HL 59: Nitrides: Preparation and Characterization II

Time: Wednesday 14:45–17:45 Location: POT 251

HL 59.1 Wed 14:45 POT 251

High Temperature Vapor Phase Epitaxy of GaN - Investigation of defect related UV luminescence — •Friederike Zimmermann[1], Franziska C. Beyer[1], Gleb Lukin[2], Tom Schneider[2], Olf Pätzold[2], Mykhailo Barchuk[3], and Johannes Heitmann[3] — [1]Institute of Applied Physics, TU Bergakademie Freiberg, 09599 Freiberg, — [2]Institute of Nonferrous Metallurgy and Purest Materials, TU Bergakademie Freiberg, 09599 Freiberg, — [3]Institute of Materials Science, TU Bergakademie Freiberg, 09599 Freiberg,

Compared to conventional growth techniques like hydride vapor phase epitaxy and metalorganic vapor phase epitaxy point defect formation for GaN grown by high temperature vapor phase epitaxy (HTVPE) is not yet well understood. We report on a photoluminescence study on GaN grown by HTVPE with a systematic variation of Ga temperature and growth pressure.

Photoluminescence spectra recorded at 15 K show a strong ultraviolet luminescence (UVL) with zero phonon line at 3.27 eV. The intensities of all other defect related transitions are lower by at least one order of magnitude. The high relative intensity of this donor-acceptor pair recombination can not be explained by a high concentration of acceptor impurities. Silicon and boron are the main impurities, whereas magnesium is present in the range of mid 10^{15} cm^{-3} only. Reduced Ga temperature and growth pressure result in better surface morphology and structural quality as well as a significant drop of relative UVL intensity.

HL 59.2 Wed 15:00 POT 251

Internal quantum efficiency of strain controlled semipolar GaInN/GaN quantum wells — •Fedor Alexej Ketzer[1], Philipp Horenburg[1], Heiko Bremers[1], Uwe Rossow[1], Florian Tendille[2], Philippe De Mierry[2], Philippe Vennéguès[2], Jesús Zúñiga-Pérez[2], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, Technische Universität Braunschweig — [2]Centre de Recherche sur l'Hétéro-Epitaxie, Valbonne, France

In this contribution we report on the effect of strain manipulation on internal quantum efficiencies (IQE) of semipolar $(11\bar{2}2)$ multi quantum well (MQW) structures. For strain control we use AlInN interlayers prior to the MQW structure. Due to the large range of possible lattice constants for different AlInN compositions, we can control the strain in the MQW in a wide range. Relaxation of strain in the MQW region is one of the main reasons for a lowered IQE at high indium concentrations, necessary for long emission wavelengths. We compare samples, grown via low pressure MOVPE on $(11\bar{2}2)$ GaN templates grown on patterned *r*-sapphire substrates, with and without AlInN interlayer and different growth conditions for the MQWs. We determine the structural properties of our samples by high resolution X-ray diffraction. The IQEs are measured by temperature and excitation power dependent photoluminescence spectroscopy with resonant excitation. We observe a redshift of our strain-manipulated samples associated with an increased indium content in the quantum wells. Our samples show high IQEs of up to 44% and 30% at 300 K for emission wavelengths of 545 nm and 575 nm, respectively.

HL 59.3 Wed 15:15 POT 251

Interplay between yellow and blue luminescence bands in GaN:C — •Zahid Usman, Martin Feneberg, Andreas Lesnik, Marc P. Hoffmann, Armin Dadgar, and Rüdiger Goldhahn — Otto-von-Guericke Universität Magdeburg, Institut für Experimentelle Physik

Carbon doped GaN has attracted much attention due to its compensating nature for unintentionally introduced background electron densities. That is why a semi-insulating buffer layer of this material is often introduced in high electron mobility transistors. Photoluminescence can be a useful tool to understand the charge states of deep defects which yield different recombination channels in GaN. Here, we present photoluminescence spectra with different excitation densities, recorded on carbon and silicon co-doped GaN samples. Depending on dopant densities, the photoluminescence spectra show yellow and blue luminescence bands with different intensity ratios. For increasing pump power density the yellow luminescence band saturates at a critical excitation power density while the blue luminescence band increases further. Our results suggest that both recombination bands evolve from the deep carbon acceptor in different charge states. The yellow band is assigned to come from carbon in (-/0) state while the blue band originates from carbon in (0/+) charge state.

