field structure and normal mode splitting in photonic crystal nanocavities, Optics Express 13, 4980 (2005).


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 (CoOP), 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.

C. Dineen, J. Förstner, A.R. Zakharian, J.V. Moloney, S.W. Kocherphysik, Linnéstr. 5, 04103 Leipzig, Germany

We numerically investigated 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].

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Transmission measurements are performed using a tapered optical fiber 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 signal, which is used to measure important optical properties and magneto-optical effects. 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.

We gratefully acknowledge support by the DFG through GRK 1286.

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. The excitons are confined within a parabolic potential well and have included deformation potential phonon scattering. The excitation 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. The excitons are confined within a parabolic potential well and have included deformation potential phonon scattering. We have included deformation potential phonon scattering but not collision of excitons.

The Boltzmann equation has been solved by a finite difference method and the method of lines using MATLAB. Using initial condition representative for actual experimental studies, we are getting the excitation 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.

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We gratefully acknowledge support by the DFG through GRK 1286.
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 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 Müller1, Sebastian Geier1, Andreas Laufer1, Bruno K. Meyer2, and Carsten Ronning2 — 1Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — 2Physikalisches 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 films on glass 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 donor/acceptor behavior. Ion implanted samples were examined to discover extrinsic donor/acceptor species and optical active impurities.


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 promising 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 of the 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 GaAsBi — Christian Wagner1, Sebastian Imhof1, Alexej Chernikov2, Martin Koch2, Nico S. Köstler2, Kolja Kolata2, Sangam Chatterjee2, Stefan W. Koch2, Xianfeng Lu3, Shane R. Johnson3, Daniel A. Beaton4, Thomas Tiedje5, Oleq Rube6,7, and Angela Thirnhardt — 1Institut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany — 2Fachbereich Physik, Philips-Universität Marburg, 35032 Marburg, Germany — 3Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-6006, USA — 4Department of Physics and Astronomy, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada — 5Department of Electrical and Computer Engineering, University of Victoria, Victoria, British Columbia V8W 3P6, Canada — 6Thunder Bay Regional Research Institute, Thunder Bay, Ontario P7A 7T1, Canada — 7Department 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 Rosemann1, Alexej Chernikov2, Verena Bornwasser1, Niko S. Köstler2, Martin Koch2, Kolja Kolata2, Sangam Chatterjee2, Stephan W. Koch2, Sebastian Imhof2, Christian Wagner2, Angela Thirnhardt2, Xianfeng Lu3, Shane R. Johnson3, Dan A. Beaton4, Thomas Tiedje5, and Oleq Rube6,7 — 1Fachbereich Physik, Philips-Universität Marburg, 35032 Marburg, Germany — 2Institut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany — 3Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-6006, USA — 4Department of Physics and Astronomy, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada — 5Department of Electrical and Computer Engineering, University of Victoria, Victoria, British Columbia V8W 3P6, Canada — 6Thunder Bay Regional Research Institute, Thunder Bay, Ontario P7A 7T1, Canada — 7Department 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 Brenneis1, Simon Hertenberger, Sonja Matich, Gerhard Aebstetter, Alexander Holleitner, and Gregor Kohlmüller — Walter Schottky Institut and Physik Departement, 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 SiO2 are structured via e-beam lithography by holes with a diameter of approximately 80 nm. The nanowires are then grown vertically on the substrate by using metalorganic chemical vapor deposition. The optical properties of the nanowires are characterized by FTIR transmission and reflectivity measurements. The nanowires are then grown vertically on the substrate by using metalorganic chemical vapor deposition. The optical properties of the nanowires are characterized by FTIR transmission and reflectivity measurements. The nanowires are then grown vertically on the substrate by using metalorganic chemical vapor deposition. The optical properties of the nanowires are characterized by FTIR transmission and reflectivity measurements.
The change of the spontaneous emission properties by the resonator towards und Funktionelle Grenzflächen, Germany

Simulation and Experiment

— Ultrafast X-Ray Diffraction on Photoexcited Superlattices: Experiment and Simulation —

Polariton lasing from a GaAs microcavity: a temperature dependent analysis in the spectral and temporal domain —

Solitary pulse propagation through quantum dot media —

Ultrafast X-Ray Diffraction on Photoexcited Superlattices: Experiment and Simulation —

Photocurrents in Semiconductor Carbon Nanotubes with Spin-Orbit Interaction —

Ultrafast X-Ray Diffraction on a STO/SRO Superlattice —

Ultrafast optical spectroscopy of layered hole-doped manganites —

Pump-Probe Spectroscopy on Superlattices: Experiment and Simulation —
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 a semi-empirical 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 a self-consistent effective on these photoinduced currents and draw the analogy to recent investigations on single-color injection of photocurrents in semiconductor quantum wells [2].


