HL 4: GaN: Preparation and Characterization I (mainly Optics)

Time: Monday 9:30–11:45 Location: EW 201

HL 4.1 Mon 9:30 EW 201

Study of site symmetry from Europium (Eu^{+3}) luminescence in Europium-implanted p-GaN — •Jayanta Kumar Mishra[1], Torsten Langer[1], Uwe Rossow[1], Kirill Trunov[2], Andreas Wieck[2], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Rare earth ions implanted into nitrides are promising for optoelectronic applications. In GaN, Europium is in a 3+ charge state. We studied the Eu^{3+} luminescence in Mg doped GaN. The most prominent luminescence is observed from the transition ${}^5D_0 \rightarrow {}^7F_2$. This transition further splits into several lines as the degeneracy of the ground state has been lifted. The contributions to this transition were found to be not only from a single Europium center but rather it is composed of different Europium centers in GaN. Considering the number of peaks from ${}^5D_0 \rightarrow {}^7F_2$ transition it would imply that Eu might not have occupied C_{3v} symmetry site, the Ga substitutional position.

We observed higher Eu^{3+} luminescence and more peaks for ${}^5D_0 \rightarrow {}^7F_2$ transition from Mg doped GaN:Eu than from undoped GaN:Eu. In Mg doped GaN more Eu sites contribute to ${}^5D_0 \rightarrow {}^7F_2$ transition.

The intensities of the split peaks of the ${}^5D_0 \rightarrow {}^7F_2$ transition are varying differently with temperature, which is further evidence for the presence of different Eu sites in Mg doped GaN:Eu.

HL 4.2 Mon 9:45 EW 201

Evidence for strain-induced defects as dominant nonradiative recombination centers in GaInN/GaN quantum wells — •Torsten Langer, Markus Göthlich, Andreas Kruse, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

Via temperature-dependent time-resolved photoluminescence spectroscopy we investigate the recombination dynamics in low-pressure MOCVD-grown GaInN/GaN single and multiple quantum well (SQW, MQW) structures. The temperature dependence of the intensities and decay times is used to separate the effect of radiative and nonradiative recombination mechanisms with the aim to understand the dominant loss mechanisms in green light emitters. We previously showed that there is a strong shortening of nonradiative lifetimes at 300 K from >4 ns down to ≈100 ps when the indium concentration exceeds 25% in 5-fold QW structures. In this contribution we show evidence that these limiting loss mechanisms for green emitters are caused by strain-induced defects: The strain energy density increases with the square of the lattice mismatch towards higher indium concentrations. We observe an exponential shortening of nonradiative lifetimes with increasing cumulative 2D strain energy density. This holds both for MQW and for SQW structures. A mere growth temperature related defect (e.g. point defects due to poor dissociation of ammonia at low T_{growth}) is not consistent with our data.

HL 4.3 Mon 10:00 EW 201

Angle resolved XPS for investigation of surface band-bending of III-nitrides — •Robert Metzner[1], Bernd Garke[1], Martin Feneberg[1], Stephanie Fritze[2], Armin Dadgar[2], Alois Krost[2], and Rüdiger Goldhahn[1] — [1]Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Abteilung Materialphysik — [2]Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Abteilung Halbleiterepitaxie

Due to surface donor states, III-nitrides suffer from Fermi level pinning at the surface leading to band-bending. To investigate this effect we establish angle resolved X-ray Photoelectron Spectroscopy (XPS) for determining size and direction of this fields. Variation of observation angles leads to different sampling depths and finally to a shift of the XPS peaks. With direction and size of these shifts, band-bending at the surface can be estimated. Samples which are expected to employ different surface band-bendings are investigated, especially c-oriented polar InN and GaN samples with various bulk doping levels. The measurements are finally compared to model calculations showing the principal applicability of the method.

