# HL 43: Poster Session: Quantum Dots and Wires - Preparation and Characterization / Devices (incl. Laser) / Ultrafast Phenomena

Time: Tuesday 9:30–12:30 Location: Poster D

HL 43.1 Tue 9:30 Poster D

**Lattice parameters and strain-accommodation in mixed zinc-blende/ wurtzite GaAs nanowires on Si** — •Ullrich Pietsch[1], Andreas Biermanns[1], Steffen Breuer[2], Anton Davydok[1], Achim Trampert[2], and Lutz Geelhaar[2] — [1]Universität Siegen, Festkörperphysik, Germany — [2]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

In this contribution we present a x-ray diffraction study of the interface structure of GaAs nanowires grown on Si(111)-substrates using the Ga-assisted growth mode in molecular beam epitaxy. Under the used growth conditions, NW growth starts with a large abundance of wurtzite structural units, but the zinc-blende structure dominates for longer growth times. Using grazing incidence diffraction, the wurtzite type GaAs in the NWs is found to exhibit a smaller inplane-lattice parameter than the corresponding zinc-blende type material. Using the applied growth mechanism, no pseudomorphic growth is obtained for NW-diameters down to 10nm. Instead, thin NWs grow relaxed, whereas for thicker NWs the plastic relaxation is incomplete. Although NWs grow dislocated, complete relaxation is hindered by a rough interface structure. This rough interface structure is likely caused by the initial etching-reaction of the liquid Ga droplets with the Si surface. Using asymmetric x-ray diffraction on single NWs, we measure both the in- and out-of-plane components of the displacement field caused by the incomplete relaxation process. Here, large fluctuations between different NWs are found, indicating that the detailed displacement field crucially depends on the (random) interface structure.

HL 43.2 Tue 9:30 Poster D

**Investigation of single GaAs nanowires through grazing incidence X-ray diffraction** — •Genziana Bussone[1,2], Rüdiger Schott[3], Anton Davydok[1], Andreas Biermanns[1], Dirk Reuter[3], Andreas D. Wieck[3], and Ullrich Pietsch[1] — [1]Universität Siegen, Festkörperphysik, Germany — [2]European Synchrotron Radiation Facility, Grenoble, France — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Semiconductor nanowires (NWs) are a promising route for the conception of advanced electronic and photonic devices. For these purposes, absence of defects and homogeneity of the crystal lattice are crucial along the entire NW. Here, we report on the characterization of free-standing GaAs NWs using X-ray diffraction with a nanometer-sized X-ray beam, allowing to probe the crystal structure along the wire. GaAs NWs have been grown on a (111)-oriented GaAs substrate by molecular beam epitaxy using the gold-assisted growth mode. The position of the NWs was controlled by a direct implantation of Au using a focused ion beam system followed by an annealing procedure, which allows to precisely locate single NWs. The controlled arrangement and the nano-focus setup of beamline ID01 at the ESRF allowed the investigation of single, freestanding NWs in a grazing incidence geometry in order to probe the inplane-lattice parameter of the NWs. For random grown NWs, this is not possible due to the large footprint of the X-ray beam. Radial scans were performed at different heights along the NW. The data show a relaxation of the crystal lattice along the wire, revealed by the increasing of the lattice spacing closer to its top.

HL 43.3 Tue 9:30 Poster D

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

Semiconductor nanowires are a promising system for applications in the areas of electronics and photonics as well as for exploring phenomena at the nanoscale. There are several approaches to grow nanowires at predetermined sites on the wafer. We report about growing GaAs-nanowires on GaAs (111)B substrates via the vaporliquid-solid (VLS) mechanism in an ultra-high-vacuum (UHV)-cluster consisting of a molecular beam epitaxy (MBE) and a focused ion beam (FIB) system. Our idea is to implant metal seeds for the nanowire growth using FIB. Due to the UHV transfer between the FIB and the MBE chamber, no further cleaning step of the substrate surface is necessary. We were able to grow single nanowires in user defined patterns on the wafer. Nanowire diameters below than 20nm were observed. The structural and optical properties of the nanowires were investigated by SEM, TEM and photoluminescence spectroscopy.