Thursday

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]


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 exciton-chains and profile [2]. 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 spectroscopy we were able to detect 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 85.30 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, V. Wegscheider, I. Cawthorpe, M. Glazov, T. Korn, D. Schuh, W. Wegscheider, and C. Schüller - Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany - 2 present adress: ETH Zürich, 8093 Zürich, Switzerland

Spin dephasing anisotropy in two-dimensional electron systems is 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 connected to the asymmetric growth profile [3]. 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 spectroscopy we were able to detect 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.

[1] Michael Griesbeck, Dominik Waller, Greg Fleischmann, Elisabeth Leierseid, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller - 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 connected to the asymmetric growth 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 spectroscopy we were able to detect 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 85.31 Thu 18:00 P4
Spin dephasing anisotropy in two-dimensional electron systems

Michael Griesbeck, Dominik Waller, Greg Fleischmann, Elisabeth Leierseid, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller - 1 Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany - 2 present adress: Laboratorium für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland

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[1] Michael Griesbeck, Dominik Waller, Greg Fleischmann, Elisabeth Leierseid, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller - 1 Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany - 2 present adress: Laboratorium für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland

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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 relaxations related to these LA phonons. We find that a squeezing of the latter, non-relativistic coherent phonon, 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.

Output control by quantum focusing in multiterminal billiards — Christian Morfonios, Daniel Buchholz, and Peter Schmelcher — Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — Theoretische Chemie, Physikalisches 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, the transport is controlled at zero magnetic field by 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 departure from this condition demonstrates the inapplicability of purely classical considerations in the deep quantum regime. The geometrical transmission through the bulk of the waveguide is controlled 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.

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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. Of the wires consists of a GaAs core surrounded by an AlGaAs layer which acts as a growth stopper, and a GaAs cap layer which acts as a spin-polarized current, the conductances of its two outputs are different.

We show, using diagrammatic methods within a local conductivity level spacing, but large compared to the onset of quantum tunneling. The investigated films are produced by conversion of the THz-Proben zu charakterisieren, wurden Messungen des Shubnikov-de Haas-Effekts bei einer Temperatur von $T \approx 4K$ und im Bereich der Magnetfelder von $0 \leq B \leq 10T$ durchgeführt. Aus diesen Messungen lässt sich die Elektronendichte im Graphen bestimmen. Bei der anschließenden Messung der Photoleitfähigkeit an den verwendeten Graphenproben wurden Messungen der Photoleitfähigkeit an den verwendeten Graphenproben durchgeführt. Die Photoleitfähigkeit der Graphenproben wurde durch eine Wellenleiterstruktur in einem Wellenleiter auf ein graphen-proben übertragen.

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 level spacing, but large compared to the onset of quantum tunneling.

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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 Lorentz 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.


Room-temperature nanosecond spin-lifetimes in bulk cubic GaN — Jan Heve Bus1, Jorg Rudolph1, Jeanette Gorewoda1, Thorsten Schupp2, Donat As3, and Daniel Hägel1

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.

Basic design of a three-terminal semiconductor structure for electrical spin-storage and read-out — Johannes Zeller, Rouven Dieh1m, Pablo Ashhoff, Andreas Merz, Heinz Kalt, and Michael Hetterschin

In recent years, spin light-emitting diodes have become well-established semiconductor as spin-injector and quantum dots which are selectively loaded with either electrons or holes. Transport properties, depending on the properties of the constituents. 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.

Silicon pin solar cells investigated by multi-frequency EDMR — Christoph Meier1, Christian Teutloff1, Matthias Feh1r, Alexander Schneeg2, Klaus Lips2, and Robert Bittl1

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. EPR spectra e.g. successfully employed to microwave-lith at 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.

Low-temperature processed Schottky-gated field-effect transistors based on amorphous oxide channel material — Michael Lorenz1, Alexander Lain1, Heiko Frenzel1, Holger von Wenckstern1, Marlis Grunwald2, Pedro Martins2, Elvira Fortunato2, and Rodrigo Martins2

Departamento de Ciencia dos Materiais, Faculdade de Ciencias e Tecnologia, FCT, Universidade Nova de Lisboa and CEMOP-UNITOVA, 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 radiofrequency magnetron sputtering of alternating layers of Pb and p-stand-ard 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 $150$ 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.

First Principles Investigation of La inplaned in high-k Dielectric Film of the Field Effect Transistors — Ebrahim Nadimi1, Rolf Ottking2, Philipp Plansitz2, Martin Trentsch3, Torben Kleming1, Rick Carter3, Christian Radehaus2, and Michael Schreiber2

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.
We attribute this strong improvement to a much higher spectral gain, InGaAlAs core waveguide and 1700 nm InP top cladding layer. The realized. The laser structure consists of 6 QD layers embedded in an homogeneous linewidth to about 23 meV (see APL 96, 191903 (2010)).

