HL 55: GaN: preparation and characterization II

Time: Friday 10:30–13:45 Location: ER 164

HL 55.1 Fri 10:30 ER 164

Time dependent changes of the spontaneous polarization field in GaN investigated via UHV-cathodoluminescence and photoluminescence — •Martina Finke, Daniel Fuhrmann, Holger Jönnen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, 38106 Braunschweig

In GaN-based quantum well structures, the spontaneous and piezoelectric fields have a strong effect on the optical properties. The spontaneous field is normally screened by charged species on the surface. Since the spontaneous field counteracts the piezoelectrical field, a reduction of the quantum confined Stark effect (QCSE) indicated by a blueshift in the peak position of luminescence and an increased intensity is expected by descreening the spontaneous field. We use cathodoluminescence under well controlled surface conditions. This leads to metastable changes of the QW emission spectra as a function of irradiation dose, which was investigated via photo(PL)- and cathodoluminescence(CL) in an UHV environment. As samples we used various GaInN quantum well structures with or without AlGaN electron barrier and a variation in GaN cap thickness. The electron-beam produces electron-hole pairs in the sample, which can be separated by the spontaneous field. The holes created in the buffer layer reduce the spontaneous field, which can be observed as a redshift and decrease in intensity of emitted light. Simultaneous measurements of PL and CL allow us to study the screening and descreening of the spontaneous field due to electron-hole pairs at various electron-beam penetration depths.

HL 55.2 Fri 10:45 ER 164

Influence of Si and Mg on the growth mechanism of GaN nanorods on Si (111) — •Florian Furtmayr[1], Christoph Stark[1], Martin Stutzmann[1], Martin Eickhoff[1], Jordi Arbiol[2], and Joan Ramon Morante[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]TEM-MAT, Serveis Cientificotecnics, Universitat de Barcelona, Barcelona, CAT, Spain

The self assembled growth of GaN nanorods (NRs) on Si (111) substrates without the use of extrinsic catalysts by PAMBE under nitrogen-rich conditions is investigated. A thin amorphous silicon nitride layer is formed in the initial stage of the growth which impedes nucleation on the substrate surface at high growth temperatures, preventing the formation of a wetting layer. Investigation of the nucleation process by SEM reveals a nucleation diameter of (12 ± 3) nm and a non-linear dependence of the nucleation density on the growth time. The observation of the low lateral growth rate of 1.7 Å/min and the homogeneous NR height distribution indicate strong desorption from the NR sidewalls, which inhibits diffusion transport to the top surface. The incorporation of Mg leads to a decrease of the nucleation time and to an increase of the lateral growth rate. In the case of Si-doping the increase of the lateral growth rate is smaller, but the rod morphology is changed to widening cones for high Si fluxes. We discuss these results in terms of the growth kinetics and show that during growth the presence of a Ga droplet on the NR top surface is very likely. PL spectroscopy as well as HRTEM have been employed.

HL 55.3 Fri 11:00 ER 164

Optische Untersuchungen zum exzitonischen Transport in GaN Epitaxieschichten — •M. Noltemeyer[1], F. Bertram[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2] und O. Schulz[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]AZZURRO Semiconductors AG, Magdeburg

Es wurden optische Flugzeitmessungen an einer mittels MOVPE gewachsenen GaN Struktur mittels hoch orts- und zeitaufgelöster Kathodolumineszenz (KL) durchgeführt. Die aus der 1-dimensionalen Diffusionsgleichung hervorgehenden Transportkenngrößen sind die Diffusivität D und Beweglichkeit μ. Um diese zu bestimmen, wird aus ortsaufgelösten KL-Untersuchungen die Diffusionslänge und aus zeitaufgelösten KL-Untersuchungen die Lebensdauer von Exzitonen im GaN für eine jeweils feste Temperatur (7-300 K) bestimmt. Zur Bestimmung der Diffusion wird dazu die untersuchte Probe mit einer für die Lumineszenz undurchlässigen, e^-transparenten Ti-Maske versehen, über deren Kante der Intensitätsverlauf der Lumineszenz ausgewertet wird. Für eine Temperatur von 7 K wurde so eine Lebensdauer von 190 ps und eine Diffusionslänge von etwa 80 nm bestimmt. Bei Raumtemperatur liegen diese Werte im Bereich von 70 ps und 120 nm. Hieraus ergibt sich eine Beweglichkeit von etwa 500-200 cm^2/Vs für 7-300 K. Des Weiteren wird der Einfluss von Streumechanismen auf die Beweglichkeit diskutiert.

