HL 58: Nitrides: Preparation and characterization I

Time: Thursday 9:30–12:30 Location: POT 112

HL 58.1 Thu 9:30 POT 112

MOVPE growth of (11-22) AlGaN/AlN on m-plane sapphire — •Humberto Foronda[1,2], Sarina Graupeter[1], Valeria Bonito-Oliva[2], Mike Pietsch[2], Priti Gupta[1], Norman Susilo[1], Frank Mehnke[1], Johannes Enslin[1], Tobias Schulz[2], Tim Wernicke[1], Klaus Irmscher[2], Martin Albrecht[2], and Michael Kneissl[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin — [2]Leibniz-Institut für Kristallzüchtung,Berlin

The efficiency of UVC-LEDs emitting below 240 nm drops with decreasing wavelength on (0001) grown $Al_xGa_{1-x}N$. One reason is a change in the optical polarization of the emitted light leading to a reduced light extraction efficiency (LEE). LEDs on semipolar planes, i.e. (11-22), overcome poor LEE due to a rotation of the wurtzite unit cell while decreasing the polarization fields. (11-22) $Al_xGa_{1-x}N/AlN$ by metalorganic vapor phase epitaxy (MOVPE) was investigated for realizing UVC-LEDs on this orientation. When growing $Al_xGa_{1-x}N$ on (10-10) sapphire, layers with (11-22) orientation were achieved, but a deterioration of the surface morphology due to misoriented grains was observed. The protrusion and density of these grains was reduced by tailoring growth and nitridation conditions on sapphire such that a grain-free planar (11-22) surface was achieved. A reduced growth rate suppressed grains at the surface as well as increasing the pressure during nitridation. (11-22) $Al_{0.65}Ga_{1-0.65}N$:Si layers with different silicon concentrations were grown, where a minimum resistivity of 0.024 Ω cm was achieved, comparable to results on (0001). AlGaN multiquantum wells revealed 240 nm photoluminescence emission.

HL 58.2 Thu 9:45 POT 112

Optoelectronic Characterization of GaN Nanowires on SiC-6H — •Andrea Wieland[1,2], Theresa Hoffmann[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut and Physics Department, Technische Universität München, Garching, Germany — [2]Ludwig-Maximilians-Universität München, Munich, Germany

Gallium nitride (GaN) nanowires (NWs) have gained interest for device fabrication due to their large surface-to-volume ratio, high crystal quality and optical waveguide characteristics. [1] As the polarity of GaN NWs influences the electronic properties at the heterointerfaces of the NWs and the substrate, polarity determination and control of the GaN NWs are key requirements to achieve desired NW-based device properties.

We have established the growth of GaN NWs on both polarities of hexagonal silicon carbide (SiC-6H) substrates by molecular beam epitaxy. Selective area growth of GaN NWs allows the variation of the NW dimensions and positions. To obtain optimal growth results the substrate temperature has been varied. Photoluminescence spectroscopy measurements at low temperatures have been performed for optical characterization of the GaN NW. Furthermore, the influence of the SiC-6H substrate polarity on the GaN NWs polarity has been investigated by means of KOH etching and contact potential difference measurements via Kelvin Probe Force Microscopy.

[1] J. Winnerl et al., J. Appl. Phys. 123, 203104 (2018)

HL 58.3 Thu 10:00 POT 112

Growth of AlN on Si(111) by reactive pulsed sputtering — •Florian Hörich, Jürgen Bläsing, Armin Dadgar, and André Strittmatter — Otto-von-Guericke University Magdeburg

Efficient, nitride-based UV light emitting diodes demand for AlN buffer structures with well-aligned crystallographic planes both in growth as well as in in-plane direction to enable low-defect densities within the subsequent layer stack. Currently, best crystallographic qualities are reported for sputtered AlN layers on sapphire substrates which are thermally annealed at temperatures up to 1700°C . This technique cannot be used with silicon substrates because of the lower melting temperature of Si. Thus, sputtering of AlN layers must be optimized to obtain low-defect density buffer structures on Si. We present our work on the growth of AlN on Si(111) by reactive pulsed sputtering, where growth temperatures below 800°C are used. The low growth temperature aims at reducing thermal stress in the epitaxial layer. We examine the effect of an Al seed layer and the impact of the nitrogen source for the crystalline quality. The thickness of the Al seed layer is critical and an optimum for a deposition time of 4 s (would correspond to a 0.2 nm Al layer) is found. Ammonia as nitrogen source is not favourable during growth of AlN directly onto the Si substrate. Since NH3 reacts with the Si surface forming SiN the growth of AlN is limited. With N2 as nitrogen source these limiting chemical reactions are not observed enabling AlN growth on top of the Al seed layer. For an AlN layer thickness of 40 nm the FWHM values of the XRD rocking curves are 0.65° (0002) and 1.35° (10-10).