HL 43.4 Tue 9:30 Poster D

**Strain in GaAs / InAs core-shell nanowire heterostructures grown on GaAs** — •Andreas Biermanns[1], Torsten Rieger[2,3], Anton Davydok[1], Mihail Ion Lepsa[2,3], and Ullrich Pietsch[1] — [1]Universität Siegen, Festkörperphysik, Germany — [2]Peter Grünberg Institut-9, Forschungszentrum Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology

The growth of semiconductor nanowires (NWs) has attracted significant interest in recent years due to the possible fabrication of novel semiconductor devices for future electronic and opto-electronic applications. Compared to planar heterostructures, the nanowire approach offers an advantage regarding the possibility to form heterostructures between highly lattice mismatched systems, because the free surface of the nanowires allows to relieve the strain more efficiently. One particular way to form heterostructures in the NW geometry, is the fabrication of core-shell devices, in which a NW core is surrounded by a shell of different material. The understanding of the mutual strain between core and shell, as well as the relaxation behavior of the system are crucial for the fabrication of functional devices. In this contribution we report on first x-ray diffraction measurements of GaAs-core / InAs-shell nanowires grown on GaAs (111) by molecular beam epitaxy. Using symmetric - and grazing-incidence x-ray diffraction, the relaxation state of the InAs shell as well as the strain in the GaAs core are measured as function of the InAs shell thickness, showing a gradual relaxation behavior of the shell.

HL 43.5 Tue 9:30 Poster D

**Vapor-solid growth of InAs nanowires on GaAs substrates by MBE** — •Torsten Rieger[1,2], Mihail Ion Lepsa[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute - 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology

There are two general regimes for the growth of self-catalyzed InAs nanowires (NWs) on GaAs (111)B substrates covered with $SiO_x$: (1) low V/III ratio and high substrate temperature and (2) high V/III ratio and low substrate temperature. In the first regime, the NW growth is due to an In droplet while in the second one, the NWs grow without a droplet in the vapor-solid mode. Here, we present a detailed study about the vapor-solid growth of InAs NWs. It is found that the appropriate $SiO_x$ layer thickness is important to achieve a high density of vertical NWs. When the thickness is higher than 5 nm, the NW density is low and they tend to grow tilted. At $SiO_x$ thicknesses around 4 nm, the density is between 10 and 20 NW/$\mu m^2$. The NW length is influenced by both In and $As_4$ beam fluxes. The length distribution is broad while the distribution of the NW diameters is narrow. Diameters down to 30 nm are achieved. Finally, the influence of the growth parameters on the crystal structure of the InAs NWs is described.

HL 43.6 Tue 9:30 Poster D

**Correlating the Crystal Structure and Quantum Transport of Individual InAs Nanowires** — •Martin Schuck[1,2], Christian Blömers[1,2], Robert Frielinghaus[2,3], Torsten Rieger[1,2], Stefan Trellenkamp[2,4], Carola Meyer[2,3], Mihail Ion Lepsa[1,2], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2,5] — [1]Peter Grünberg Institut -9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA - Fundamentals of Future Information Technology — [3]Peter Grünberg Institut -6, Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Peter Grünberg Institut -8, Forschungszentrum Jülich, 52425 Jülich, Germany — [5]II. Physikalisches Institut, RWTH Aachen, 52074 Aachen, Germany

InAs nanowires often exhibit crystal phase mixing between zinc blende and wurtzite structure resulting in a high density of stacking faults and undulations of the band gap. Up to now, their influence on the quantum transport properties is not clear. To unravel possible correlations, a detailed investigation of the crystal structure combined with transport measurements of the same individual nanowire is required. Here we present a process technology suitable to address this problem. First windows are etched into $Si_3N_4$ transmission electron microscopy (TEM ) membranes. Then InAs nanowires, grown by molecular beam epitaxy (MBE), are dispersed on the membranes. Some InAs nanowires will span across a window and will be contacted via standard electron beam lithography to perform transport measurements. Consequently, this setup fulfills the requirements and transport measurements as well as TEM are performed on an individual nanowire.

HL 43.7 Tue 9:30 Poster D

**Elemental and Structural Analysis of Nanowires in Cross-Sectional Specimens** — •Benedikt Bauer, Johannes Bill, Marcello Soda, Andreas Rudolph, Elisabeth Reiger, and Josef Zweck — Universität Regensburg, Regensburg, Germany

To use nanowires (NWs) as building blocks for future electronics, functionalization is needed. One way to achieve this is the growth of radial heterostructures, also known as core-shell approach.