A formation of rather round-shaped dots was type InP (100) were investigated. It could be shown that the supply than 41

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.

In the last years a strong effort was made in the development of InP/AlGaInP quantum dot lasers with different length 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 at different operating parameters, which are pulse width, frequency and temperature. We achieved lasing operation at room temperature.

Gain and reflectance measurements of a 1050nm VECSEL chip was 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 impact of different VECSEL Chip anti reflectivity coatings. The measured gain curves are to be found in good agreement with experiments in laser operation.

Preparation and immobilization of noble metal nanoparticles for plasmonic solar cells — Ulrich Christian Schröder1, Martin Gnauck1, Robert Möller2, Bettina Rudolph2, Wolfgang Fritzsch2, and Carsten Ronning1 — 1Institute of Solid State Physics, University of Jena, Max-Wien-Platz 1, D-07743 Jena — 2Institut 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 hereto far 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.

Preparation and immobilization of noble metal nanoparticles for plasmonic solar cells — Rolli Wang1,2, Martin Pitzer1,2, DongZhi Hu1,2, Daniel M. Schaad1,2, and Lijilana Fruek2 — 1Institut für Angewandte Physik, Karlsruhe Institut für Technologie (KIT) — 2DFG 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 photovoltaic efficiency. In this paper, we report on the fabrication 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 particularly focus on the use of noble metal nanoparticles as plasmonic scattering elements 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 agglomeration and allows control of
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 85.60 Thu 18:00 P4**

**Semiconductor-Insulator-Semiconductor solar cells on wetchemically etched silicon nanowire carpets using different tunnel barrier materials** — **Martin Schreivogel**, Björn Hoffmann, Gerald Brönnstrup, Vladimir Sivarov, and Silke Christiansen — 1Institut für Phototechnische Technologien, Jena — 2Max-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 substrates 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 or by chemically depositing an oxide. The oxide deposition is carried out in an 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 Cu2ZnSnS4 nanoparticles and thin films studied with XRD and SEM** — **Folker Zutz**, Christine Choisy, Ingo Riedel, and Jürgen Parisi — Thin Film Photovoltaics, Energy and Semiconductor Research Laboratory, University of Oldenburg, D-26111 Oldenburg

Cu2ZnSnS4 (CZTS) is a compound semiconductor with an absorption coefficient of $10^4\text{cm}^{-1}$ 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 microcrystals. 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 investigations (X-ray diffraction, electron microscopy) of CZTS and the average grain size (charge transport). We report on struc-

tural 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)Se2-based thin film absorbers prepared with different throughput speeds** — **Max Meussen**, Oliver Neumann, Syed Farhad Rezaei, Björn Hoffmann, William Fram Witte, Dimitrios Harissos, and Gottfried H. Bauer — 1Institut für Physik, Carl von Ossietzky Universität Oldenburg, Germany — 2Zentrum 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 AFMfeatures on Cu(In,Ga)Se2 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 and the 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 (CIGS) have a strong potential for achieving high efficiencies at low production costs. Volume production of CIGS-modules has already started to exploit their favorable attributes such as low cost processing and reasonable module efficiency. In this study we investigated industrially produced CIGS-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 $V_{OC}$ and the series resistance $R_s$. The calculated maximum module efficiency can be observed. X-ray diffraction was employed to relate these effects to the crystallographic structure of the actual CIGS-sfilms.

Light-infrared 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)Se2 solar cells by voltage dependent electroluminescence** — **Felix Daum** and Christian Schret, Stefan Puttnins, Andreas Rahm, and Marius Grundmann — 1Solarion AG, Ostende 5, 04288 Leipzig, Germany — 2Institut für Experimentelle Physik II, Universität Leipzig, Linnestr. 5, 04103 Leipzig, Germany

Cu(In,Ga)Se2 (CIGS) thin film solar cells deposited on flexible polycrystalline oxide films using innovative techniques and a fabrication process to 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 is 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 CIGS. 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, we will report on 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$_2$Se$_2$** — **Janos Kiss**, Thomas Gruhner, 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 CuIn$_2$Se$_2$ (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 out of 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$_2$Se$_2$ via performing density functional theory (DFT) calculations on large supercells. We found that bulk CuIn$_2$Se$_2$ 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$_2$Se$_2$.
Preparation and characterization of Bi$_2$S$_3$ 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$_2$S$_3$ was deposited in vacuum and examined for its suitability for solar cells.

The bismuth sulfide thin films were grown in a recently designed ultrahigh 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$_2$S$_3$ was additionally deposited on epitaxial LaAlO$_3$ and SrTiO$_3$ substrates in order to enhance directional growth of the thin films.

