HL 33: III-V semiconductors II

Time: Wednesday 14:15–18:30 Location: EW 201

HL 33.1 Wed 14:15 EW 201

Measurement of 002 structure factors for GaAs from electron spot diffraction patterns — Knut Müller[1], •Marco Schowalter[1], Andreas Rosenauer[1], Jacob Jansen[2], John Titantah[3], and Dirk Lamoen[3] — [1]Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee1, 28359 Bremen — [2]National Centre for HREM, Laboratory of Materials Science, Delft University of Technology, Lorentzweg 1, 2628 Delft, The Netherlands — [3]Departement Fysica, Universiteit Antwerpen, Groenenborgerlaan 171, B-2020 Antwerpen, Belgium

Accurate knowledge of chemically sensitive structure factors (SF) is essential e.g. for quantitative analysis of the composition in ternary semiconductor nanostructures, such as InGaAs, by TEM. Recent calculations also account for the electron redistribution due to bonding effects and are to be proven experimentally. A new method was developed to measure SF from Bragg intensities in TEM diffraction patterns. An appropriate microscope setup for nanodiffraction under parallel illumination has been worked out. Using the program package ELSTRU, the procedure first extracts the integrated intensities of each Bragg spot and subtracts the background. In the first of two refinements, the local thickness and orientation of the specimen as well as the Debye-Waller factors are refined by the routine MSLS. For the second refinement of one SF in question, a Bloch-wave simulation program was developed that fits experimental and calculated intensities. The method was succesfully tested on simulated images with background.

HL 33.2 Wed 14:30 EW 201

Optical studies on surface passivation by both wet-chemical sulfur treatment and epitaxial core-shell growth of GaAs Nanowires — •Steffen Münch[1], Niklas Sköld[2], Stephan Reitzenstein[1], Johanna Trägardh[2], Alexander Gorbunov[1,3], Martin Kamp[1], Lars Samuelson[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]The Nanometer Structure Consortium, Lund University, 22100 Lund, Sweden — [3]Institute for Solid State Physics, Russian Academy of Science, 142432 Chernogolovka, Russia

We report on the optical characterization of chemical and core-shell passivation techniques applied to GaAs nanowires (NWs). In particular, standard and time resolved micro photoluminescence (PL) spectroscopy was employed to investigate the effect of surface passivation on GaAs NWs. In case of GaAs surface passivation is of particular interest due to the large surface recombination velocity inherent to this material system. Chemical and core-shell passivation techniques were applied to GaAs NWs grown on a (111)B GaAs substrate using Au as catalysts. The core-shell NWs were realized by overgrowing a GaAs core in a MOVPE reactor with a 50 nm thick $Al_{0.5}In_{0.5}P$ shell. Surface treatment results in an enhancement of free excitonic emission by a factor of about 40 and 110 for sulfur passivated and core-shell NWs, respectively. Furthermore, the effect of surface passivation is reflected in a strong reduction of the surface recombination velocity S to 2.5 x 10^4cm/s for the core-shell NWs compared to typical values of about 1 x 10^6cm/s reported for untreated GaAs NWs.

HL 33.3 Wed 14:45 EW 201

Swift heavy ion irradiation for recovery from implantation defects of GaN — •Anne-Katrin Nix[1], Sven Müller[1], Carsten Ronning[1], Andrey Kamarou[2], Elke Wendler[2], Werner Wesch[2], Christina Trautmann[3], and Hans Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller Universität, Jena, Germany — [3]Gesellschaft für Schwerionenforschung, Darmstadt, Germany

Doping GaN by ion implantation (100 keV Mg-ions) is a desired task for the realization of lateral optoelectronic devices, but results in a high level of lattice defects. Thermal annealing can be used for recrystallisation, but surface melting and dopant diffusion hampers the annealing effect. Here, we present an alternative annealing method. The GaN crystals are irradiated with swift heavy ions, thus, the sample is locally heated during a timespan of 10^{-12} seconds , surrounding material stays unaffected. Mg ions were implanted into GaN with fluences of 3x10^{13} ions/cm^2 and 10^{14} ions/cm^2. These samples were irradiated with several ion species at different energies (578 MeV Cr, 55 MeV Xe, 140 MeV Kr, 1GeV Xe and 593 MeV Au), thus the electronic energy loss is varied (8 keV/nm, 17 keV/nm, 19 keV/nm, 27 keV/nm, 43 keV/nm). Directly after implantation and after irradiation, the photoluminescence was examined at low temperature (12 K), the obtained spectra are compared to well known spectra of GaN and GaN:Mg. For an annealing effect is seen after Cr-irradiation, GaN samples were irradiated with 668 MeV Ni (9 keV/nm) with varying fluences to examine a fluence dependence of the annealing process.