HL 55.4 Fri 11:15 ER 164

In-situ investigation on the surface electronic structure of GaN(0001)-2×2 — •Richard Gutt, Pierre Lorenz, Marcel Himmerlich, Juergen A. Schaefer, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany

The surface electronic structure of GaN(0001)-2×2 surfaces has been studied *in-vacuo* directly after growth. GaN thin films have been deposited on 6H-SiC(0001) by plasma assisted molecular beam epitaxy. After growth, the samples were cooled down in nitrogen plasma leading to a 2×2 reconstruction measured by reflection high energy electron diffraction. Further characterization by atomic force microscopy as well as *ex-situ* X-ray diffraction and photoluminescence proves a high sample quality. The presented X-ray photoelectron spectroscopy data show stoichiometric GaN with no evidence of contaminations and a bulk valence band structure in excellent agreement with recently published DFT calculations [1]. Ultraviolet photoelectron spectroscopy detects two additional surface states, 2 eV and 3 eV below E_F. The 2×2 reconstruction is a necessary condition for the occurrence of the state at 2 eV. Storage under typical UHV conditions ($< 2 \cdot 10^{-10}$ mbar) for several hours results in a disappearance of both the reconstruction and the 2 eV state, indicating an extremely high surface reactivity. In addition, a very high reactivity towards oxygen and water is found and will be discussed in another contribution.

[1] D. Segev, C.G. Van de Walle, J. Cryst. Growth 300 (2007) 199

HL 55.5 Fri 11:30 ER 164

Properties of GaN-based thin film LEDs grown by MOVPE in dependence on the Si substrate orientations — •F. Schulze[1], A. Dadgar[1,2], S. Fritze[1], J. Blaesing[1], M. Wieneke[1], A. Diez[1], and A. Krost[1,2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University, 39016 Magdeburg, Germany — [2]Azzurro Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg, Germany

The use of silicon as a substrate for GaN-based optoelectronic devices offers many advantages in terms of cost reduction and large size availability. For an optimization of the optical output performance, a subsequent delamination of the silicon substrates may be very helpful due to the absorbing properties of silicon in the range of visible light. Mechanical abrasion and chemical etching are a usual approach to obtain thin film LEDs on specular carriers with a good thermal conductivity. However, the crystallographic orientation of silicon strongly influences the abrasion resistance and the chemical etching rate. Therefore, GaN based LED structures were grown by MOVPE on different substrate orientations as Si(111), Si(011), and Si(001). We report on the quality of GaN-based devices in dependence on these surfaces. The influence of the thinning process will be discussed comparing the crystallographic properties of the device structures analysed by x-ray diffraction techniques. Furthermore, the impact of the different surface orientations on optical properties of the LEDs were analysed by electro- and cathodoluminescence.

HL 55.6 Fri 11:45 ER 164

Impact of seed and buffer layer growth on the quality of AlGaN on Si(111) — •P. Saengkaew, A. Diez, M. Noltermeyer, J. Blaesing, B. Bastek, F. Bertram, A. Dadgar, J. Christen, and A. Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, 39106, Magdeburg, Germany

AlGaN with its bandgap ranging from 3.4 to 6.3 eV, is a very attractive material to fabricate UV photodetectors and UV LEDs. For efficient devices, high-quality AlGaN films are required. Growing high-quality AlGaN grown on Si (111) by MOVPE, the lattice mismatch and different thermal expansion of them have to be overcome. Not only the growth parameters of AlGaN but also the seeding and buffer layers play an important role to improve the quality of AlGaN grown on them. Conventionally AlN layers are employed as a seeding layer to grow Al0.1Ga0.9N on Si. We investigated the impact of the growth

seeding parameters as growth temperature, pressure, time, and V/III ratio of the AlN seeding and buffer layers on the crystalline quality and strain state of AlGaN by high-resolution X ray diffraction, AFM, and CL .Best values achieved for the simple AlN / AlGaN structure are 0.33 degree and 0.55 degree for the (0002) and (10-10) omega scans, respectively. A further improvement can be achieved by introducing an AlN based superlattice between the seeding and AlGaN buffer layer. For the best structure we achieve values for the (0002) and (10-10) omega scans of 0.15 degree and 0.39 degree, respectively.