Optical and Electrical Characterization of InP-based Low Bandgap Multijunction Solar Cells — Anja Dobrich, Nadine Szabó, Klaus Schwarzbauer, 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 multijunction 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/InAs 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.

Herstellung, Kontaktierung und Charakterisierung von GaAs Mikro-Photovoltaikzellen — Michael Kwantek, Anne Ludwig, Rüdiger Schott, und Andreas D. Weck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

In the last years the band gap of silicon has to be reduced by further miniaturization of the solar cells. This means that the energy demand of the photovoltaic cell is reduced. A new module design with increased energy efficiency can be achieved by using two or more different energy sources.

In the 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.

This 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 und sie auf Funktionalität und Energiebedarf immer weiter zu zwingen. Doch besonders auch für dezentrale Energieversorgungsanlagen eignet sich die Photovoltaikzelle als möglicher Weg.

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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 constrains the short-circuit current density. The required light-trapping can be achieved by implementing AR, textured TCO and back contact (BC) which is why we use the term "BC" in the following. 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.

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


Epitaxie auf kristallinem Silicium durch Excimer-Laser-Beschallung — Ingo Sill, Gudrun Andra und Fritz Falk — Institut für Photonische Technologien e.V., Jena

Dünnfilmssolarzellen aus kristallinem Silicium sind eine günstige Alternative zu Waferzellen. Multikristalline Dünnfilmzellen aus Silizium auf einem Substrat aus Borosilikat-Glas können mit Hilfe des LUC 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 Keimbildung wird anschließend epitaktisch verdichtet, indem darauf Bor-dotierter a-Si durch Elektronenstrahlverdampfen abgeschieden und gleichzeitig das a-Si durch wiederholtes Bestrahlen mit dem Puls eines Excimer-Lasers epitaktisch kristallisiert. Um den Prozess hinsichtlich der Abscheidung großer a-Si Kristallite zwischen den einzelnen Laserpulsen zu optimieren, wurde ein einzelner Kristallisationsschritt untersucht. Dabei wurde die Keimbildungsdichte, die a-Si-Dicke, die Substrattemperatur und die Fluenz des Excimer-Lasers variiert, um die Abhängigkeit des Epitazieintervalls von diesen Parametern zu messen und zu verstehen. Experimentelle Ergebnisse werden mit Simulationsrechnungen verglichen.

Thickening of polycrystalline silicon layers by solid phase epitaxy — Ingmar Höger, Annette 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. Dioxide-layer crystallization by means of a short irradiation of the bare substrate results in grain diameters in the range of around 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 amorphous silicon growth due to the irradiation. Further, in order to minimize the recombination time and to lead to a lower bulk lifetime, high temperature annealing treatments have been performed. 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.

Time-resolved photoluminescence imaging of silicon wafers using a CCD camera — David Kilian, 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.

Transmission Electron Microscopy for thin film solar cells — Nies Reininghaus, Vitali Schmidt, Wiebke Hachmann, Stefan Gruss, Helmut Stieber, and Ulrich Heinzmann — Molecular and Surface Physics, Bielefeld University — 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 micromorphc 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.

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. It is possible to 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.


Atomic and electronic structure of non-planar Si/SiO2 interfaces — Kaori Seino, Friedrich Schiller-Universität Jena, Jena, Germany — 2Department 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
Dopant-induced morphology evolution of silicon via wet chemical etching — Guodong Yuan1,2 and Saskia F. Fischer1,2 1Institute of physics, Humboldt-Universität zu Berlin, D-12489 Berlin, Germany 2Werkstoff- und Elektronenmikroskopie, 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 electron-assisted etching [1]. In this contribution, we discuss the SiNWs etching process in detail. The morphology evolution of the 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 wet chemical etching produced 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.


Low temperature Coulomb anomaly in CMOS compatible silicon quantum dots — Stefan Jauregui1, Matthias Rudolph1, Dharmraj Kotekar-Patil1, David Wharam1, Dieter Kern1, Marc Sanquer2, and Maud Vinet3 1Eberhard Karls Universität, Tübingen, 2CEA INAC, Grenoble, France 3CEA 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 modes in silicon quantum dots which show Coulomb blockade behaviour. The size of the Coulomb diamond 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 of $\frac{dV_g}{dV_C} > 1$. 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.

Investigation of an InGaN - GaN nanowire heterostructure — Friederich Limbach1, Armando Rastelli2, Oliver G. Schmidt1,2, and Christoph Reinheimer1 1Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allianz für Materialien und Systeme, Johannes Gutenberg Universität Mainz, 2Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany

In this contribution, we report on transport measurements of nanoscale enhancement modes in quantum dots which show Coulomb blockade behaviour. The size of the Coulomb diamond 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 of $\frac{dV_g}{dV_C} > 1$. 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.