To access core and shell(s) of core-shell NWs separately for structural and compositional analysis in transmission electron microscopy (TEM) the NWs must be cut perpendicular to their axis into $\lesssim 100$ nm thick slices to allow for an investigation in cross-section. For this we use ultramicrotomy as a fast and gentle method which has some advantages over other thin film preparation methods: In contrary to embedding and grinding it is possible to cut several tens of sample slices from one specimen block which also allows to access different regions along the NW axis and therefore different stages of the growth process. Compared to focused ion beam cutting the preparation induced crystal damage and surface amorphization is rather low.

The technique was used on GaAs/(Ga:Mn)As core-shell NWs as well as on GaAs/AlGaAs mutli-core-shell NWs grown in molecular beam epitaxy (MBE). We present high resolution TEM images and energy dispersive X-ray (EDX) analysis results to illustrate the potential of this preparation method.

HL 43.8 Tue 9:30 Poster D

**Alloy formation during InAs nanowire growth on GaAs(111)** — •Anton Davydok[1], Torsten Rieger[2,3], Muhammad Saqib[1], Andreas Biermanns[1], Thomas Grap[2,3], Mihail Lepsa[2,3], and Ullrich Pietsch[1] — [1]Festkörperphysik, Universität Siegen, Walter-Flex-Str. 3,57072, Siegen, Germany — [2]Peter Grünberg Institut-9, Forschungszentrum Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology

The growth of semiconductor nanowires has attracted significant interest in recent years due to the possible fabrication of novel semiconductor devices for future electronic and opto-electronic applications. A possible way to obtain nanowires is the growth in molecular beam epitaxy on the (111)B oriented surface of the desired substrate, covered by a thin oxide layer. A crucial parameter in this method is the initial thickness of the oxide layer, often determined by an etching procedure. In this contribution, we report on the structural investigation of InAs nanowires grown on GaAs substrates covered by different oxide-layers using x-ray diffraction. In this contribution, we report on the structural investigation of InAs nanowires grown via an In droplet on GaAs substrates covered by different oxide layers using x-ray diffraction.Using a combination of symmetric and asymmetric x-ray diffraction, we observe that for growth on a defective oxide layer, alloy formation takes place and a large amount of InGaAs is formed, whereas for growth on an initially smooth oxide layer, only pure InAs is formed.

HL 43.9 Tue 9:30 Poster D

**Optical studies of InAs Quantum Dots on GaAs doped with rare earth ions by ion beam implantation** — •Markus K. Greff, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

Single spins in semiconductors could offer the possibility to integrate information storage and processing in a single material basis and the development of quantum information processing based on solid state systems. We dope InAs Quantum Dots (QD) with Eu that possesses a nearly half filled, strongly localised f-shell in GaAs. This, in combination with the strong carrier confinement in the QDs, could lead to a stronger magnetic coupling between the magnetic ion and the confined carriers. The QDs and the surrounding GaAs matrix have been doped with Eu at 30 keV by ion beam implantation and subsequently annealed by rapid thermal annealing using proximity capping to avoid surface degradation from arsenic loss.

In this contribution we would like to present results of first photoluminescence measurements at 77 K which show that, due to the interaction of the QDs and the Eu ion, a new distinct peak, which origin is not yet fully understood, appears in the PL spectrum.

HL 43.10 Tue 9:30 Poster D

**Capacitance-Voltage spectroscopy of InAs quantum dots under external applied strain** — •Sascha René Valentin, Arne Ludwig, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum

Self-assembled InAs quantumdots (QDs) are integrated on a variety of interesting optical and electronic devices and are also highly interesting from a fundamental point of view. Electric fields are often used to tune the optical and electronic properties of QDs. Just recently it has been shown that external applied strain can reversibly shift the optical emission energy of QDs. Theoretical calculations indicate that the shift in the emission energy originates rather in the changed Coulomb interaction between the charge carriers than in the shift of the energy levels themselves. In this project we want to directly measure the interaction energies of the carriers using capacitance voltage (CV) spectroscopy. In the device we present, a thin electrically contacted CV-membrane is bonded to a PMNPT-piezoelectric actuator. This allows to apply strain to the QDs. The devices are equipped with ohmic contacts and Schottky gates and thus enable electrical measurements of a QD ensemble. CV results for a membrane sample are presented.

