HL 80: GaN: Preparation and Characterization V (mainly Cathodoluminescence)

Time: Thursday 11:15–13:30 Location: ER 270

HL 80.1 Thu 11:15 ER 270

Optical properties of ZnO/GaN/InGaN core-shell nanorods — •Ingo Tischer[1], Mohamed Fikry[2], Ren Zhe[2], Manfred Madel[1], Matthias Hocker[1], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institut für Quantenmaterie, Gruppe Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

ZnO/GaN/InGaN core-shell nanorods standing upright in a well defined pattern can be used for sensing applications. As a first step, we grew ZnO nanopillars on top of GaN pyramids resulting in an ordered array of upright ZnO nanorods with average distance of 6 μm and ≈ 500 nm thickness. This structure was coaxially overgrown with GaN and a subsequent single InGaN quantum well. We report about the different spectral features that are found in these structures. We investigated the various contributions from Zn doping and from the quantum well by spatially resolved cathodoluminescence, transmission electron microscopy, and photoluminescence.

HL 80.2 Thu 11:30 ER 270

Growth and optical properties of mask-free and uncatalyzed GaN nanorods by metal-organic vapor phase epitaxy — •Christian Tessarek and Silke Christiansen — Max Planck Institute for the Science of Light, Erlangen, Germany

Nanorod (NR) structures have the potential to significantly reduce the defect density in heteroepitaxially grown GaN. Furthermore, in case of a high density and high aspect ratio the surface to volume ratio is increased in comparison to a two dimensional film.

Our approach is the growth of mask-free and uncatalyzed GaN nanorods by metal-organic vapor phase epitaxy. A simple three step method is utilized consisting of nitridation of the sapphire substrate, deposition of a GaN nucleation layer and finally the growth of GaN NRs. Vertically aligned and hexagonal shaped NR structures were achieved with a density of up to 10^8 cm^{-2}, diameters in the range from 100 nm to some μm, heights up to 30 μm or aspect ratios of up to 30, depending on the growth parameters.

Optical properties of the GaN NRs were determined using spatially and spectrally resolved room temperature cathodoluminescence. It will be shown that the yellow defect band luminescence can be suppressed while the GaN near band edge emission is increased. Finally, the appearance of whispering gallery modes in regular hexagonal shaped GaN NRs will be presented.

HL 80.3 Thu 11:45 ER 270

Cathodoluminescence investigation of polarization field effects in InGaN MQWs with AlInGaN barriers — •Silvio Neugebauer, Sebastian Metzner, Frank Bertram, Jürgen Christen, Lars Groh, Jürgen Bläsing, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

The optical properties of $In_{0.25}Ga_{0.75}N$ multiple quantum wells (MQWs) with quaternary AlInGaN barriers have been investigated using highly spatially, spectrally and time-resolved cathodoluminescence (CL) microscopy. The samples were grown on c-plane sapphire substrates by MOVPE using an optimized AlGaN/GaN template. The Indium and Aluminum content of the barriers were increased systematically starting with binary GaN towards matched polarization with respect to the InGaN quantum well. In time-resolved CL measurements, the polarization unmatched reference sample with GaN barriers exhibits a blue-shift of the QW emission wavelength during the onset of the e-beam excitation. The blue-shift clearly indicates the screening of polarization fields. In complete contrast, the polarization matched sample shows a red-shift during onset which indicates that relaxation of carriers into potential fluctuations is the dominant process of the recombination kinetics. During decay both samples consistently show a red-shift of the emission wavelength (field effects as well as potential fluctuations). The results clearly indicate drastically reduced polarization fields when using quaternary barriers.

HL 80.4 Thu 12:00 ER 270

Optical and Structural Properties of an AlInN/AlGaN Distributed Bragg Reflector using Scanning Transmission Electron Microscopy Cathodoluminescence — •Gordon Schmidt, Peter Veit, Alexander Franke, Frank Bertram, Jürgen Christen, Christoph Berger, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Magdeburg, Germany

We present a direct nano-scale correlation of the optical properties and crystalline real structure of a lattice matched distributed Bragg reflector (DBR) using cathodoluminescence spectroscopy (CL) in a scanning transmission electron microscope (STEM).