Influence of the nanowire interdistance on growth conditions and crystal structure of self-catalyzed GaAs nanowires grown by chemical vapor deposition — Detlev Grützmacher1,2, Andreas Heidemaier1, Elisabeth Reiger1,2, Joachim Hubmann3,4, Elisabeth Reiger1,2, Elisa Sutter2, and Detlev Grützmacher1,2 1Institut für Festkörpernadeln, Universität Regensburg, Germany 2Laboratoire des Matériaux Semiconducteurs, EPFL Lausanne, Switzerland

Nanostructures grown in bottom-up processes are considered as possible building blocks for future electronic devices. For this use it is necessary to control the 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.


Voltage-dependent excited state spectroscopy of single lateral InGaN/GaN quantum dot molecules — Meike Seible1, Matthias Heidemaier1, Jie Peng2, Gabriel Besten2, Liuhan Wang2, Armando Rastelli2, Oliver G. Schmidt1,2, and Peter Mönchler1 1Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allianz für Materialien und Systeme, Johannes Gutenberg Universität Mainz, 2Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, 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.

Time-dependent measurements of single In(Ga)As quantum dots embedded in GaAs reversed pyramid cavities — Christoph Reinheimer, Daniel Rölke, Daniel Schaadt, Heinz Schreiber, and Detlev Grützmacher
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.


HL 85.89 Thu 18:00 P4
Optical properties of GaAs quantum dots fabricated by filling of self-assembled nanoholes — Andreas Grae1, David Sonnenberg2, Christian Hevesi3, Andrei Schliwa2, and Wolfgang Hansen1 — Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany — 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 (diameter 10 m) in the Al0.1Ga0.9As layer on the AlAs/GaAs quantum dots. 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, we present a study of neutral exciton and biexciton peaks of single QDs. Furthermore, a model using the eight-band k-p theory and configuration interaction [2] is used to interpret the experimental results.


HL 85.90 Thu 18:00 P4
Towards site controlled growth of InAs quantum dots on patterned GaAs by microsphere photolithography — Ulrich Rengstl1, Elisabeth Kohorkaya1, Robert Rosbach2, Michael Jetter2, and Peter Michler1 — 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 etching, do not work because we use a scanning confocal microscope, which has the disadvantage of high time consumption. A faster method for patterning a large surface uses microsphere photolithography [1]. For partial exposure of UV-sensitive photore sist, 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 photore sist, 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 pre patterning also leads to an increased accumulation of deposited InAs inside the holes, which supports island growth.


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 Beckel1, Bastian Mariquardt1, Martin Gellert1, Axel Lorke1, Tobias Nowozin2, Andreas Marent2, and Dieter Bimberg2 — 1Faculty of Physics, University of Duisburg-Essen, Lothringer Str. 1, 47057 Duisburg, Germany — 2Institut 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
results differ very strongly: from 50 \textup{cm}^2\textup{V}^{-1}\textup{s}^{-1} for electrical transport measurements. This suggests that the mobility for electrical transport in nanoporous ITO films is comparable to bulk ITO to 0.4 \textup{cm}^2\textup{V}^{-1}\textup{s}^{-1}. 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 transparent electrodes. An interesting possibility to realize transparent electrodes is the printing of dispersions containing ITO nanoparticles\cite{1}. We study here the charge carrier concentration and mobility of various nanoporous indium tin oxide (ITO) films, using Hall measurements and optical spectroscopy\cite{2}. For the carrier density inside the particles (2 - 4 \cdot 10^{20}\textup{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 results can be used for interpretation. For the mobilities in these layers the results differ very strongly: from 50 \textup{cm}^2\textup{V}^{-1}\textup{s}^{-1} in optical spectroscopy (which is comparable to bulk ITO) to 0.4 \textup{cm}^2\textup{V}^{-1}\textup{s}^{-1} in Hall measurements. This suggests that the mobility for electrical transport in nanoporous ITO films is strongly suppressed by scattering at interparticle boundaries.\cite{1}

The NWs were grown in a self-assembled precursor layer using molecular beam epitaxy, substrate patterning was achieved by optical and electron beam lithography. The NWs were alloyed with 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 20\textup{nm} from the substrate-interface.

X-ray characterization of Au-free grown GaAs nanowires on Si — Andreas Biermanns\textsuperscript{1}, Steffen Bruerek\textsuperscript{2}, Anton Davydov\textsuperscript{1}, Lutz Gerlhaar\textsuperscript{2}, and Ulrich Pietsch\textsuperscript{1}

Institute of Semiconductor Physics, Technische Universität München, Am Coulombwall 3, D-85748 Garching, Germany

Semiconductor nanowires (NWs) 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 x-ray diffraction on particular zinc-blende segments and lattice parameters of individual wires we measured separately. Using asymmetric x-ray diffraction on particular zinc-blende (ZB) and wurzite (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 20\textup{nm} from the substrate-interface.