HL 59.4 Wed 15:30 POT 251

Time-resolved Investigation of Charge Transfer in Asymmetric Cubic $Al_{0.64}Ga_{0.36}N/GaN$ Double Quantum Wells Grown by MBE — •Tobias Wecker[1], Gordon Callsen[2], Axel Hoffmann[2], Dirk Reuter[1], and Donat Joseph As[1] — [1]Department of Physics, University of Paderborn, 33098 Paderborn — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin

Non-resonant carrier transfer between quantum wells (QWs) is of high significance for many devices like quantum cascade lasers. In this study, time-resolved photoluminescence is used to investigate this effect in asymmetric double QWs for low temperatures. Asymmetric cubic $Al_xGa_{1-x}N/GaN$ double QWs with an Al content of x = 0.64 * 0.03 were grown on 3C-SiC (001) substrate by radio-frequency plasma-assisted molecular beam epitaxy. Three samples with different barrier thickness d were analyzed (1 nm, 3 nm, 15 nm). The two QWs are 2.5 nm and 1.35 nm thick, to show separated emission bands in the luminescence. Three clearly distinguishable emission bands at 3.49 eV, 3.73 eV and 4.12 eV are observed and could be assigned to the different layers. A correlation between the carrier lifetimes in the QWs and the barrier thickness is found. Exploiting rate equations the intensity ratios of both QW emissions have been calculated. Electronic coupling between the QWs is only observed for barrier thicknesses below 3 nm.

Coffee Break

HL 59.5 Wed 16:15 POT 251

Time-integrated and time-resolved luminescence studies of planar and 3D InGaN/GaN heterostructures — •Angelina Vogt[1], Jana Hartmann[1,2], Hao Zhou[1], Sönke Fündling[1,2], Hergo-Heinrich Wehmann[1,2], Andreas Waag[1,2], and Tobias Voss[1] — [1]Institute of Semiconductor Technology and Laboratory for Emerging Nanometrology, TU Braunschweig, 38092 Braunschweig — [2]Epitaxy Competence Center, ec2, 38092 Braunschweig

Three-dimensional core-shell GaN-based heterostructures with embedded InGaN quantum wells (QWs) on non-polar sidewalls are promising candidates for a novel LED architecture based on GaN material free of extended defects. In order to optimize the internal quantum efficiency (IQE) of the 3D heterostructures, a detailed knowledge of the radiative and non-radiative recombination channels and their rates is required. Here, we compare the spectrally and temporally resolved photoluminescence (PL) of InGaN/GaN 3D heterostructures with the respective data of planar InGaN/GaN structures. All heterostructures were grown by MOVPE. We used time-integrated PL measurements to analyse the homogeneity of the indium in the QWs. The luminescence dynamics of the InGaN QWs were investigated by time-resolved experiments in order to characterise the fundamental optical relaxation and recombination processes. We analyse the processes for different structures, laser photon energies and temperatures. Due to the quantum confined Stark effect (QCSE), we find a biexponential decay characteristic for the planar structures, while the 3D structures with the non-polar InGaN QWs as light-emitters show a monoexponential decay of the InGaN PL.

HL 59.6 Wed 16:30 POT 251

Depth and laterally resolved cathodoluminescence spectroscopy on Ga(In)N quatum well structures — •Matthias Hocker[1], Pascal Maier[1], Ingo Tischer[1], Tobias Meisch[2], Marian Caliebe[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Semiconductor Physics Group, University of Ulm — [2]Institute of Optoelectronics, University of Ulm

We present the combination of lateral and depth-resolved cathodoluminescence (CL) spectroscopy on a Ga(In)N based LED sample. It is demonstrated how the analysis of depth-resolved CL measurements can be enhanced by taking semiconductor-specific parameters such as exciton diffusion length and band gap energies into account for the corresponding Monte-Carlo simulation of the primary electron scattering. The results of the depth-resolved measurement were found to be in very good agreement with the layer thickness values expected from growth conditions. We show, how a semi-threedimensional schematic model of the sample under investigation can be reconstructed from the experimental data, and which amount of information can be obtained by this measurement method.

HL 59.7 Wed 16:45 POT 251

Photoluminescence spectroscopy of Ge-doped cubic GaN — •Michael Deppe[1], Jürgen W. Gerlach[2], Dirk Reuter[1], and Donat J. As[1] — [1]Universität Paderborn, Department Physik, Warburger Straße 100, 33098 Paderborn — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, 04318 Leipzig

Recently, germanium was introduced as an alternative to silicon for n-type doping of cubic GaN. We demonstrated that free carrier concentrations up to 3.7×10^{20} cm^{-3} can be obtained and the incorporation of Ge is in good agreement to the trend of the Ge vapour pressure curve in a doping range spanning several orders of magnitude [1]. In this contribution we report on the optical properties of Ge-doped cubic GaN determined by photoluminescence (PL) spectroscopy. Cubic GaN layers with nominal thicknesses of 600 nm were grown by plasma-assisted molecular beam epitaxy on 10 μm thick 3C-SiC(001)/Si(001) substrates. The Ge doping level was varied by about six order of magnitude by varying the Ge effusion cell temperature between 600 °C and 1000 °C. PL spectra were obtained for sample temperatures between 13 K and 300 K. Above a Ge concentration of approximately 2×10^{18} cm^{-3} the near band edge emission lines merge to a broad band. A donor ionization energy of about 36 meV was estimated.