HL 43.11 Tue 9:30 Poster D

**Structural characterization of InAs and $In_{0.25}Ga_{0.75}As$/GaAs nanostructures grown on GaP(001)** — •Christopher Prohl, Yannick Rodriguez Sillke, Andrea Lenz, Josephine Schuppang, Murat Öztürk, Gernot Stracke, André Strittmatter, Dieter Bimberg, Holger Eisele, and Mario Dähne — Institut für Festkörperphysik, Technische Universität Berlin

Due to the low lattice mismatch, GaP is an interesting material for the implementation of III-V-semiconductor applications into silicon-based technology. Therefore, the development of epitaxially grown nanostructures on GaP substrates for opto-electronic devices, like quantum dots, is an interesting task. InAs/GaP quantum dots are also promising for new nanomemory cells due to higher expected localization energies of the charge carriers inside the QDs than in InAs/GaAs QDs, resulting in longer storage times. In this contribution, first results of molecular beam epitaxy (MBE) grown samples of InAs quantum dots on a GaP(001) substrate, characterized by reflection high energy diffraction (RHEED) and scanning tunneling microscopy (STM) will be presented. RHEED clearly shows a 2D→3D transition, while first STM images show 3D islands, which are similar in size and density to comparable InAs/GaAs QDs. Furthermore, capped $In_{0.25}Ga_{0.75}As$/GaAs/GaP and GaAs/GaP nanostructures grown by metal organic vapor phase epitaxy (MOVPE) were identified by cross-sectional STM (XSTM). XSTM images of $In_{0.25}Ga_{0.75}As$/GaAs/GaP and 2 ML GaAs on GaP(001) show that the GaAs is not assembled within the nominal 2 ML, but segregated along growth direction.

HL 43.12 Tue 9:30 Poster D

**3D-Determination of InGaAs Quantum Dots in Cross-Section TEM Specimens** — •Maren Schiersch[1], Tore Niermann[1], André Strittmatter[2], Tim David Germann[2], Gernot Stracke[2], Jan-Hindrik Schulze[2], Udo W. Pohl[2], and Michael Lehmann[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Because Quantum Dots (QDs) offer a variety of applications, they are a current hot research topic. TEM investigations of QDs structures are usually performed in cross-section. However, in cross-section the QD-layer is only imaged in projection. So it is not possible to access the number of QDs or density at all. To investigate the distribution of QDs we apply a method using tilt series [1]. At increased tilt angles, the planar QD distribution becomes visible using dark-field images in the light of the chemical sensitive reflection {200}. As result the QD size and density as well as the thickness of the specimen can be evaluated from the recorded tilt series. Furthermore, the angular distribution, the distribution of QDs and thus the distance of nearest neighbors are determined. This method is applied on specimens with InGaAs-QDs buried in GaAs with different In-concentrations. This work is supported by the DFG Collaborative Research Centre 787.

[1]: Beanland, R. et al.: Electron tomography of III-V quantum dots using dark field 002 imaging conditions. In: Journal of Microscopy. The Royal Microscopical Society, February 2010 (237), p. 148-154

HL 43.13 Tue 9:30 Poster D

**TEM-Investigation of strain fields in In(Ga)As quantum dots** — •Moritz Hartwig[1], Tore Niermann[1], André Strittmatter[2], Tim David Germann[2], Gernot Stracke[2], Jan-Hindrik Schulze[2], Udo W. Pohl[2], and Michael Lehmann[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

In Stranski-Krastanov growth-mode the strain of the wetting layer is relaxed by growth of 3D islands. This is exploited in the self-organized growth of In(Ga)As quantum dots (QD) on GaAs substrate. These QDs are buried under a further GaAs layer. The remaining strain fields have an effect on the optoelectronic properties of these nanostructures. TEM dark-field images in the light of strong reflections (like {400} in GaAs) are extremely sensitive to strain fields. In order to investigate only the strain fields of single QDs, dark field images of the chemically sensitive {200}-reflection are utilized under large specimen tilt angle preventing imaging of QDs, which are not isolated. The strain components in in-plane and in growth direction are investigated individually. A change in the symmetry of the strain fields in growth direction is observed in specimen with an additional strain-reducing layer. Furthermore, a slight asymmetry of the in-plane component is found, possibly caused by a distorted shape of the QDs.
This work is supported by the DFG Collaborative Research Centre 787 "Semiconductor Nanophotonics".