HL 33.4 Wed 15:00 EW 201

Effects of localized Boron states on the transport properties of n-BGaInAs — •Jörg Teubert[1,2], Peter J. Klar[2], Wolfram Heimbrodt[1], Andrew Lindsay[3], and Eoin P. O'Reilly[3] — [1]Department of Physics and Material Sciences Center, Philipps-University Marburg, Germany — [2]Institute of Experimental Physics I, Justus-Liebig University Gießen, Germany — [3]Tyndall National Institute, Lee Maltings, Cork, Ireland

The incorporation of isovalent boron on cation sites of GaAs results in strongly localized electronic states resonant with the conduction band. All present experimental and theoretical results indicate that these states have only minor influence on the conduction band structure. We show however that such states strongly affect the electronic transport behaviour of this unusual semiconductor alloy. We study the influence of these boron cluster states on the electronic transport of n-type BGaInAs-layers. We performed magnetotransport measurements at temperatures from 1.6 K to 300 K using magnetic fields up to 10 T and hydrostatic pressure up to 20 kbar. At ambient pressure and low carrier concentration both strong negative MR effects at low fields and a giant exponential positive MR at high magnetic fields can be observed. The latter is regarded as proof of a hopping transport mechanism and is interpreted as a metal insulator transition under the influence of an external magnetic field. Under hydrostatic pressure the results are dominated by the complex interplay between extended band states, localized boron states and dopant states.

HL 33.5 Wed 15:15 EW 201

Optical properties of InN layers grown by high pressure CVD — •Ronny Kirste[1], Mustafa Alevli[2], Markus R. Wagner[1], Christian Thomsen[1], Nikolaus Dietz[2], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics and Astronomy, Georgia State University (GSU), Atlanta, GA

Including Indium Nitride (InN) into the ternary $Ga_{1-x}Al_xN$ system enables the fabrication of tunable emitters operating from the infrared to the ultraviolet wavelength regime. At present, the growth of InN with chemical vapour deposition is still a great challenge due to low growth temperatures required to stabilize the compound. The use of a novel high pressure chemical vapour deposition (HPCVD) system allows to grow single crystalline high quality InN at temperatures up to 950°C at reactor pressures around 15 bar. We present micro-Raman analysis results on InN samples fabricated under different growth conditions and on different substrate templates. Analyzing the non-polar strain sensitive E_2(high) mode we evaluate the crystalline quality and strain in those samples. Additionally, luminescence measurements on those samples were performed. We discuss the spectra regarding the band edge and correlate the results with the data obtained from Raman spectroscopy.

15 min. break

HL 33.6 Wed 15:45 EW 201

Morphologische und strukturelle Untersuchungen an AlInN auf GaN/Si(111) — •Aniko Gadanecz, Jürgen Bläsing, Armin Dadgar, Christoph Hums, Thomas Hempel, Jürgen Christen und Alois Krost — Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Fakultät für Naturwissenschaften, Universitätsplatz 2, 39016 Magdeburg, Germany

AlInN ist ein, u.a. für elektrische und optoelektronische Anwendungen hochinteressanter III-V-Halbleiter, wie z.B. für Hochleistungs-FETs und Bragg-Spiegel. Mittels metallorganischer Gasphasenepitxie (MOCVD) gewachsene AlInN-Schichtserien auf GaN/Si(111) verschiedener Schichtdicken bis max. 100 nm und mit In-Konzentrationen im Bereich von 9% bis 36% wurden untersucht. Als besondere Eigen-