Coupled Quantum Dots for Thermoelectric Measurements — Holger Thierschmann, LUIS MAIER, Johannes Knorr, Matthias Mühlbauer, Hartmut Behm, and Laurenz 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\cite{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 \textup{mK}.

Electroluminescence from silicon nanoparticles — Jens Thiels\textsuperscript{1}, Martin Geller\textsuperscript{1}, Axel Lorkke\textsuperscript{2}, Hartmut Wigger\textsuperscript{2}, and Cedrik Meier\textsuperscript{1}\textsuperscript{*}

1Fakultät für Physik und CeNIDE, Universität Duisburg-Essen, 44201 Essen; 2Institut für Verbrennung und Gasdynamik and CeNIDE, Universität Duisburg-Essen

Nanophotonics & Nanomaterials Group, University Paderborn

Si nanoparticles are tunable 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 engineered from silicon nitride by a low-temperature microwave plasma using SiH\textsubscript{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 Au electrode on the back-side of the silicon wafer.
and a Si-doped GaAs back contact. A strong EL emission from the Si nanoparticles is observed with the unaided eye\textsuperscript{1}. The EL spectra of the devices were investigated in a ϕ-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.

\textsuperscript{1}Theis et al. Nanotechnology 21, 455201 (2009)

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**Engineering self-assembled SiGe islands for robust electron confinement in Si** — Roman O. Rezavi\textsuperscript{1,2}, Sumit K. Varshney\textsuperscript{1,2}, Vladimir M. Fomin\textsuperscript{1}, Armando Rastelli\textsuperscript{3}, and Oliver G. Schmidt\textsuperscript{4}.

1Institute for Integrative Nanosciences, IFW-Dresden, D-01069 Dresden, Germany — 2Laboratory 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 (001) islands are derived within the framework of the available parameters. Shape fluctuations during Si cappeing 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.

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**Analysis of squeezed LO phonon states in a QD with the help of the Wigner function** — Daniel Wigger\textsuperscript{1}, Doris Reiter\textsuperscript{1}, Tilman Kuhn\textsuperscript{1}, and Vollrath Martin Axten\textsuperscript{2}.

1Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — 2Theoretische 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.

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**Effects of phonon-induced dephasing on Rabi oscillations in GaAs quantum dot** — Sebastian Lörker\textsuperscript{1}, Doris Reiter\textsuperscript{1}, Vollrath Martin Axten\textsuperscript{2}, and Tilman Kuhn\textsuperscript{1}.

1Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — 2Theoretische 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.

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**Kondo effect in double quantum dots with magnetic field-tuned coupling** — Daniel Tutuc\textsuperscript{1,3}, Rolf Haug\textsuperscript{1,3}, Brendan Coulghan\textsuperscript{2,3}, Lars Mühlf\textsuperscript{2,3}, Sabine Tornow\textsuperscript{2,3}, and Gertrud Zwicknagel\textsuperscript{1,3}.

1Konzentrat für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland — 2Institut für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland — 3Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — 4Institut für Mathematische Physik, Technische Universität Braunschweig, D-38106 Braunschweig — 5NTH 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 competition 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 emerge from the chiral nature 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 of the ground state and discuss the validity of simplified effective coupling models.


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**X-ray characterization Si-doped InAs nanowires grown on GaAs** — Muhammad Saqib\textsuperscript{1}, Andreas Riemann\textsuperscript{1}, Thomas Graf\textsuperscript{2}, Mihail Lepsa\textsuperscript{1}, and Ullrich Pietzsch\textsuperscript{1}.

1Universität Siegen, Festkörperphysik, Germany — 2Forschungszentrum Jülich, Institut für Bio- und Nanosysteme (IBN)-1, Germany

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 region 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 peaks shapes and from charge stability diagrams. Capacitances resulting from different geometrical models are compared with those obtained from the transport measurements.

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**Geometry effects on Coulomb charging in CMOS-compatible SOI-SETs** — Matthias Rastelli\textsuperscript{1}, Daniel Wigger\textsuperscript{1}, Stefan Jauerneck\textsuperscript{1}, David Wharam\textsuperscript{1}, Dieter Kern\textsuperscript{1}, Marc Sanquer\textsuperscript{1}, and Maud Vinet\textsuperscript{1}.