HL 43.14 Tue 9:30 Poster D

**Characterization of tensile-strained GaAs/GaSb nanostructures** — •Jan Grosse[1], Andrea Lenz[1], Josephine Schuppang[1], Holger Eisele[1], Marie Duhamel[2], Alban Gassenq[3], Thierry Taliercо[3], Eric Tournie[3], and Mario Dähne[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut Supérieur de l'Electronique et du Numérique, 41 Boulevard Vauban, 59046 Lille cedex, France — [3]Université Montpellier 2, Institut d'Electronique du Sud, UMR CNRS 5214, 34095 Montpellier cedex 5, France

The Ga(In)As/GaSb material system may act as a model system for tensile-strained nanostructures, which are promising for near-to-mid infrared applications. However, compared to a compressively strained system such as In(Ga)As/GaAs the structural properties of tensile-strained layers are practically unexplored up to now. In order to investigate the size, shape, and stoichiometry of semiconductor nanostructures, cross-sectional scanning tunneling microscopy (XSTM) is a very powerful method. Here, we present an XSTM study of the characteristics of different GaAs layers with varying nominal layer thickness grown by molecular beam epitaxy (MBE). Atomically resolved XSTM-images will be presented, which show a non-coherent wetting layer as well as some agglomerations for one and two monolayer (ML) thick GaAs films and the formation of quantum dot-like structures in case of three and four ML thick GaAs films.

HL 43.15 Tue 9:30 Poster D

**Measurement of electrostatic potential at group III-N semiconductors using electron holography** — •Jae Bum Park, Tore Niermann, and Michael Lehmann — Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17. Juni 135, D-10623 Berlin, Germany

Off-axis electron holography (EH) allows acquiring the whole information of the electron wave, i.e. amplitude and phase, the latter is usually lost. The phase of the electron wave is sensitive to electrostatic potential variation due to doping profiles from pn-junctions and piezoelectric fields at quantum wells. We employ this interference technique on group III-N semiconductor heterostructures. Because the phase of the electron wave is also affected by the specimen thickness, thickness measurement approaches like dark field imaging (DF) and convergent beam electron diffraction (CBED) are applied. However, the determined potentials from measured phase information normally show a discrepancy from the expected one. Additionally the surface depletion effect must be taken into account for quantitative analysis of the electrostatic potential from the reconstructed phase. This research is performed to investigate the influence of these effects on the observed mismatch of the potential. This work is carried out within the DFG collaborative research center CRC 787 Nanophotonik.

HL 43.16 Tue 9:30 Poster D

**Low density 1.55 $\mu$m Indium phosphide based quantum dots** — •Matusala Yacob, Mohamed Benyoucef, and Johann Peter Reithmaier — Institute of Nanostructure Technologies and Analytics (INA), Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Germany

Due to their unique optical and mechanical properties, semiconductor quantum dots (QDs) can be used as a building block of quantum information processing. However, for this application circular and low density QDs operating in the telecom wavelength bands should be realized. In this work, we investigate the effect of growth parameters on shape, size and density of InAs QDs grown on lattice matched InAlGaAs/InP system using solid source molecular beam epitaxy. A red-shift of photoluminescence emission wavelength from 1.2 to 1.8 $\mu$m with increase in InAs coverage was observed. The QD density is reduced using two approaches. In the first approach, the substrate temperature was decreased after QD growth by introducing growth stop. This allows ripening of InAs structures creating large sized dots with relatively low density. In the second approach, the QD growth rate is decreased to increase the migration length of ad-atoms. Single dot emissions at 1.55 $\mu$m were observed confirming the formation of large sized dots with low QD density.

HL 43.17 Tue 9:30 Poster D

**Electrical Contacting of Pyramidal Microcavities for Single-Photon Applications** — •Daniel Rülke, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

In order to fabricate electrically driven single-photon devices, we have established a manufacturing process for the contacting of single pyramidal microcavities. The cavities consist of reversed GaAs pyramids with InAs quantum dots (QDs) located close to their tip and have been fabricated by a combination of molecular-beam epitaxy, e-beam lithography and wet-chemical etching. These cavities reveal very good outcoupling efficiencies for the QD emission and guarantee low numbers of QDs in the cavity, due to their shape. Electrical contacts to individual cavities have been realized by free-standing GaAs and PMMA bridges.