The structure was grown by metal organic vapor phase epitaxy on sapphire substrate using an optimized buffer. The highly reflective DBR consits of 35 periods of AlInN and AlGaN $\lambda/4$ layers and is capped by a 200 nm thick $3\lambda/2$ GaN cavity. The STEM-CL images clearly resolve the complete sequence of the DBR structure.

The $Al_{0.2}Ga_{0.8}N$ buffer layers emit intense CL at a wavelength of 318 nm. The DBR layers are laterally and vertically homogeneous with sharp AlInN/AlGaN interfaces. Local spectra show a blueshift of the DBR emission from 327 nm to 323 nm in growth direction. The direct comparison of the STEM image with the simultaneously recorded monochromatic CL mapping of the DBR luminescence clearly identifies the AlGaN/AlInN interfaces as the origin of this emission. This indicates the formation of a 2D electron gas in the polarization field induced potential well at these interfaces.

HL 80.5 Thu 12:15 ER 270

Spontaneous polarization of GaN derived from stacking fault luminescence — •Jonas Lähnemann[1], Oliver Brandt[1], Uwe Jahn[1], Carsten Pfüller[1], Claudia Roder[1], Pinar Dogan[1], Frank Grosse[1], Abderrezak Belabbes[2], Friedhelm Bechstedt[2], Achim Trampert[1], and Lutz Geelhaar[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin — [2]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Wurtzite crystals exhibit a spontaneous polarization P_{sp} in equilibrium, which together with the piezoelectic polarization leads to electric fields in heterostructures and thus has an immediate impact on device design. Amongst these, GaN stands out as the material used for solid-state lighting. So far, only an indirect experimental determination of P_{sp} for GaN has been reported using a thermodynamic approach and theoretical predictions exhibit a significant variation.

We derive P_{sp} for GaN from the emission energies of excitons bound to different types of stacking faults (SFs). Employing micro-photoluminescence and cathodoluminescence spectroscopy, we observe emission lines from the intrinsic and extrinsic SFs in strain-free GaN micro-crystals. By treating the sheet charges associated with these SFs as a plate capacitor, we obtain P_{sp} from the observed transition energies. To support our model, we use self-consistent Poisson-Schrödinger calculations and density functional theory. This approach should be applicable also to other wurtzite semiconductors.

HL 80.6 Thu 12:30 ER 270

Electro- and cathodoluminescence microscopy of an InGaN/GaN LED structure based on semipolar {10-11} faceted GaN pyramids — •Martin Thunert[1,3], Sebastian Metzner[1], Thomas Hempel[1], Frank Bertram[1], Jürgen Christen[1], Clemens Wächter[2], Michael Jetter[2], and Peter Michler[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Universität Stuttgart, Institut Für Halbleiteroptik und Funktionelle Grenzflächen, Germany — [3]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

The luminescence distribution of an InGaN/GaN LED structure grown by selective MOVPE is analyzed by spatially and spectrally resolved electroluminescence (EL) and cathodoluminescence (CL) microscopy at room temperature. Self organized grown hexagonal GaN pyramids have been selectively overgrown by an InGaN/GaN MQW and subsequently metal contacts complete the LED structure. By CL measurements a homogeneous InGaN luminescence distribution over the semipolar side facets as well as a red shifted emission on the top and the corner of the pyramid was observed due to higher indium incorporation. In contrast, EL investigations of the identical pyramid show a continuous shift of the InGaN emission caused by inhomogeneous lateral current distribution. With increasing injection current the spatially averaged EL peak of the investigated pyramid reveals a very strong blueshift of 290 meV and a high increase in intensity indicating screening of the QCSE and filling of potential fluctuations or local inhomogeneities due to the formation of new current paths.

HL 80.7 Thu 12:45 ER 270

Optical and Structural Nano-Characterization of 62x InGaN MQW on GaN/AlInN DBR — •Marcus Müller[1], Gordon Schmidt[1], Peter Veit[1], Thomas Hempel[1], Frank Bertram[1], Jürgen Christen[1], Munise Cobet[2], Raphaël Butté[2], Jean-Françcois Carlin[2], and Nicolas Grandjean[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Institute of Condensed Matter Physics, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Using low temperature cathodoluminescence spectroscopy (CL) directly performed in a scanning transmission electron microscope (STEM) we present optical and structural properties of a 62x InGaN multi quantum well (MQW) on top of a AlInN/GaN distributed Bragg reflector (DBR). The structure was grown by MOVPE on a sapphire substrate using an optimized GaN buffer.