schaft von AlInN gilt das gitterangepasste Wachstum auf GaN bei einem In-Gehalt von 17,4 %; eine Abweichung der Konzentration von 17,4% verursacht im Falle eines auf GaN voll verspannten Gitters eine kompressive oder tensile Verspannung. Überschreitet zusätzlich die Schichtdicke einen kritischen Wert, sind die Schichten bereits nach dem Wachstum teilrelaxiert bzw. vollständig relaxiert. Je stärker ausgeprägt die Relaxation der Schichten, umso größer die Tendenz für eine Entmischung, wodurch phasenseparierte Gebiete unterschiedlicher In-Konzentrationen entstehen und die Qualität deutlich verschlechtert wird. Die morphologischen und strukturellen Eigenschaften, wie Relaxation, Phasenseparation und Oberflächenmosaizität wurden mittels hochauflösender Röntgenbeugung, Röntgenreflektometrie und Feldemissions-Rasterelektronenmikroskopie (FEREM) untersucht.

HL 33.7 Wed 16:00 EW 201

Eigenschaften des In-Defekt-Komplexes im III-V-Halbleiter AlN — •Bettina Steitz und Reiner Vianden — Helmholtz-Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn

Nach Implantation des Isotops ^{111}In in einen AlN-Film auf Saphir-Substrat kann man mittels der Methode der gestörten Winkelkorrelation (PAC) beobachten, dass sich die radioaktiven Sonden nach einer Ausheiltemperatur von 1273K in unterschiedlichen Umgebungen befinden. Frühere Messungen zeigten, dass neben einem Anteil von 45%, der ein Verhalten aufweist, wie er für Indium auf einem ungestörten Al-Gitterplatz zu erwarten ist, der Rest erfährt eine weitere Wechselwirkung, wie sie für einen In-Defekt-Komplex typisch ist.

Um dessen Natur näher zu untersuchen, wurden die AlN-Proben zusätzlich mit verschiedenen Dosen von ^{115}In und ^{24}Mg implantiert. Dies führte zu der Beobachtung, dass bei Implantation von ^{115}In mit der Dosis $10^{14}\,\frac{\mathrm{Ionen}}{\mathrm{cm}^2}$ sowohl der Anteil der Sonden, auf die der Defekt wirkte, sank, wie auch die Gitterfrequenz sich verlangsamte. Im Gegensatz dazu führte eine Implantation von Mg mit der Dosis $10^{14}\,\frac{\mathrm{Ionen}}{\mathrm{cm}^2}$ zwar ebenfalls zu einer Abnahme des Defektanteils der Sonden, jedoch zu einem Anstieg der Gitterfrequenz.

HL 33.8 Wed 16:15 EW 201

Strain fields in the vicinity of nanoindentions on (100) surfaces of GaAs — •Christian Röder[1], Gert Irmer[1], Michael Schaper[2], Ralf Hammer[3], and Manfred Jurisch[3] — [1]Institut für Theoretische Physik, TU Bergakademie Freiberg, Leipziger Straße 23, 09596 Freiberg, Germany — [2]Institut für Werkstoffwissenschaft, TU Dresden, Helmholtzstraße 7, 01062 Dresden, Germany — [3]Freiberger Compound Materials GmbH, Am Junger Löwe Schacht 5, 09599 Freiberg, Germany

We present results of micro-Raman and micro-photoluminescence (PL) investigations on undoped GaAs samples with Vickers indentations on (100) surfaces generated with low indentation loads down to 5 mN. Because of the slight indentation loads cracks did not occur. In the vicinity up to 10xD of such indentations with a diagonal length of D we observed a characteristic shift of the Raman LO phonon mode. Converting this shift we found a strain field pattern reflecting the crystal symmetry. Referring to the [011] and [0-11] directions the observed residual stress is different indicating various stress relaxation mechanisms. Furthermore the Raman spectra provide information about the crystallinity and stress induced defect density. It is assumed that GaAs is in an amorphous state below the indenter top. PL measurements were performed at 293 K with the special emphasis on the study of the strain induced splitting between the heavy and light hole valence bands. The observed splitting of the PL signal is discussed in correlation to theoretical stress models and the Raman results.