HL 43.18 Tue 9:30 Poster D

**All-oxide junction field-effect transistors** — •Friedrich-Leonhard Schein, Holger von Wenckstern, Heiko Frenzel, and Marius Grundmann — Institut für Experimentelle Physik II, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Germany

We report on the first ZnO-based junction field-effect transistors (JFETs) using an all-oxide $p$-$n$-junction as top-gate contact. The oxide materials were grown by pulsed-laser deposition on an $a$-plane sapphire substrate. A ZnO channel layer was deposited at 680 °C followed by room temperature deposited $p$-type $ZnCo_2O_4$. Sputtered Au contacts serve as Ohmic source and drain electrodes as well as current spreading layer for the gate electrode. Standard photolithography and lift-off was used for device processing. The $p$-type conductivity of $ZnCo_2O_4$ thin films [1, 2], which are X-ray amorphous if grown at room temperature, was confirmed by Seebeck effect measurements. An average transmittance of $T_{\mathrm{VIS}} = 54\,\%$ was determined for a 40 nm thin film of this material.

The normally-on JFETs exhibit a channel mobility of $\mu_{\mathrm{ch}} = 8.4\,\mathrm{cm}^2/\mathrm{Vs}$, a subthreshold slope $S = 91\,\mathrm{mV/decade}$ and a current on/off-ratio larger than $10^7$. These properties are similar to that of the best oxide-based FETs, typically having $\mu_{\mathrm{ch}} = 5 - 15\,\mathrm{cm}^2/\mathrm{Vs}$, $S < 100\,\mathrm{mV/decade}$ and $I_{\mathrm{on/off}} > 10^7$ [3].

[1] M. Dekkers *et al.*, Appl. Phys. Lett. **90**, 021903 (2007).
[2] S. Kim *et al.*, J. Appl. Phys. **107**, 103538 (2010).
[3] M. Grundmann *et al.*, Phys. Status Solidi A **207**, 1437 (2010).

HL 43.19 Tue 9:30 Poster D

**Passivation of ZnO-based MESFETs** — •Fabian J. Klüpfel, Stefan Müller, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Abteilung Halbleiterphysik, Linnéstr. 5, 04103 Leipzig

Transparent semiconductors related to ZnO have recently drawn much atttention of the scientific community, e.g. for the application in liquid crystal displays. ZnO-based devices are known to be very sensitive to surface-related effects [1]. The surface termination can for instance lead to highly conductive surface conduction paths [2]. This can be exploited for applications such as gas or chemical sensors. However, to build stable electronic circuits it is neccessary to reach a stable interface, which keeps the electric properties of the device within the desired figures of merit. This can be done by passivating the devices with suitable materials. For thin film transistors based on (Ga,In,Zn)O channels, the usage of the epoxy based photo resist SU-has been proposed [3]. ZnO-based Schottky diodes have been successfully passivated with a $CaHfO_3$ layer [2]. We could show, that these materials are also suitable for the passivation of (Mg,Zn)O-based metal-semiconducor field-effect transistors. The static device properties could even be enhanced in some cases, while the dynamic properties up to 1 Mhz were not affected. Also the influence on the temperature stability and the avoidance of vacuum induced effects has been investigated.

[1] Allen *et al.*, Trans. Electr. Dev. 56, 2160 (2009)
[2] von Wenckstern *et al.*, J. Elec. Mat. 39, 559 (2009)
[3] Olziersky *et al.*, J. Appl. Phys. 108, 064505 (2010)

HL 43.20 Tue 9:30 Poster D

**High Temperature Characteristics of Tungsten/Silicon Schottky Diodes** — •Markus Arnold, Michael Pleul, Daniel Lehmann, and Dietrich R. T. Zahn — Semiconductor Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

For Schottky diodes the diffusion of metal into the semiconductor at elevated temperature plays an important role for the properties as traps are created at or close to the interface.

The electrical behaviour of three types of Schottky diodes is compared at high temperatures. Tungsten is the contact metal for all cases, but the silicon substrate is varied between p-doped, nominally undoped, and n-doped. In situ current-voltage (I-V) measurements and capacitance-voltage (C-V) measurements of Tungsten/Silicon Schottky diodes are presented.

The Schottky diodes are annealed up to 700 °C in vacuo to characterise the diode stability during annealing. The influence of the dopant species on the barrier height and the diffusion properties are discussed. Deep-level transient spectroscopy (DLTS) measurements are presented revealing the annealing dependent trap concentration at the Schottky interface.