Direct comparison of the STEM images with simultaneously recorded CL mappings resolve the complete layer sequence, especially the MQW. In particular, the DBR layer stack is laterally and vertically homogeneous with sharp AlInN/GaN interfaces. CL mappings of the DBR show a luminescence at 352 nm originating exclusively from AlInN layers.

A dominant emission with a broad spectral range of the InGaN MQW can be observed. Low temperature mappings (T < 20 K) exhibit a systematic redshift of the spectral position of the MQW from the bottom (410 nm) to the top (460 nm), indicating strain relaxation, higher indium incorporation, and/or increasing quantum well thickness.

HL 80.8 Thu 13:00 ER 270

Cathodoluminescence microscopy and X-ray diffraction measurements of semipolar ($1\bar{1}01$) **GaN structures with InGaN SQWs on patterned Si(001) substrate** — •Christopher Karbaum[1], Frank Bertram[1], Sebastian Metzner[1], Jürgen Christen[1], Jürgen Bläsing[1], Alois Krost[1], Shujian Liu[2], Vitaliy Avrutin[2], Natalia Izyumskaya[2], Ümit Özgür[2], and Hadis Morkoç[2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Depart. of Electrical and Computer Engineering, VCU, Richmond, USA

The optical and crystalline properties of GaN bars with ($1\bar{1}01$) faceted surfaces were investigated using spatially and spectrally resolved cathodoluminescence (CL) at liquid helium temperature and high resolution X-ray diffraction (HRXRD), respectively. Triangular-shaped GaN bars with semipolar ($1\bar{1}01$) facets and an InGaN LED structure atop were grown on a structured Si(001) substrate exhibiting V-shaped grooves aligned along Si[110]. In the c^+-wing near the Si side facet the (D^0,X) emission of GaN is shifted to lower energies (3.451 eV) due to tensile strain. Intense CL from basal plane stacking faults (BSF) at 3.424 eV can be found in the c^--wing. The CL from the top view reveals intense and broad InGaN emission with an inhomogeneous distribution of the peak energy on the micrometer-scale and emission maxima centered at about 2.48 eV and 3.10 eV. The temperature dependence of the above mentioned CL will be presented. HRXRD measurements indicate an orientation disorder of about one degree of the GaN bars in each direction.

HL 80.9 Thu 13:15 ER 270

Cathodoluminescence study of InGaN quantum wells grown in different crystallographic orientations — •Sebastian Metzner[1], Frank Bertram[1], Holger Jönen[2], Torsten Langer[2], Uwe Rossow[2], Andreas Hangleiter[2], Stephan Schwaiger[3,4], Ferdinand Scholz[3], and Jürgen Christen[1] — [1]Inst. of Experimental Physics, Otto-von-Guericke-Univ. Magdeburg — [2]Inst. of Applied Physics, Technische Universität Braunschweig — [3]Inst. of Optoelectronics, University of Ulm — [4]now with OSRAM Herbrechtingen

The optical properties of very thin (∼1.5 nm), high indium containing (∼30 %) InGaN QWs which had been grown on conventional polar c-plane GaN/sapphire as well as on semi- and non-polar GaN templates were investigated using spatially, spectrally, and time-resolved cathodoluminescence microscopy. The non-polar QWs were heteroepitaxially grown on m-plane SiC, a-plane GaN/r-plane sapphire templates and homoepitaxially grown on freestanding m-plane GaN. For the semi-polar sample, a planar template of (11-22)GaN grown directly on pre-patterned (10-12)sapphire has been used. Therefore, the sapphire substrate was structured into trenches providing c-plane like sidewalls for the subsequent GaN growth. With the c-direction being inclined to the normal of the surface, the coalescence of GaN stripes forms a planar semipolar (11-22)GaN surface. Especially the local indium incorporation causing lateral fluctuations and the impact of the polarization fields on the recombination kinetics for the various orientations were analyzed in detail at liquid helium and room temperature.