HL 4.4 Mon 10:15 EW 201

Optical Investigation of Mg-doped AlGaN layers — •Sarah Osterburg[1], Martin Feneberg[1], María Fátima Romero[1], Bernd Garke[1], Jianchang Yan[2], Jianping Zeng[2], Junxi Wang[2], and Rüdiger Goldhahn[1] — [1]Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Abteilung für Materialphysik, Deutschland — [2]Semiconductor Lighting R&D Center, Institute of Semiconductors, Chinese Academy of Sciences. P.O. Box 912. Beijing 100083, P.R.China

The emission and absorption features of Al-rich Mg-doped $Al_xGa_{1-x}N$ films ($0.58 \leq x \leq 0.735$) around the band edge were determined by different experimental techniques. We employed Photoluminescence (PL), synchrotron-based Photoluminescence Excitation Spectroscopy, synchrotron-based Spectroscopic Ellipsometry (SSE) and conventional Spectroscopic Ellipsometry at several temperatures between 5 K and room temperature. The data were compared to get a detailed view about the interband transitions taking place in the range from 4 eV to 6 eV. We analyze the Stokes shift of the different samples and clarify the influence of statistical alloy fluctuations on carrier localization.

HL 4.5 Mon 10:30 EW 201

Systematic optical characterization of InAlN/GaN heterostructures with different In content — •María Fátima Romero, Martin Feneberg, Rüdiger Goldhahn, Pascal Moser, Armin Dadgar, and Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität, Magdeburg, Germany

The luminescence properties of $In_xAl_{1-x}N$/GaN heterostructures are systematically investigated as a function of the In content (6.7 %-20.8 %). The recombination between the electrons confined in the two-dimensional-electron-gas (2DEG) at the heterointerface, and the photoexcited holes in the GaN buffer is identified and analyzed. We find a systematic shift of the recombination with the In content from about 80 meV below the GaN exciton emission (for x=0.067), to only few meV with increasing In concentration. These results are compared with theoretical model calculations and can be understood with changing band alignment and polarization offset between AlInN and GaN.

HL 4.6 Mon 10:45 EW 201

Optical studies on doped and nominally undoped AlN layers — •Benjamin Neuschl[1], Martin Feneberg[2], María Fátima Romero[2], Rüdiger Goldhahn[2], Zhihong Yang[3], Thomas Wunderer[3], Jinquiao Xie[4], Seiji Mita[4], Anthony Rice[5], Ramón Collazo[5], Zlatko Sitar[5], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Group Semiconductor Physics, University of Ulm, Ulm — [2]Institut für Experimentelle Physik, Abteilung Materialphysik, Otto-von-Guericke-Universität Magdeburg, Magdeburg — [3]Palo Alto Research Center Inc., Palo Alto, California, USA — [4]HexaTech Inc., Morrisville, North Carolina, USA — [5]Department of Materials Science and Engineering, North Carolina State University, Raleigh, North Carolina, USA

We present optical spectroscopy studies in the near band edge region on high quality c-plane aluminum nitride (AlN) samples grown homoepitaxially by MOCVD on bulk AlN substrates. We analyze the near band edge region in detail by highly energy resolved photoluminescence, reflectivity and photoluminescence excitation spectroscopy. The linewidth of the bound exciton emission peak is as low as 500 μeV and demonstrates thus the excellent crystalline quality of the samples. Multiple sharp emission bands were found in the range from the free exciton to the bound excitons and their replicas. Correlations allow for a direct calculation of defect binding energies. Beyond, spectral contributions from excited exciton states and excitons with holes from the deeper valence band are analyzed.