HL 43.21 Tue 9:30 Poster D

**High Temperature Induced Traps in Tungsten/GaN Schottky Diodes** — •Michael Pleul, Markus Arnold, Daniel Lehmann, and Dietrich R. T. Zahn — Semiconductor Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

The properties of metal/semiconductor interfaces like in Schottky diodes are highly dependent on traps near the interface created by the diffusion of metal into the semiconductor. The investigation comprises *in situ* I-V (current-voltage) and C-V (capacitance-voltage) measurements of Tungsten/GaN Schottky diodes at different annealing temperatures up to 700 °C. In addition DLTS (Deep Level Transient Spectroscopy) measurements are performed to reveal the annealing dependent trap concentration.

HL 43.22 Tue 9:30 Poster D

**Low-threshold polymeric microgoblet lasers** — •Tobias Grossmann[1,2,4], Torsten Beck[1,2], Klinkhammer Sönke[2,3,4], Christoph Vannahme[4], Uli Lemmer[2,3], Timo Mappes[4], and Heinz Kalt[1,2] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology KIT, 76128 Karlsruhe, Germany — [2]DFG Center for Functional Nanostructures CFN, KIT, 76128 Karlsruhe, Germany — [3]Light Technology Institute, KIT, 76128 Karlsruhe, Germany — [4]Institute of Microstructure Technology, KIT, 76128 Karlsruhe, Germany

Optical whispering-gallery-mode (WGM) resonators like microspheres or microtoroids have evolved in recent years to versatile photonic devices with applications like lasers, filters or sensors. In particular, polymeric microcavities are of high potential since they combine a multitude of outstanding properties: exceedingly high quality factors (Q-factors), easy doping and thus realization also of active resonators and low material costs.

We have recently introduced a novel type of polymeric resonator with surface-tension induced cavity geometry: microgoblets of PMMA on silicon. These resonators are produced by subsequent planar lithography of the PMMA, isotropic etching of the silicon and a thermal reflow step. The latter not only leads to the goblet-like shape but also to a smooth cavity surface with reduced lithographic blemishes and thus to Q-factors of passive resonators exceeding $10^6$. When doped with rhodamine 6G these resonators are efficient lasers at 600nm with a laser threshold as low as 3nJ/pulse.

HL 43.23 Tue 9:30 Poster D

**Development of monolithic dual frequency quantum dots based semiconductor laser suitable for tunable continuous wave terahertz generation** — •Vitalii Sichkovskyi, Kamen Kozhuharov, and Johann Peter Reithmaier — Technische Physik, Institute of Nanostructure Technologies and Analytics, University of Kassel, Heinrich-Plett Str. 40, D-34132 Kassel, Germany

Presently there is a considerable research activity in the development of new terahertz (THz) sources. The most promising candidate as a compact, tunable and low-cost THz emitter is the combination of a photomixer and an optical beat source. Here we report on developing of monolithic difference frequency generation source. It is designed as two coupled distributed-feedback (DFB) lasers tuned by controlling the temperature of the individual DFB laser. MBE grown laser structure consists of a GRINSCH design including single In0.60Ga0.40As QDs active layer embedded in 800 nm core waveguide surrounded by 1600 nm AlGaAs claddings layers. The broad area lasers processed from the laser structure revealed high internal quantum efficiency of 95%, low transparency current density of 139 Acm-2, high slope efficiencies $> 0.45$ W/A per facet, and low temperature sensitivity of the emission wavelength as low as 0.096 nm/K. Deep structure plasma etch processes for the GaAs and InP gratings of the dual-wavelength DFB lasers were developed and optimized, providing excellent anisotropy and uniformity of the structures. Platinum micro-heaters for the tuning of the lasers were fabricated and tested on RWG lasers, providing temperature increase at the ridge of 65°, at heater current of 140 mA.

HL 43.24 Tue 9:30 Poster D

**Intersubband dynamics in two-photon quantum well infrared photodetectors** — •Carsten Franke[1], Harald Schneider[1], Jérôme Faist[2], and H. C. Liu[3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]ETH Zürich, 8093 Zürich, Switzerland — [3]Shanghai Jiao Tong University, 200240 Shanghai, China

Two-photon quantum well infrared photodetectors (QWIPs) are interesting nonlinear devices for autocorrelation measurements in the mid-infrared and THz-regime. Here we investigate two-photon QWIPs in the mid-infrared with absorption wavelengths at around six microns, based on the material systems InGaAs/AlGaAs on GaAs and GaInAs/AlInAs on InP. We study the intersubband relaxation dynamics by interferometric autocorrelation. To create the necessary mid infrared sub-picosecond pulses, we use a regenerative amplifier system with subsequent wavelength conversion by optical parametric amplification and difference frequency generation. With this we can create mid-infrared laser pulses shorter than 200 fs tunable from 3 to 10 $\mu$m. For the intersubband relaxation time we determined values between 590 and 730 fs.