HL 58.4 Thu 10:15 POT 112

Room temperature excitonic recombination processes in GaInN/GaN quantum wells at studied via carrier density dependent time-resolved photoluminescence — •S. Müllner[1,2], P. Henning[1,2], P. Horenburg[1], H. Bremers[1,2], U. Rossow[1], and A. Hangleiter[1,2] — [1]Institute of Applied Physics, Technische Universität Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, Braunschweig, Germany

Our experimental results indicate excitonic recombination processes in nonpolar m-plane GaInN/GaN quantum wells (QW) even at high carrier densities. This follow-up study from polar c-plane GaInN/GaN, where a similar trend has been reported, was realized by time-resolved photoluminescence experiments at room temperature in which the excess carrier density, δn, is tuned by the laser fluence. Of particular interest is the regime of high carrier densities. Here, we find that the nonradiative lifetime $\tau_{\mathrm{nr}} \sim 1/\delta \mathrm{n}$, evidencing excitonic Auger recombination. In addition, we observe a constant radiative lifetime, τ_{r}, with δn. In the model of free charge carrier recombination, this is expected for the low injection regime in which the background carrier density $n_0 \gg \delta \mathrm{n}$, however, for the high injection regime, a $\tau_{\mathrm{r}} \sim 1/\delta \mathrm{n}$ dependence is predicted. Assuming excitonic recombination, $\tau_{\mathrm{r}}(\delta \mathrm{n})$ is constant for high carrier densities, as we observe it, even further underlying excitonic recombination. We assure that we are in the high carrier density regime by comparing $\tau_{\mathrm{nr}}(\delta \mathrm{n})$, where the transition between the low and high injection regime is signatured by an increase of τ_{nr}, associated with defect recombination.

HL 58.5 Thu 10:30 POT 112

STEM and STEBIC analysis of screw dislocations in GaN to investigate structural and electronic properties — •Tobias Westphal[1], Sevastian V. Shapenkov[2], Oleg S. Vyvenko[2], and Michael Seibt[1] — [1]University of Goettingen, IV. Physical Institute, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Faculty of Physics and IRC Nanotechnology Research Park, St. Petersburg State University, Ulyanovskaya 1, 198504, St. Petersburg, Russia

As GaN has a quite high grown-in dislocation density, in the order of $10^6\,\mathrm{cm}^{-2}$ - $10^8\,\mathrm{cm}^{-2}$ depending on the growth technique, investigating the electronic and optical properties of dislocations is of particular interest. Freshly introduced a-screw dislocations produced by indentations perpendicular to the basal (0001) plane of specially undoped low-resistance GaN show an intense dislocation related luminescence (DRL) with an energy peak at around 3.18 eV [1]. This red shift of about 300 meV with respect to the band gap can be explained by a dissociated dislocation, where the stacking fault ribbon forms a quantum well. Therefore, structural investigations of the dislocation core with high spatial resolution are of tremendous interest.

In this contribution, we report about STEM and scanning transmission electron beam induced current (STEBIC) measurements of dislocations in GaN. Measuring EBIC inside the TEM increases the spatial resolution compared to EBIC in the SEM, as the generation volume inside the sample is much smaller, which allows us to investigate single dislocations near the indentation prick.

[1] O. Medvedev et al., J. Appl. Phys. 123, 161427 (2018)

30 min. break.

HL 58.6 Thu 11:15 POT 112

Investigations on the defect luminescence in high aluminum containing AlGaN heterostructures — •Marcel Schilling, Norman Susilo, Tim Wernicke, and Michael Kneissl — Technische Universität Berlin, Institute of Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany

The realization of deep ultraviolet light emitting diodes (DUV-LEDs) with emission wavelength near 232 nm is very challenging as the photon energy is very close to the band gap of AlN, i.e. AlGaN layers with extremley high Al mole fraction are required. One problem is, that during metal organic vapor phase epitaxy of AlGaN crystalline point defects like vacancies or impurities are incorporated. Deep levels in the energy band gap associated to these point defects result in non-radiative carrier recombination decreasing the internal quantum efficiency (IQE) of DUV-LEDs. Therefore the understanding of the generation of point defects during the growth in high aluminum containing AlGaN layers is crucial for the development of efficient DUV-LEDs. In this study the defect luminescence of AlGaN layers is investigated by photoluminescence spectroscopy. The origin of the defect luminescence is determined by comparing defect luminescence spectra with transition energies for different defects and defect complexes reported in literature. Furthermore, the AlGaN layer quality is improved by optimizing the growth conditions in the reactor in correlation with the purity of the photoluminescence spectra. For example the defect luminescence in a 72% AlGaN layer near a wavelength of 442 nm, is investigated and most probably assigned to a V_{Al}^{3-} vacancy.

