HL 31: Poster: Nitrides

Time: Monday 17:00–20:00 Location: P2

HL 31.1 Mon 17:00 P2

Time-resolved photoluminescence studies of Ge-doped gallium nitride nanowires — •Evelyn Röder[1], Nils Rosemann[1], Pascal Becker[2], Jörg Teubert[2], Martin Eickhoff[2], and Sangam Chatterjee[1] — [1]Philipps-Universität Marburg, Marburg, Germany — [2]I. Physikalisches Institut Justus-Liebig-Universität Gießen, Gießen, Germany

GaN nanowires (NWs) exhibit their large surface-to-volume ratio makes them ideal systems to investigate surface-related effects such as the influence of, e.g., band bending. Additionally, these NWs exhibit a low defect density due to the self-assembly during growth. This makes them an ideal system to investigate the influence of doping on the crystal structure and the related optical properties. Previous studies investigated the influence of Si- and Mg-doping on such NWs[1]. These structures show a quenching of the luminescence due to surface band bending. This quenching also shows a non-linear dependence on the doping. As a next step the doping was changed to the germanium, which has a much larger covalent radius than Si or Mg. We studied several Ge-doped ensembles of GaN nanowires using a standard streak-camera setup. By this the spectral shift and changes in the dynamics of carriers, due to the doping are obtained.[1] J. Appl. Phys. 104(7), 074309, (2008)

HL 31.2 Mon 17:00 P2

The role of Si during the growth of GaN micro- and nanorods — •Christian Tessarek[1], Martin Heilmann[1], Christel Dieker[2], Erdmann spiecker[2], and Silke Christiansen[1,3] — [1]Max Planck Institute for the Science of Light, Erlangen — [2]University Erlangen-Nuremberg, Center for Nanoanalysis and Electron Microscopy, Erlangen — [3]Helmholtz Centre Berlin for Materials and Energy, Berlin

Self-assembled GaN micro- and nanorods on sapphire substrates have been grown by metal-organic vapor phase epitaxy via a self-catalyzed vapor-liquid-solid (VLS) growth mode [1]. The aspect ratio/vertical growth of the rods is strongly dependent on the Si/Ga ratio. Furthermore, Si improves the rod morphology and rods with a regular hexagonal shape, smooth sidewall facets and sharp edges are obtained. Whispering gallery modes are observed in optical investigations representing the high quality of the rods [2].

Structural investigations have been carried out utilizing transmission electron microscopy and energy dispersive X-ray spectroscopy. A SiN layer is existing on the sidewall facets of the GaN rods. The SiN layer acts as an antisurfactant for GaN and is thus stabilizing the sidewall facets. The influence of the SiN layer on the thermal resistivity and on the subsequent InGaN quantum well growth will be discussed. Finally, a model will be presented explaining the role of Si during the VLS GaN rod growth [3].

[1] C. Tessarek et al., J. Appl. Phys. **114**, 144304 (2013). [2] C. Tessarek et al., Opt. Express **21**, 2733 (2013), and Jpn. J. Appl. Phys. **52**, 08JE09 (2013). [3] C. Tessarek et al., Cryst. Growth Des., submitted.

HL 31.3 Mon 17:00 P2

Terahertz spectroscopy of electron transport in GaN — •Thomas Rene Arend[1], Stefan Gerhard Engelbrecht[1], Menno Johannes Kappers[2], and Roland Kersting[1] — [1]Photonics and Optoelectronics Group, Ludwig-Maximilians-Universität München, Germany — [2]Department of Materials Science and Metallurgy, University of Cambridge, UK

Structural imperfections in epitaxial GaN, such as threading dislocations and surface inhomogeneities limit the electronic conductivity. Terahertz (THz) spectroscopy is applied for characterizing charge transport in n-doped GaN fabricated by MOVPE. We use Schottky devices that allow for switching the electron density. The resulting differential THz signal is proportional to the high frequency conductivity of the electrons. Devices with low threading dislocation density (4e8cm-2) and low doping density (5e16cm-3) show the classical Drude response. Increasing the dislocation density to 4e9cm-2 leads to unexpected deviations from Drude behavior, such as a negative imaginary conductivity at low frequencies. Even more drastic is the impact of a high doping concentration (4e18cm-3), which leads to a negative imaginary conductivity over the entire THz spectrum accessible. The experimental data are well reproduced by the Bruggeman model, where we assume a conducting and an insulating phase. The calculations deliver the ratios of the components as well as scattering times and mobilities. In all samples, the scattering times are about 50fs. But increasing the doping concentration or the density of threading dislocations decreases the volume fraction of the conducting phase from 95% to about 50%.