1Eberhard Karls Universität, Tübingen — 2CEA INAC, Grenoble, France — 3CEA 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.
Semiconductor nanowires (NWs) 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 a 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 5.105** Thu 18:00 P4

**Electronic transport properties of InAs nanowires** — Önder Göl, Christian Blömers, Hilde Hardtegen, Mihail Ion Leipa, Kamil Sladek, Andreas Penz, Thomas Gräp, Detlev Grützmacher, and Thomas Schäpers — Institute of Bio- and Nanosystems (IBN) 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 5.106** Thu 18:00 P4

**Spin noise spectroscopy of single semiconductor quantum dots** — Ramin Darbashi, Michael Schmid, Klaus Piek, Hans Werner Schuhmacher, Jens Hübler, and Michael Oestreicher — 1Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — 2Physikalisches Institut der Universität, Hausdorff-Kolloquium 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 dot ensembles. In this contribution we present results on a single hole. The investigated sample are InAs quantum dots with a density gradient enclosed in a Bragg mirror cavity. The charge state is determined via the spin flip rate and polarization dependence of the photoluminescence. We present transport experiments in order to determine 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 bolometer to realise an intrinsically stable, low temperature measurement system with direct optical access.


**HL 5.107** Thu 18:00 P4

**Magnetotransport on ferromagnetic (Ga,Mn)As/GaAs core-shell nanowires** — Christian Butschkow, Stefan Jauerneck, Dieter Kern, David Wohratal, and Mauro A. Sano — Technische Physik, Institute of Nanostructure Technologies and Analytics, 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 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 microscopy) and optical (macro- and microphotoluminescence) 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 laserinaTIRF(Total Internal Reflection Fluorescence) laser, we monitor the evolution of the lattice constants and structure of the nanowires. 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 5.108** Thu 18:00 P4

**Triple dot structures from CMOS-compatible SOI-FETs** — Dhammaia Kotik-Katt, Matthias Ruf, Stefan Jauerneck, Dieter Kern, David Wohratal, Marc Sanquer, and Mauro A. Sano — Iberhard Karls Universität, Tübingen — 2CEA INAC, Grenoble, France — 3CEA 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 computers or quantum cellular automata (QCA).

**HL 5.109** Thu 18:00 P4

**Droplet epitaxy of InGaAs quantum dots on (100) GaAs substrate** — Verena Zürcher, Aleksandr Gushterov, Mohamed Benyoucef, and Johann Peter Reithmaier — Technische Physik, Institute of Nanostructure Technologies and Analytics, 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 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 microscopy) and optical (macro- and microphotoluminescence) 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 laserinaTIRF(Total Internal Reflection Fluorescence) laser, we monitor the evolution of the lattice constants and structure of the nanowires. 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 5.110** Thu 18:00 P4

**Optical properties of ZnO/ZnMgO nano heterostructures** — Nilson Neubauer, Bengiang Cao, Marius Grundmann, and Frank Cichos — 1Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig — 2Semiconductor Physics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

ZnO nanowires are promising candidates for the fabrication of nanoscaled light emitting diodes. Due to the large energy bandgap and excitonic 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 nanostructures. Due to quantum confinement effects in such heterostructures even single-photon emission is possible, a key requirement for the devices as building blocks for charge based quantum computers or quantum cellular automata (QCA).
in a Hanbury Brown-Twiss setup to study photon correlations.

Control of the carrier density of an inverted GaAs/AlGaAs heterojunction using high mobility transistor (HMET) heterostructure with embedded quantum dots via a backgate — Sächsa René Valentin, Arne Ludwig, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätstrasse 150, D-44780 Bochum.

InAs quantum dots 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 2DEG. In this contribution we show a strategy to control 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.

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

Highly asymmetric nuclear spin pumping is observed in a 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 nuclear 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, whereby the pumping of the nuclear spin system is due to hyperfine-mediated spin flip transitions between the states of the neutral exciton manifold.


Copper doped GaN has been reported to exhibit ferromagnetic behavior at Cu concentrations between 0% and 2.3%. To clarify the role of the Cu-doping mechanism of ferromagnetism in this system. Above all, a detailed study of the processes. A strong dependence of the observed dynamic nuclear spin pumping is observed in a 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 nuclear 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, whereby the pumping of the nuclear spin system is due to hyperfine-mediated spin flip transitions between the states of the neutral exciton manifold.


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 goal 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 MOVPE GaInN/AlGaN 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.

Influence of crystal defects on the magnetic properties of Gd-doped GaN — Stefan Shvarkov, Dirk Reuter, Andreas D. Wieck, Hans-Werner Bläser, Yvon Cordier, Jindrich Hemberg, and Achim Trambper — 1Ruhr-Universität Bochum, Lehrstuhl für Angewandte Festkörperphysik, Universitätsstr. 150, 44780 Bochum, Germany — 2Ruhr-Universität Bochum, Universitätstr. 150, 44780 Bochum, Germany — 3CNRS-CHRE, rue Bernard Grégory, 06560 Valbonne, France — 4Paul Drude Institut für Festkörperlelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany.

Influence of crystal defects on the magnetic properties of Gd-doped GaN is presented. GdN 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⁺ implants were inserted. In addition, the electrical transport properties of Gd-implanted Al₀.₅Ga₀.₅N/GaN high electron mobility transistor (HEMT) structures have been studied. Gd was implanted in the MBE-grown Al₀.₅Ga₀.₅N/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.