HL 43.25 Tue 9:30 Poster D

**From bistability to break-down of normal-mode splitting in microcavity systems** — •Regina Kruse, Stefan Declair, Jens Förstner, and Stefan Schumacher — Physics Department and Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Paderborn, Germany

We study the nonlinear excitation dynamics of a microcavity system with normal mode splitting. Our model includes a single optical cavity mode coupled to an electronic two-level system. The results from the corresponding Maxwell-Bloch equations are compared to a full 3D FDTD calculation [1]. In agreement with earlier studies [2] we observe bistable behaviour for continuous wave excitation while scanning the frequency range around the resonances with the pump. Additionally to this steady-state behaviour we explicitly study the nonlinear system dynamics in time. With this method we are able to analyze the transition from nomal-mode splitting to bistable behaviour until the strong coupling regime breaks down for high excitation densities.

[1] S. Declair, X. Song, T. Meier and J. Förstner: Simulation of Mutual Coupling of Photonic Crystal Cavity Modes and Semiconductor Quantum Dots *AIP Conf. Proc. 1398, 123 (2011). [2] J. Gripp, S. Mielke and L. Orozco: Evolution of the vacuum Rabi peaks in a detuned atom-cavity system *Phys. Rev. A56, 3262 (1997).

HL 43.26 Tue 9:30 Poster D

**Optical excitation conditions for generating squeezed phonon states in a quantum dot** — •Daniel Wigger[1], Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

We study theoretically squeezing properties of phonons generated after optical excitation of a semiconductor quantum dot (QD). We model the QD in the strong confinement limit as a two level system coupled by the Fröhlich interaction to longitudinal optical (LO) phonons. An ultrashort laser pulse creates an exciton in the QD, which leads to a shift of the equilibrium position of the lattice ions. Thus lattice vibrations, i.e. phonons, are created. For an excitation with two pulses we find that Schrödinger cat states, i.e. superpositions of coherent states, build up. Depending on the time delay and relative phase between the pulses and on the coupling strength the fluctuation properties of theses states can fall below their vacuum limit, i.e. squeezing occurs [1]. By using the Wigner function we can illustratively analyze the influence of the material and excitation parameters on the fluctuation properties.

[1] Sauer et el., PRL 105, 157401 (2010)

HL 43.27 Tue 9:30 Poster D

**Optical excitation of squeezed LO phonons in a quantum well** — •Thomas Papenkort[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany

Squeezed states combine questions of fundamental quantum mechanics with the promise of a precision of measurements that was previously deemed impossible to achieve. With squeezed light fields this promise has already been achieved, and it is only natural to try to carry over these huge successes to the field of solid state physics: that is, to learn how to generate squeezed phonon states in crystals.

In this contribution we present quantum-kinetic simulations showing how to generate squeezed phonon states in a quantum well by optical driving. In such states the uncertainty of the lattice displacement or momentum is reduced below its zero-temperature value. We demonstrate how to calculate the coupled electron-phonon dynamics within a realistic microscopic model of a quantum well, achieving quantitative results for, e.g., the squeezing factor. We fully take into account spatial averaging, which is both unavoidable experimentally and crucial for the lattice uncertainty variables. Our simulations then reveal which ultrashort laser excitations are capable of generating squeezed states and predict the strength and time-dependence of the squeezing factor.

HL 43.28 Tue 9:30 Poster D

**Laser-induced nonthermal melting in Si** — •Tobias Zier, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretical Physics, University of Kassel, Germany

When a solid is excited by an intense ultrashort laser pulse a nonequilibrium state is created, where the electrons are very hot (several 10,000 K) and the ions remain cold. In silicon bond softening occurs after such an excitation. If the intensitiy of the laser pulse is high enough, some phonon modes become unstable. This causes ionic motion and a disordering within the first picosecond. This phenomenon is known as nonthermal (ultrafast) melting and has been studied intensively for different materials since the invention of ultrashort laser pulses. Recently, a new effect in this context was observed: the concerted decay of several x-ray diffraction peak intensities. To understand this new phenomenon we did some MD-simulations and calculated the structure-factors for every timestep after the excitation. With this information we were able to calculate the time-evolution of the x-ray diffraction peak intensities.