15 min. break

HL 55.7 Fri 12:15 ER 164

Luminescence Characterization of GaN/InGaN Micro-disk Structures on Silicon — •A. Franke[1], F. Bertram[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2], K. X. Lin[3], S.L. Teo[3], and S. Tripathy[3] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Azzurro Semiconductors AG, Magdeburg, Germany — [3]Institute of Material Research and Engineering, Singapore 117602

The most common way to fabricate vertical surface emitting lasers like micro-cavities lasers uses DBRs on both sides of the cavity. An alternative approach to achieve an optical confinement is the fabrication of free standing micro-disk emitters. The investigated micro-disk sample consists of a standard MOVPE grown GaN LED structure with InGaN quantum wells as the active region. The 3 μm thick structure was patterned into 300 μm circular columns using dry and subsequently wet etching to remove and undercut the silicon surrounding the micro-disk. To investigate the optical properties we use micro-photoluminescence (PL) and cathodoluminescence spectroscopy at 4 K. The local spectra exhibit two emission peaks: a dominant emission at 2.66 eV related to the InGaN/GaN QWL and at 3.46 eV stemming from the GaN emission. PL mapping across the surface of the disk shows a statistical distribution for the GaN emission. In contrast, for the QWL emission a symmetric circular pattern with a 5 – fold symmetry of alternating 2.69 eV emission interrupted by a 2.66 eV emission can be observed.

HL 55.8 Fri 12:30 ER 164

Degradation of InGaN quantum wells during high temperature growth steps — •Holger Jönen, Daniel Fuhrmann, Daniel Dräger, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig

The strong decrease of the internal quantum efficiency (IQE) of GaN based light emitters for longer wavelengths is well known. As possible reason for this behaviour the stronger piezoelectric field and a reduced material quality with increasing In content are often discussed. Furthermore, we found that with increasing In content the thermal stability of the layers becomes a critical issue. In this contribution we will focus on the thermal stability of InGaN QWs in LED structures grown by MOVPE. The quantum well growth is followed by a GaN spacer, AlGaN electron barrier and GaN capping layer. High temperatures are unavoidable during the MOVPE growth of these layers (e.g. for efficient Mg doping), in contrast to the low temperatures needed for high In concentration ($x_{\mathrm{In}} > 30\%$) in the quantum wells. Ramping the growth temperature is also commonly used for the barriers in MQW structures to improve the interface quality of the layers. The influence of such high temperature growth processes on the optical and structural properties of InGaN quantum wells is studied in detail. For this purpose we varied the growth parameters for the individual layers and found that the growth of the spacer layer is most critical and that the thermal budget of the GaN cap must be minimized.

HL 55.9 Fri 12:45 ER 164

Spatial distribution of structural defects in GaN — •I. Tischer[1], M. Schirra[1], M. Feneberg[1], G.M. Prinz[1], R. Sauer[1], K. Thonke[1], T. Wunderer[2], J. Hertkorn[2], F. Lipski[2], P. Brückner[2], F. Scholz[2], A. Chuvilin[3], U. Kaiser[3], I. Knoke[4], and E. Meissner[4] — [1]Institut für Halbleiterphysik, Universität Ulm — [2]Institut für Optoelektronik, Universität Ulm — [3]Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm — [4]Abt. Kristallzüchtung, FHG-IISB, Erlangen

Non-polar and semi-polar GaN facets with reduced piezo-electric fields are promising substrates for high-efficiency optoelectronic devices. Due to the lower material quality compared to c-plane GaN these substrates typically show luminescence lines at 3.30 and 3.41 eV which are related to structural defects such as stacking faults. Here we study selectively overgrown triangular shaped GaN stripes with stable $\{1\bar{1}01\}$ facets. They were purposely grown under non-optimal conditions so as to show the defect luminescence strongly.

Spatially resolved cathodoluminescence including monochromatic CL images and CL line scans of sample cross sections and of $\{1\bar{1}01\}$ facets yield the intensity distribution of the 3.41 and 3.30 eV lines. Correlation of CL results with those from TEM support literature reports that the 3.41 eV line is related with basal plane stacking faults. The 3.30 eV defect is found to appear frequently in the close vicinity of the 3.41 eV defects but not exclusively there. Details of the spatial distribution together with CL measurements at varying temperatures towards the electronic nature of the defect will be discussed.