**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 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 nitride based light emitters. We investigate the possibility of intra- and inter-band Auger recombination in wurtzite GaInN. Using density functional theory and the local density approximation we compute Auger recombination rates for InN concentrations \( x \) ranging from 0 to 100%.


**Locally resolved imaging of internal electric fields in GaN/GaInN quantum wells by differential phase contrast microscopy**

Matthias Lohn¹, Johannes Thalhammer¹, Michael Jettker², Ferdinand Scholz³, and Josef Zweck¹ — ¹Fakultät für Physik, Universität Regensburg, D-93053 Regensburg — ²Fakultät für Physik, Universität Stuttgart, D-70569 Stuttgart — ³Institut für Optoelektronik, Universität Ulm, D-89081 Ulm

InGaN/GaN-based lateral diodes emitting in the green spectral range are still difficult to achieve. The efficiency "drop" 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 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.

This work is part of the PolarCon project (DFG FOR 957).

**6S-band Auger recombination in GaN 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 nitride based light emitters. We investigate the possibility of intra- and inter-band Auger recombination in wurtzite GaInN. Using density functional theory and the local density approximation we compute Auger recombination rates for InN concentrations \( x \) ranging from 0 to 100%.


**Internal quantum efficiency of high In content GaInN quantum well structures**

Fedor Alexeev, Helger Jönsson, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technische Universität Braunschweig, Institut für Angewandte Physik, Mendelssohnr. 2, 30106 Braunschweig

The efficiency of GaN/AlGaN quantum well (QW) structures is quite low compared to GaN/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 GaN/GaN structures is based on the observation that every dislocation in highly efficient c-plane GaN/GaN structures is decorated with a so-called V-pit, a hexagonal shaped inverted pyramid with (1011) sidewalks. On these sidewalks, thinner quantum wells act as a barrier, suppressing nonradiative recombination at the defects. TEM measurements on highly efficient 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.


**Optical investigation on the valence band structure of AlGaN with low AI content**

Tobias Meisch¹, Frank Lipskii², Kamran Forghani², Benjamin Neuschl¹, Martin Feneberg³, Ferdinand Scholz³ — ¹Institut of Quantum Matter, ULM University, 89069 ULM, Germany — ²Institut for Optoelectronics, ULM University, 89069 ULM, Germany — ³Institut 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 \( \approx +20 \text{ meV} \) (GaN) to \( \approx -200 \text{ meV} \) (AlN), whereas the spin orbit splitting should remain constant at \( \approx 20 \text{ meV} \). Therefore, for unstrained AlGaN ternary layers an interchange of the character of the topmost valence band from \( \Gamma_6 \) to \( \Gamma_7 \) is theoretically expected for an Al content in the range of 5-10%, manifesting itself mainly in a change of polarization of optically excited carriers. 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.

**Dielectric functions of wurtzite GaN at elevated temperatures**

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Dielectric functions of wurtzite GaN at elevated temperatures are still difficult to achieve. The efficiency "droop" in the green spectral range of subsequent layers on the optical properties of the QWs. The thickness and the growth rate of the GaN barrier directly following the QW structure turned out to be key parameters for improving the efficiency of our structures.

**Internal quantum efficiency of high In content GaInN quantum well structures**

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The internal quantum efficiency (IQE) of GaN based light emitters shows a strong reduction for emission wavelengths 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 GaN 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 wavelength 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.
tured — Christian Möller1, Svatoslav Shklovets2, Gerhard Gobsch3, Klaus Köhler2, and Oliver Ambacher2 — 

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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.

18:00 04 Characterization and simulation of coupled GaInN quantum wells — Christopher Hein, Holger Jönin, Heiko Bremere, 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.

18:00 04 Polariton effects in wide-gap semiconductors as a function of temperature — Marie-Ellen Klemm1, Svatoslav Shklovets2, Gerhard Gobsch3, and Oliver Ambacher2 — 1Technische Universität Ilmenau, Ilmenau, Deutschland — 2Fraunhofer-Institut für Angewandte Festkörperphysik, Freiburg, Deutschland

Polariton 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 polariton effects should become not observable.

In this work we measured polarized reflectance and photoreflectance for high-quality c-plane epitaxial films of wurtzite 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 polariton 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.

18:00 04 Optoelectronic properties of InGaN quantum well light emitting diodes on semipolar GaN — Jens Rass, Marcus Staschert, Simon Ploch, Tim Wernnicke, Patrick Vogt, and Michael Kneissl — Technische Universität Berlin, Institute of Solid State Physics, Secretariat EW-6.1, 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 (10T1) and (2011) 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.
Several experiments investigating the efficiency droop in AlGaN-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.