HL 33.9 Wed 16:30 EW 201

Nanofabrication of surface templates for low and high density quantum dots formation — •Tino Pfau, Aleksander Gushterov, and Johann Peter Reithmaier — Technische Physik, INA, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

To overcome statistical variations of the dot position and the dot size in a self-assembled dots formation process, surface templates with nanoscale dimensions are developed based on electron beam lithography and wet-chemical etching. In comparison to dry etching, wet chemical etching avoids crystal damage and defect related non-radiative recombination processes should play a much smaller role. Here, different wet chemical surface preparation methods are examined to create atomically flat surfaces on GaAs as well as to create etched hole densities higher than 10^{10}cm^{-2} as growth templates. The surfaces are characterized by scanning electron microscopy (SEM) and atomic force microscopy (AFM).

HL 33.10 Wed 16:45 EW 201

Enhancing nitrogen solubility in diluted nitrides by surface kinetics: An *ab initio* study — •Hazem Abu-Farsakh[1,2] and Jörg Neugebauer[1,2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [2]Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

$GaAs_{1-x}N_x$ alloys with low N content have recently attracted a lot of attention as material system of choice for making infrared laser diodes relevant e.g. for optical fiber communications. A specific challenge for practical applications is the low equilibrium solubility of N in bulk GaAs at typical growth temperatures (500 K). Interesting options to enhance N solubility are: (i) employing surface kinetics and (ii) growing quaternary $In_yGa_{1-y}As_{1-x}N_x$ alloys. In order to further explore/optimize these methods it is crucial to identify the atomistic growth processes of N adatoms on/in the GaAs surface.

We have therefore employed density functional theory to calculate the complete surface phase diagram of N at GaAs(001) surfaces, considering all relevant reconstructions and different layers. Besides, we studied the kinetic barriers and surface segregation of N on these surfaces and found clear evidence that N can be incorporated only in the topmost surface layer [1]. Using the phase diagrams we provide an estimate of N concentration as function of growth conditions. The surface solubility shows a rich behavior depending strongly on the specific surface structure. Based on these results we have been able to identify optimal growth conditions allowing for maximum N incorporation.

[1] M. Albrecht, H. Abu-Farsakh *et al.*, Phys. Rev. Lett. **99**, (2007).

15 min. break

HL 33.11 Wed 17:15 EW 201

MOVPE Growth of Antimonides on InP Substrate — •Christian Grasse, Ralf Meyer, Gerhard Böhm, and Markus-Christian Amann — Walter Schottky Institut, Technische Universität München

Electrically tunable Lasers like the Tunable Twin Guide Laser play an important role in the optical fiber telecommunication and are based on the principle of the plasma effect. Due to the injection of carriers in a tuning zone with a separate controllable current the emission wavelength of the lasers can be changed. To avoid heating of the laser, which would counteract the electrically tuning effect, requires to decrease the recombination of holes and electrons in the tuning zone, so that just a little current is needed for wavelength matching. A Typ-II heterostructure accomplishes this task due to the local separation of the carriers. For good partition high bandoffsets are needed, which is achieved by the aluminium free combination of GaInAsP and the barely explored alloy GaInPSb.

Growth via a MOVPE reactor and characterisation of GaInPSb on InP substrate in a temperature range of 500 to 575°C are presented. As precursors TMGa, TEGa, TMIn, TMSb and Phosphin are used with hydrogen as carrier gas. SIMS-, XPS-, Hall-, and photoluminescence measurements show an unexpected growth behaviour and evidence of clustering, which would limit an application in a device. To illustrate the difficulties of growing materials, which contain phosphor and antimony, comparative growth studies of GaPSb, InPSb, GaAsSb and GaInAsSb have been done and will be discussed.

HL 33.12 Wed 17:30 EW 201

Core levels, valence band structure and unoccupied states of clean InN surfaces — •Marcel Himmerlich, Anja Eisenhardt, Juergen A. Schaefer, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany

In this study we used a surface analytics system directly connected to a MBE growth module to study the surface properties of thin InN films. The samples were prepared by plasma assisted molecular beam epitaxy on $GaN/Al_2O_3(0001)$ templates and exhibited a 2×2 reconstruction after growth. The prepared samples were analysed by photoelectron spectroscopy as well as electron energy loss spectroscopy (EELS). For the occupied states, a very good agreement to available theoretical calculations is found [1,2]. Although, the valence band maximum is located at 1.6 eV, indicating strong downward band bending of $\sim$0.9 eV, photoemission is detected up to E_F. This indicates that the Fermi level is pinned above the conduction band minimum, as recently predicted [1]. The spin-orbit splitting of the In4d level at 17.8 eV could be resolved using He II radiation. Furthermore, from the fine structure of the secondary electron cascade peak we extract the energy of different unoccupied states 0 eV to 9 eV above the vacuum level. These measurements enable us to identify features in the InN EELS spectra, with a loss energy larger than 16 eV, as interband transitions from the In4d level.