HL 31.4 Mon 17:00 P2

Oxidative chemical vapor deposition of p-conductive polymers on ZnO and GaN — •Max Rückmann[1], Stephanie Bley[1], Florian Meierhofer[2], Jens Reinhold[2], Lutz Mädler[2], Jürgen Gutowski[1], and Tobias Voss[1] — [1]Institute of Solid State Physics, Semiconductor Optics, University of Bremen, 28359 Bremen, Germany — [2]Foundation Institute of Materials Science (IWT), Department of Production Engineering, University of Bremen, Germany

Semiconducting ZnO and GaN nanowires can be used as optoelectronic components if a pn-junction can be realized. One possibility to create such a junction is the deposition of organic p-conductive polymers (here: polypyrrole (PP) and poly(3,4)-ethylenedioxythiophene (PEDOT)) on to the surface. For the deposition of polymer layers, we use oxidative chemical vapor deposition (oCVD), with a monomer and an oxidizing agent (here: $FeCl_3$) in the gaseous phase, respectively. A constant flow of the monomer, supported by nitrogen carrier gas, passes the reaction chamber while the oxidizing agent evaporates and initiates the polymerization and thus p-doping directly on the sample surface. We demonstrate that a homogenous, thickness controlled coating of different ZnO and GaN samples can be achieved by carefully adjusting the process parameters like reaction time, substrate temperature, and the oxidizing agent's amount and evaporation temperature. We discuss the results of structural, optical and electrical characterization of the hybrid structures for different deposition parameters.

HL 31.5 Mon 17:00 P2

Optical investigations of exciton-phonon coupling in GaInN quantum wells — •Manuela Klisch, Fedor Alexej Ketzer, Torsten Langer, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

The photoluminescence of GaInN quantum wells shows asymmetric luminescence spectra, which can be consistently explained via sidebands due to coupling of excitons with longitudinal optical phonons (LO-phonons) and due to Fabry-Perot interferences. Therefore we investigate different GaInN quantum well structures grown via low pressure MOVPE by continuous wave photoluminescence. The Huang-Rhys factor, which describes the coupling strength between electron-hole pairs and LO-phonons, is determined by a fit considering Fabry-Perot interferences and up to three LO-phonon sidebands. To determine the origin of the strong coupling between LO-phonons and the recombining electron-hole pairs we change several parameters. The Huang-Rhys factor is analysed as a function of temperature, well width and indium content. We observe that the Huang-Rhys factor increases with the well width and indium content. For this effect we provide an explanation that compares excitons to donor-acceptor pairs considering the Huang-Rhys factor. We observe a thermally activated behavior of the Huang-Rhys factor. At temperatures below 120 K, this behavior is consistent with a thermalization of excitons and the S-shaped temperature dependence of the emission energy. Towards higher temperature, monotonously increasing Huang-Rhys factors are observed likely due to contributions of excitonic 2s states.

HL 31.6 Mon 17:00 P2

GaInN/GaN multiple quantum well structures grown via plasma-assisted MBE — •Patricia Herbst, Christopher Hein, Andreas Kraus, Fedor Alexej Ketzer, Ronald Buss, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig, Germany

The material system containing the group-III-nitrides takes an important role for optoelectronic devices, e.g. light-emitting diodes (LED). In particular, the promising features of GaInN/GaN multiple quantum wells (MQW) need further studies because the physical processes taking place are not fully understood. The growth of GaInN/GaN single layers as well as MQW was investigated using a RF-MBE (RIBER 32). Indium concentrations, surface morphologies, relaxation and layer thicknesses were analyzed in the growth temperature range from 470°C up to 750°C at different fluxes. Varying layer thicknesses (1-45nm) were analyzed revealing a correlation between indium concentration, relaxation and layer thickness. With increasing layer thickness InGaN relaxes and a higher indium concentration is detected. A five fold $Ga_{0.89}In_{0.11}N$/GaN MQW was realized emitting at 2.84 eV (15K). Superlattice fringes with pendellösungen appear in XRD measurements around the (0002)-Bragg reflection. The predicted In-concentration via XRD corresponds to the photoluminescence spectroscopy data. Even at 300K a quantum well emission could be observed corresponding to an internal quantum efficiency of 0.2%.