HL 58.7 Thu 11:30 POT 112

Indium rich cubic group III Nitrides fabricated with molecular beam epitaxy — •Falco Meier, Dirk Reuter, and Donat J. As — Department of physics, Paderborn University

Indium Nitride (InN) and Indium Gallium Nitride (InGaN) are one of the most important semiconductor materials with a wide variety of applications, such as infrared LEDs, high-frequency and high temperature electronic devices. InN synthesized in the metastable cubic phase (c-InN) has received intensive attention because of its high electron mobility, the low phonon scattering, and the small direct band gap. Due to the high degree of symmetry in c-InN strong build-in electric fields are avoided. However, it is difficult to grow high-crystalline-quality InN because of its low dissociation temperature and the lack of lattice matched substrates. In this work we use a c-GaN buffer layer on a pseudo-substrate of 3C-SiC(001)/Si(001) for the growth of cubic InN and In-rich InGaN with plasma assisted molecular beam epitaxy. A set of parameters for the growth of phase-pure c-InN with a thickness of about 100 nm is determined. A smoothening of the Surface where the e-Beam of the reflection high-energy electron diffraction hits the Sample was verified with Atomic Force Microscopy. High resolution x-ray diffraction indicates that phase pure c-InN grow fully relaxed on the c-GaN buffer layers. The hexagonal phase content was below 5%. In-rich c-InGaN with nominal 10% and 20% Ga contents are also grown. Post growth characterization show that only a part of the nominal offered Ga content are incorporated into the c-InGaN compound indicating spinodal decomposition at the low growth temperatures.

HL 58.8 Thu 11:45 POT 112

Capacitance-Voltage spectroscopy at room temperature of self-assembled GaN quantum dot ensembles under illumination — •Carlo Alberto Sgroi[1], Julien Brault[2], Jean-Yves Duboz[2], Peter Conrad[1], Arne Ludwig[1], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]CNRS - CRHEA, Rue Bernard Grégory, 06560 Valbonne, France

We present capacitance voltage (CV) measurements under illumination at room temperature of charge-tunable self-assembled wurtzite GaN quantum dots (QDs) in an $Al_xGa_{1-x}N$ matrix grown by MBE.

GaN and its alloys have excellent properties such as their thermal stability, high thermal conductivity and wide bandgap energies which make them an ideal candidate for next-generation GaN-based power devices and QD storage devices. Due to polarization and strain effects in wurtzite $GaN/Al_xGa_{1-x}N$ heterostructure layers, the band structure is different where QDs and wetting layer (WL) are, respectively. Large electric fields and phonon processes promote charge transfer through the WL.

Performing CV spectroscopy on an AlGaN-Schottky diode structure with embedded GaN QDs, we observe a hysteresis effect in the charging and discharging of the QDs at room temperature. Under illumination of 395 nm, bandgap excitation of the QDs, we change the electron exchange mechanism and are able to remove the hysteresis effect completely.

HL 58.9 Thu 12:00 POT 112

Effect of low temperature GaN underlayers on the carrier lifetimes in GaInN/GaN quantum wells — •Philipp Horenburg[1], Philipp Henning[1], Savutjan Sidik[1], Uwe Rossow[1], Heiko Bremers[1,2], and Andreas Hangleiter[1,2] — [1]Institute of Applied Physics, Technische Universität Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, Braunschweig, Germany

We demonstrate the impact of low temperature GaN underlayers (UL) grown under various conditions on the carrier lifetimes and the radiative efficiency and in GaInN/GaN quantum well (QW) structures. Since nonradiative recombination is associated with crystal defects in close proximity to the QW, the material grown underneath has a substantial influence on the carriers in QW. As the recombination dynamics can be significantly affected by changes in the density of defects and background carriers, the QW is not least susceptible to the growth conditions of this UL. We have grown a series of c-plane QW structures by low-pressure MOVPE on sapphire substrates. While GaInN is widely used an UL material, we chose a pure GaN UL grown at low temperature. Power and temperature dependent measurements show a strong increase of the internal quantum efficiency by two orders of magnitude compared to structures without a low temperature UL. Time-resolved photoluminescence measurements reveal that, with increasing thickness of the UL, not only the nonradiative lifetime increases, but also the radiative lifetime is affected just as for GaInN UL. These observations suggest that not the composition, but particularly the growth conditions affect the recombination dynamics in the QW structure.

HL 58.10 Thu 12:15 POT 112

Luminescence of GaN quantum dots on highly reflective deep UV Bragg mirrors — •Hannes Schürmann[1], Christoph Berger[1], Gao Kang[2], Gordon Schmidt[1], Peter Veit[1], Frank Bertram[1], Sebastian Metzner[1], Armin Dadgar[1], Jürgen Bläsing[1], André Strittmatter[1], Mark Holmes[2], and Jürgen Christen[1] — [1]Institute of Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Institute of Industrial Science, The University of Tokyo, Japan

Towards the realization of room temperature stable and efficient single photon emitters, we present the structural and optical properties of GaN quantum dots (QDs) embedded in an AlGaN semi-microcavity with deep UV Bragg reflectors (DBR).

The structure was grown by MOVPE on AlGaN/sapphire template. Embedded in an AlGaN λ-cavity, the GaN QDs result from a 2 nm GaN layer with growth interruption. The DBR consists of 50 AlN/AlGaN pairs with 99.7 % reflectivity. Mesa structures were produced by reactive ion etching to investigate individual QDs.

Quasiresonantly excited QDs exhibit narrow emission lines between 269 - 273 nm with FWHM down to 0.9 meV at 8 K. Autocorrelation measurements reveal a clear antibunching with $g^{(2)}(0)$ values down to 0.34, which proofs single photon statistics of QD emission matching the DBR stopband.