HL 55.10 Fri 13:00 ER 164

The role of V-shaped pits in (AlGaIn)N LED structures — •Lars Hoffmann, Heiko Bremers, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, Technical University of Braunschweig, Germany

Despite the high density of threading dislocations generally found in group-III-nitride semiconductors, the light emission efficiency of GaInN/GaN quantum well (QW) structures is exceptionally high at room temperature. Therefore, nonradiative recombination processes of charge carriers in a QW must be suppressed. This can be explained by our V-shaped pit model, where every threading dislocation is decorated with a hexagonal V-shaped pit. The QWs inside a V-shaped pit are thinner compared with the QWs on c-plane. Thus the effective band gap is significant larger and the charge carriers will be kept away from the threading dislocations. In our GaInN/GaN QW structures with high internal quantum efficiency we find in TEM well-controlled V-shaped pits around the dislocations. In order to clarify the situation for commercial devices we investigated blue and green LEDs from various suppliers. We find that V-shaped pits are decorating virtually all threading dislocations in the QW region. This indicates that suppression of nonradiative recombination by V-shaped pits may be a desirable mechanism for achieving high light emission efficiency. We also discuss the effect of pits in GaN/AlGaN QW structures, where the typical emission efficiency is much lower than for GaInN/GaN structures.

HL 55.11 Fri 13:15 ER 164

Influence of anisotropic strain on excitonic transitions in a-plane GaN films — Marcus Röppischer[1], •Carsten Buchheim[1], Rüdiger Goldhahn[1], Gerhard Gobsch[1], Armin Dadgar[2], Matthias Wieneke[2], Jürgen Bläsing[2], and Alois Krost[2] — [1]Institute of Physics, Technical University Ilmenau, PF100565, 98684 Ilmenau, Germany — [2]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Universitätsplatz 2, 39016 Magdeburg, Germany

GaN films on non- or semipolar substrate surfaces are important for light emitters in the ultraviolet spectral region, because on these substrates the polarisation induced electric fields are minimized. With the optical axis in the sample plane, one has to account for both, the ordinary and the extraordinary dielectric function (DF) for the design of devices. Different thermal expansion coefficients and lattice mismatch for the two in-plane directions result in anisotropic in-plane stress. As a consequence the transition energies of the A-, B- and C-exciton are unequally shifted and the oscillatory strengths are changed. In this work the ordinary and extraordinary components of the DF of a-plane GaN films on r-plane sapphire are determined by spectroscopic ellipsometry. The optical selection rules are verified. The results are confirmed by polarisation dependent photoreflectance measurements in which the excitonic transition energies were determined for differently strained samples. Different oscillatory strengths are observed for the incident light polarized parallel and perpendicular to the optical axis. The experiments are supported by 6×6 $\vec{kp}$ band structure calculations.

HL 55.12 Fri 13:30 ER 164

SNOM studies of GaInN/GaN and GaN/AlGaN QW structures — •Peter Clodius, Frank Hitzel, Daniel Fuhrmann, Carsten Netzel, Holger Jönen, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technical University of Braunschweig, Institute of Applied Physics

Blue or green light emitting GaInN/GaN-based quantum well (QW) structures achieve quite high internal quantum efficiencies (IQE) at room temperature. In contrast In-free QW-structures based on GaN/AlGaN emitting in the UV-range suffer from low IQE values. This is caused by the high density of defects in this material and non-

radiative recombination occuring at these defects. We present studies of photoluminescence with a high spatial resolution, performed on GaInN/GaN and GaN/AlGaN QW structures. The measurements were performed using a scanning near-field optical microscope (SNOM). The measurements on the GaInN/GaN QWs show that nearly every line defect in these structures is decorated by a so-called V-pit (an inverted hexagonal pyramid with $(10\bar{1}1)$ planes as sidewalls). On the sidewalls of these pits the growth rate of the QW is reduced, which leads to thinner QWs on the facets than on the c-plane. These thinner QWs form a barrier which prevents carriers from nonradiative recombination at the line defects. We investigate short wavelength GaInN/GaN and GaN/AlGaN structures with the aim of clarifying whether such pits play a role in such structures as well.