HL 31.7 Mon 17:00 P2

RF-MBE growth of AlN on sapphire utilizing AlN nucleation layers — •Christopher Hein, Andreas Kraus, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU-Braunschweig, Germany

AlN is a promising material for laser as well as quantum well structures due to its high thermal conductivity and stability as well as large bandgap. Further AlN can be used to grow self assembled GaN quantum dots. We report on our AlN growth on sapphire with a Riber 32P RF-MBE. Experiments cover the investigation of the influence of nucleation layers. Before growth a nitridation step at a temperature of 200°C was performed. AlN nucleation layers were grown at 400°C. 500 nm thick epilayers were grown at 700°C using either continuous or metal modulated epitaxy. Growth rates were 3.4 nm/min with a III/V ratio of ~ 1. AFM micrographs of samples with increasing nucleation layer thickness show a decreasing RMS roughness down to 0.7 nm. Strikingly a narrow peak in symmetric XRD omega scans was observed, whose FWHM was resolution limited. The appearance of the narrow peak is also seen in MOVPE grown AlN on sapphire for layer thicknesses below 1-2 μm. It is assumed to originate from an interference effect of small crystallites highly ordered in c-direction. This assumption can be confirmed by our experiments with increasing AlN nucleation layer thicknesses giving rise to smaller grains as seen by AFM. Relating this to the results from omega scans, the intensity of the narrow peak decreases with increasing nucleation layer thickness, hinting at a correlation between grain size and the interference.

HL 31.8 Mon 17:00 P2

Photoreflectance studies on InGaN/GaN multi-quantum well structures — •Stefan Freytag[1], Christoph Berger[1], Pavel Y. Bokov[2], Armin Dadgar[1], Rüdiger Goldhahn[1], Alois Krost[1], and Martin Feneberg[1] — [1]Institut für Experimentelle Physik , Otto-von-Guericke-Universität, Magdeburg, Germany — [2]Moscow State University, Moscow, Russia

Wurtzite(0001) oriented InGaN/GaN multi-quantum well structures were investigated by photoreflectance spectroscopy at variable temperatures. To achieve a systematic understanding, structures were varied from sample to sample, i.e. quantum well thickness, barrier thickness, number of quantum wells and the width of the cap layer. We clearly observe free excitons in the GaN matrix and find a very prominent photoreflectance feature from the InGaN quantum wells. The energy position of this contribution as a function of temperature is compared to photoluminescence yielding data on localization effects. Finally, additional features in photoreflectance which are located energetically between the quantum wells and the GaN excitons are found and possible origins are discussed.

HL 31.9 Mon 17:00 P2

Structural and luminescence properties of an AlInN/AlGaN based microcavity structure — •Max Trippel, Gordon Schmidt, Peter Veit, Frank Bertram, Christoph Berger, Armin Dadgar, Alois Krost, and Jürgen Christen — Institute of Experimental Physics, Otto-von-Guericke-University, Magdeburg, Germany

Using transmission electron microscopy combined with cathodoluminescence spectroscopy (STEM-CL) we present the spatially resolved optical properties of a microcavity structure (MC) on nanometer scale. In addition, the temperature dependence of the spectral characteristics of the active medium were investigated by photoluminescence.

The MC structure was grown by metal-organic vapor phase epitaxy (MOVPE) on a c-plane sapphire substrate with an optimized AlGaN buffer structure. A lattice matched 45 pairs $Al_{0.85}In_{0.15}N/Al_{0.2}Ga_{0.8}N$ distributed Bragg reflector (DBR) operates as the bottom mirror. The active medium consists of an InGaN/AlGaN multiple quantum well (MQW) embedded in a λ-cavity.

At 4.2 K the photoluminescence spectrum is dominated by the MQW emission at about 360 nm followed by sideband peaks at 370 nm and 383 nm which are assigned to longitudinal optical phonon replica. The STEM-CL images clearly resolve the complete stacking sequence of the MC structure. Highly spatially resolved STEM-CL linescans reveal a constant MQW peak position along growth direction indicating spectrally identical QWs. Within the DBR stack, we observe an emission at about 335 nm originating from the AlGaN layers.

HL 31.10 Mon 17:00 P2

MOVPE growth of group III-Nitrides on ruthenium coated silicon and sapphire substrates — •Silvio Neugebauer, Armin Dadgar, Jürgen Bläsing, Peter Veit, and Alois Krost — Institute of Experimental Physics, Otto-von- Guericke-University Magdeburg, Germany

We present results on MOVPE growth of group III-Nitrides on ruthenium coated sapphire and high index silicon substrates. The growth on high index silicon substrates is a promising way for achieving semipolar GaN and hence a possibility to overcome the spontaneous and piezoelectric polarization field in conventionally grown c-axis devices. Unfortunately, the received GaN c-axis tilt angle with respect to the surface normal is a function of AlN seed layer thickness for a given high index silicon substrate. Higher tilt angles were achieved for thinner AlN seed layers with the drawback of an increased chance of meltback etching. Therefore we investigated the application of a ruthenium layer deposited on the silicon substrate serving the purposes of a higher GaN c-axis tilt angle and reduced melt-back etching. On the other hand the deposition of ruthenium on sapphire substrates seems to be quite promising for the growth of III-Nitrides. The lattice mismatch of ruthenium compared to sapphire is as small as -1.5% and -1.1% along the a- and c-direction respectively. This is an excellent requirement for the epitaxial growth of film bulk acoustic wave resonators, which essentially consists of a piezoelectric thin film in a matrix of two electrodes. Unfortunately the growth of III-Nitrides on ruthenium is quite challenging. The possibilities and limitations are discussed.