[1] M. Deppe, J. W. Gerlach, D. Reuter, and D. J. As, Phys. Stat. Sol (b) (2016) (submitted)

HL 59.8 Wed 17:00 POT 251

Polarity Control of GaN Nanowires — •Max Kraut, Martin Hetzl, Theresa Hoffmann, and Martin Stutzmann — Walter Schottky Institut and Physics Department, Technische Universität München, Garching, Germany

Heteroepitaxial GaN nanowires (NWs) have gained much interest in current research. However, the nucleation process of the GaN crystals, and in particular the orientation of the polar axis of the wurtzite crystal is not fully understood yet. Inconsistent results have been reported whether N, Ga or mixed polarity is the dominant feature. This indicates a complex interplay of growth mode, substrate type and growth parameters. We have systematically investigated the polarity distribution of GaN NWs grown by molecular beam epitaxy via selective area growth (SAG). Thanks to its high chemical and physical stability, diamond (111) has been used as a model substrate to elucidate the influence of the growth parameters, namely III/V flux ratio and substrate temperature T_{sub}. The polarity of individual NWs has been identified by Kelvin Probe Force Microscopy (KPFM) which allows a statistical investigation of large NW arrays. We find that T_{sub} is the driving force for the polarity distribution of GaN NWs on diamond whereas the III/V flux ratio plays a minor role. In particular, a variation of the fraction of Ga-polar SAG GaN NWs ranging from 45% up to 90% has been achieved by adjusting T_{sub}. In the case of self-assembled NWs and a comparably elevated temperature, N polarity is found to be the dominant crystal orientation. The findings obtained on diamond are in agreement with GaN NW growth on other substrates.

HL 59.9 Wed 17:15 POT 251

Misfit strain as a control parameter in epitaxy of In-rich non- and semipolar GaInN/GaN multi quantum well structures — •Philipp Horenburg[1], Fedor Alexej Ketzer[1], Heiko Bremers[1], Uwe Rossow[1], Florian Tendille[2], Philippe De Mierry[2], Philippe Vennéguès[2], Jesús Zúñiga-Pérez[2], and Andreas Hangleiter[1] — [1]Institute of Applied Physics, TU Braunschweig, Germany — [2]Centre de Recherche sur l'Hétéro-Epitaxie, Valbonne, France

We demonstrate the role of misfit strain as an independent parameter in MOVPE growth of m-plane and $(11\bar{2}2)$-oriented, In-rich GaInN quantum wells (QWs). Reducing the misfit strain in the active zone is an essential task to improve the material quality and efficiency of light emitting structures. In order to manipulate the strain state of the QWs, we insert a metamorphic AlInN buffer layer as a growth template for the active zone. With the buffer layer being partially relaxed towards larger in-plane lattice constants, the lattice mismatch at a given In composition of the GaInN is reduced as compared to GaN as a template. As a consequence, we see a decrease of the strain energy in the QWs as compared to samples without AlInN under identical QW growth conditions. We further see evidence for an increased In incorporation efficiency up to InN mole fractions of 38% in both structural analysis by high resolution X-ray diffraction and room temperature photoluminescence spectroscopy. Thus, strain manipulation opens up an additional degree of freedom in epitaxy of GaInN QWs in addition to thermodynamic parameters such as the QW growth temperature.

HL 59.10 Wed 17:30 POT 251

Influence of electric field variation on optical properties of semipolar InGaN/GaN light emitting diodes — •Stefan Freytag[1], Michael Winkler[1], Tim Wernicke[2], Luca Sulmoni[2], Ingrid Koslow[2], Duc V. Dinh[3], Brian Corbett[3], Peter J. Parbrook[1], Martin Feneberg[1], Michael Kneissl[2], and Rüdiger Goldhahn[1] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität, Magdeburg, Germany — [2]Technische Universität Berlin, Institute of Solid State Physics — [3]Tyndall National Institute, University College Cork, Cork, Ireland

Semipolar InGaN/GaN quantum-well (QW) structures with the $(20\bar{2}\bar{1})$ and $(20\bar{2}1)$ surface orientations have attracted a lot of interest in recent years for applications in efficient light emitting diodes. Studies revealed unexpected differences in the energy splitting of QW emission energy as well as the optical polarization degree ρ between the two orientations. We report a comprehensive electro-optical (electroreflectance) characterization of those structures embedded in p-/n-junctions. The analysis yields the optical polarization dependent absorption related transition energies between depletion and forward bias. The data are compared to bias dependent photoluminescence and electroluminescence measurements. Results have been interpreted based on k·p theoretical model calculations.