[1] D. Segev and C.G. Van de Walle, Europhys. Lett., 76 (2006) 305
[2] P.D.C. King et al., Appl. Phys. Lett., 91 (2007) 092101

HL 33.13 Wed 17:45 EW 201

Increased binding energy of impurities near a semiconductor-vacuum interface — A.P. Wijnheijmer[1], •J.K. Garleff[1], P.M. Koenraad[1], K. Teichmann[2], M. Wenderoth[2], S. Loth[2], and R.G. Ulbrich[2] — [1]PSN, Eindhoven University of Technology, the Netherlands — [2]IV. Phys. Inst., Georg-August Univ. Göttingen, Germany

We have recently shown that a STM tip can be used as a tool to manipulate the charge state of individual impurities below the cleavage surface of a semiconductor. This manipulation allowed us to determine the binding energy of single donors and acceptors as a function of their depth (up to 1 nm) below the surface. We found that the binding energy strongly increases near the surface. In the case of a Si-donor in GaAs the binding energy increases continuously from 5.6 meV in the bulk to about 150 meV close to the surface. Our STM techniques also allowed for the determination of the size and shape of the Coulomb field of single ionized donors. We found that the range of the potential is strongly reduced relative to the bulk value. Both the reduced range of the Coulomb potential and the increased binding energy can be related to a reduced dielectric constant and increased effective mass near the surface. We will discuss the implications of these findings. This work was supported by NWO, VICI project and DFG SFB 602 TP A7 and DFG SPP 1285.

HL 33.14 Wed 18:00 EW 201

Manipulation of charge on a single donor atom by Scanning Tunneling Microscopy — •K. Teichmann[1], M. Wenderoth[1], S. Loth[1], R.G. Ulbrich[1], J.K. Garlef[2], A.P. Wijnheijmer[2], and P.M. Koenraad[2] — [1]IV. Phys. Inst. Georg-August-Universität Göttingen — [2]PSN, Eindhoven University of Technology, the Netherlands

We investigated Silicon donors in highly doped GaAs by spatially resolved Scanning Tunneling Spectroscopy at 6 K. Recently it was shown by Feenstra [1], that the shape of the tip has a strong influence of the extension of the tip induced bend bending (TIBB) in the semiconductor. Sharp tips produce a lateral extension of TIBB in the semiconductor within the range of nanometers. The charge of an individual impurity can be manipulated by the TIBB in the following way: Donors, away from the tip, will be neutral, as the thermal energy at 6K is much smaller than the ionisation energy of the donor. The bands and the donor energy levels are lifted for positive sample voltage. At a certain amout of TIBB the donor ground state is lifted above the onset of the conduction band and the donor will be ionised. In the measurement the ionisation of the donor is seen as a peak in the dI/dV signal. In spatially resolved dI/dV maps the signal has a ring like structure. For higher applied voltages the diameter of the ring increases. By comparing the calculated TIBB and the voltage dependence of the lateral displacement of the measured peak a value of about 150 meV for the donor level can be extracted. This work was supported by DFG SFB 602 and DFG SPP 1285.

[1] R. M. Feenstra, J. Vac. Sci. Technol. B21(5) 2080 (2003)

HL 33.15 Wed 18:15 EW 201

Selective etching of independent contacts in a double quantum-well structure: quantum-gate transistor — •Stefan Lang, Lukas Worschech, Monika Emmerling, Micha Strauss, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Double GaAs quantum wells (QWs) embedded between modulation-doped AlGaAs barriers with different Al contents were grown by molecular beam epitaxy.Independent electric contacts to each well were realized by applying different etching techniques without substrate removal. In particular the lower quantum well was electrically pinched off by a local undercut of the lower AlGaAs barrier. The upper QW was locally depleted by top etched trenches. Transistor operation of quantum wires defined in such bilayers is demonstrated at room temperature with one GaAs serving as channel controlled by the other nearby GaAs layer as efficient gate.