HL 31.11 Mon 17:00 P2

Morphology and atomic structure of GaN surfaces and InGaN/GaN quantum wells — •Sabine Alamé[1], Andrea Navarro-Quezada[1], Daria Skuridina[2], Tim Wernicke[2], Michael Kneissl[2], Patrick Vogt[2], and Norbert Esser[1,2] — [1]Leibniz-Institut für Analytische Wissenschaften - ISAS - e.V. — [2]Technische Universität Berlin, Institut für Festkörperphysik, Germany

We present a study on the morphology and optoelectronic properties of buried group-III polar $In_{0.11}Ga_{0.89}N$ and $In_{0.07}Ga_{0.93}N$ single quantum wells (SQWs) upon (0001) surface preparation. The SQWs were grown in a GaN matrix by MOVPE on sapphire substrate, with thicknesses of 3 to 5 nm, the thicknesses of the GaN cap layers were varied from 1 to 10 nm. For the surface preparation the samples underwent thermal annealing between 400°C and 800°C under ultra high vacuum conditions and in nitrogen plasma. X-ray photoelectron spectroscopy revealed, that annealing up to 650°C in nitrogen plasma ambient removes about 90 % of surface oxides and carbons from the oxidized surface without affecting the emission of the underlying SQW, as determined by photoluminescence spectroscopy. It was found, that the indium content of the QWs decreases, whereas the emission wavelength seems not to be changed within the error margin. Low energy electron diffraction showed a (2x2) surface symmetry for the annealed GaN (0001) cap layers, with an increasing surface order for higher annealing temperatures. Clean surfaces in combination with conserved optical properties of the SQWs serve as a starting point for further studies on the interaction of adsorbates with the SQW layers.

HL 31.12 Mon 17:00 P2

Analysis of semipolar gallium nitride layers by μ-Raman spectroscopy — •Lisa Hiller[1], Philipp Schustek[1], Matthias Hocker[1], Sebastian Bauer[1], Marian Caliebe[2], Tobias Meisch[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University, 89081 Ulm, Germany — [2]Institute of Optoelectronics, Ulm University, 89081 Ulm, Germany

In recent years, great efforts have been undertaken to explore semipolar gallium nitride (GaN) layers, which are predicted to reduce significantly the built-in electric fields. We investigate thick semipolar $(11\bar{2}2)$-oriented GaN layers grown on pre-structured sapphire by a sequence of metalorganic vapour phase epitaxy and hydride vapour phase epitaxy.

Confocal Raman spectroscopy with micron-scale resolution gives access to bulk information by non-destructive depth resolved scanning of the sample. The strain analysis on the basis of Raman tensor elements provides a tool of determining local strain fields, which we compare to finite element based simulations. It allows us to characterize different structural domains resulting from the two different growth processes. Furthermore, uncontrolled high dopant concentrations could be identified by the observation of coupled phonon-plasmon modes. Spatially and spectrally resolved cathodoluminescence and secondary ion mass spectrometry confirm these findings.

HL 31.13 Mon 17:00 P2

Development of a dedicated low noise EBIC measurement system — •Manuel Knab[1], Matthias Hocker[1], Ingo Tischer[1], Junjun Wang[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, University of Ulm — [2]Institute of Optoelectronics, University of Ulm

The homogeneity of the active region has a major impact on the efficiency of semiconductor-based light emitting devices. Electron beam induced current (EBIC) is a measurement technique for the characterization of semiconductors inside a scanning electron microscope (SEM). It is mainly used to visualize and locate the active region of light emitting diodes (LED) and for other regions with built-in fields. It also allows to determine the minority carrier diffusion length in semiconductors.

The concept of our system is the amplification of the signal directly inside the SEM in close vicinity of the sample to avoid stray capacitances, and to obtain a low noise EBIC signal with maximum bandwidth. An optimized current amplifier is integrated directly into the sample holder in order to amplify the electron beam induced current in the nA range. Furthermore, it is possible to obtain sample images by recording directly the current absorbed by the specimen. The advantage of this method is to have no detector shading contrast by the sample surface shape.