HL 4.7 Mon 11:00 EW 201

Raman spectroscopic characterization of freestanding GaN layers — •Christian Röder[1], Frank Lipski[2], Cameliu Himcinschi[1], Jens Kortus[1], and Ferdinand Scholz[2] — [1]TU Bergakademie Freiberg, Institute of Theoretical Physics, Leipziger Str. 23, D-09596 Freiberg, Germany — [2]Ulm University, Institute of Optoelectronics, Albert-Einstein-Allee 45, D-89081 Ulm, Germany

In contrast to established growth techniques of other semiconductor materials, GaN technology is currently based on heteroepitaxy on foreign substrates like sapphire (0001), 6H-SiC (0001) or silicon (111). Due to the lattice mismatch and the difference in the thermal expan-

sion coefficients between GaN and substrates there are serious problems such as a large density of defects and structural imperfections as well as high induced stress. In this work we investigated several GaN layers separated from the sapphire substrate during cool-down from growth temperature. This allows to avoid thermal stress induced by mismatch of the thermal expansion coefficients. Using confocal Raman spectroscopy we obtained depth spatial information. We have chosen to analyze the position of the non-polar E_2(high) phonon mode which is only affected by strains. Assuming a planar stress state the determined wavenumber shifts were converted to stress values. Additionally, photoluminescence (PL) measurements were performed at 87 K being in good agreement with the Raman results.
The authors would like to thank the European Union (EFRE) as well as the Free State of Saxony for financial support within the ADDE project.

HL 4.8 Mon 11:15 EW 201

Local changes in the growth of the active region on semipolar templates produced by ELO — •Clemens Waechter, Julian Mack, Ulrich Rengstl, Elisabeth Koroknay, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen und Research Center SCoPE, Universität Stuttgart, Allmandring 3, 70569 Stuttgart

The growth on semipolar substrates is in the focus of material research as the active regions grown on semipolar substrates are less influenced by the Quantum Confined Stark Effect (QCSE). Since the production of native semipolar substrates is still very resource (and therefore cost) intensive, the growth on semipolar templates produced by epitaxial lateral overgrowth (ELO) on sapphire substrates offers a less expensive approach. Next to this, the properties of the grown template change the local growth conditions of the following layers. For example, the different strain situations for InGaN layers grown on pyramidal GaN templates lead to an increased Indium incorporation on the edges and apex. Also, depending on the locally available growth area, there are local changes in the growth conditions due to transport processes in the gas phase. For this contribution, pyramidal templates were produced by ELO. The size and density of the pyramids are controlled by the growth mask. After the growth, photoluminescence measurements (PL) were performed. In these measurements, we observe a strong influence of the pyramid density on the local emission spectra of the InGaN layer. The results of these measurements shall be presented and discussed in this contribution.

HL 4.9 Mon 11:30 EW 201

Structural and optical quality of GaN films grown on Sc_2O_3/Y_2O_3/Si(111) — •Lidia Tarnawska[1], Peter Zaumseil[1], Peter Storck[2], and Thomas Schroeder[1] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]SILTRONIC AG, Hanns-Seidel Platz 4, 81737 Munchen, Germany

Growth of GaN on Si wafers is intensively pursued to provide high quality cost effective GaN virtual substrates for electronic and optoelectronic applications. The direct deposition of GaN layers on Si is, however, a big challenge due to high reactivity of the Si surface with nitrogen, large lattice mismatch, and difference in thermal expansion coefficients. To solve the integration problems different semiconducting and insulating buffer layers were used in the past. We present a novel approach for the integration of GaN on Si(111) via Sc_2O_3/Y_2O_3 bilayer buffer system. Samples were prepared in a multichamber molecular beam epitaxy system on 4-inch Si(111) wafers. To obtain complete information on the quality of GaN/Sc_2O_3/Y_2O_3/Si(111) heterostructures in-situ (RHEED and XPS) and ex-situ (XRD, SEM, TEM, EDX and PL) measurements were performed.Our studies show that the oxides buffer approach provides a template of high structural quality for GaN overgrowth. XRD analysis prove that the growth of single crystalline, wurzite GaN layers are achieved. The main defects in 900 nm-thick GaN layers are threading dislocations, with density in the order of 10^{10} cm^{-2}, and stacking faults, resulting in cubic inclusions within the hexagonal matrix. 10K photoluminescence show a relatively sharp (FWHM of 22 meV) donor bound exciton line at 3.45 eV.