HL 64: GaN: Preparation and Characterization III

Time: Wednesday 16:30–18:30 Location: EW 202

HL 64.1 Wed 16:30 EW 202

Overcoming the limiting factors to achieve green lasing — •Andreas Kruse, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

Group-III nitrides based materials have attracted great interest for optoelectronic devices such as light emitting diodes (LEDs) and laser diodes (LDs). However, for long wavelength emitting LEDs and LDs many challenges need to be overcome to improve their device performance. We focus our study on investigations of limiting factors of optical gain in InGaN-based laser structures by extending the emission wavelength to the green spectral range. For this purpose we carry out optical gain measurements using the variable stripe length method (VSLM) on laser structures grown on c-plane substrates (sapphire and GaN) with various parameters in the active zone (e.g. QW thickness, numbers of QWs, indium content). After optimization of structural parameters and growth conditions we have been able to achieve positive optical gain above 510 nm with low waveguide losses for our double quantum well (DQW) laser structures. The detailed study of optical gain behaviour reveals a small variation of inhomogeneous broadening of gain spectra with decreasing growth temperature. Additionally, we observe an influence of piezoelectric field on the modal gain amplitude with increasing indium content. Moreover, we discuss the impact of the nonradiative recombination processes on the optical gain. We observe a correlation between defect recombination and the inhomogeneous broadening, associated with the increased strain at high In content.

HL 64.2 Wed 16:45 EW 202

Impact of silane on heteroepitaxial growth and properties of a-plane GaN — •Matthias Wieneke, Thomas Hempel, Hartmut Witte, Antje Rohrbeck, Peter Veit, Jürgen Bläsing, Armin Dadgar, Jürgen Christen, and Alois Krost — Otto-von-Guericke-Universität Magdeburg, FNW/IEP, Universitätsplatz 2, 39106 Magdeburg

Silane is a well-established Si precursor to achieve n-type doped GaN layers. In the case of a-plane GaN layers we have demonstrated earlier a significant reduction of basal plane stacking faults to less than 10^4 cm^{-1} by using a silane flow rate to get a nominal Si doping level in the range of 10^{20} cm^{-3} [1]. By varying the silane flow rate as well as other growth parameters, e. g., growth temperature, V/III ratio, reactor pressure, their influences on the morphological and micro structural properties of Si doped a-plane GaN were investigated. Furthermore, we also found an evident dependency on the buffer layer thickness. Here heavily Si doped GaN grown on an about 1.5 μm thick coalesced GaN buffer layer exhibits no defect reduction. Based on these results some possible causes of the successful BSF reduction, e.g., selective etching or SiN nanomasking, will be discussed. [1] Wieneke et al., Physica Status Solidi B 248, 578 (2011)

HL 64.3 Wed 17:00 EW 202

In-situ Measurements and X-ray Diffraction of AlInN/AlGaN Distributed Bragg Reflectors — •Christoph Berger, Jürgen Bläsing, Armin Dadgar, Alexander Franke, Thomas Hempel, Jürgen Christen, and Alois Krost — Otto-von-Guericke-Universität Magdeburg

We report on the MOVPE-growth of lattice-matched $Al_{0.85}In_{0.15}N$/ $Al_{0.2}Ga_{0.8}N$ distributed Bragg reflectors (DBRs) with up to 45 layer pairs. These DBRs are suited as bottom mirrors in GaN-based microcavities for the realization of vertical cavity surface emitting lasers or even polariton lasers, which are working in the strong coupling regime. For the latter high Q-factors of the microcavities are prerequisite, thus the mirrors need to exhibit reflectivities above 99 %. To achieve such values, a high number of mirror pairs is required. Thus, the structures become vulnerable to relaxation processes or crack formation. Furthermore, the mirrors have to be laterally and vertically homogeneous with smooth interfaces. To evaluate the strain-state and the smoothness already during growth, the process was monitored by in-situ curvature and reflectance measurements. Subsequently, the Bragg reflectors were investigated by different methods of X-ray diffraction (XRD). This included high resolution XRD, asymmetrical reciprocal space mapping, as well as experiments under grazing incidence and in transmission geometry. From these various measurements, it could be ascertained that the crack-free structures are grown fully strained and possess a high structural and optical quality, enabling reflectivities of 99 % in the near UV region.

HL 64.4 Wed 17:15 EW 202

Pulsed growth of InN and $Ga_{1-x}In_xN$ with large x by MBE — •Andreas Kraus, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technische UniversitätBraunschweig, Institut für Angewandte Physik, Mendelssohnstraße 2, 38106 Braunschweig

High In content GaInN is still a material which gains much attention due to its outstanding optical and electrical properties. Because of the large lattice mismatch and differences in bond strength to nitrogen high quality material is very hard to achieve.
To get a deeper understanding of the growth kinetics of this material system, InN and GaInN layers were grown on GaN templates by radio frequency molecular beam epitaxy using a pulsed growth mode. The approximately 100 nm thick InN layers were sequentially grown in 352 periods of $c_0/2$ In and N followed by a few seconds where only nitrogen reaches the surface. Hereby the time of nitridation was varied. The growth was monitored in-situ by reflection high energy electron diffraction and by optical reflectometry as well as ex-situ by atomic force microscopy and high resolution X-ray diffraction. Comparing the samples grown with different nitridation times during every In pulse, the samples with the longest nitridation time exhibit best structural quality in terms of XRD rocking widths and surface roughness measured by atomic force microscopy.
The results of these experiments were used to realize $Ga_{1-x}In_xN$ layers with x≈0.9. Also superlattice structures, where nominally 2 nm GaN are followed by $c_0/2$ InN, were grown. However, XRD analysis reveals that instead of pure InN, $Ga_{1-x}In_xN$ with x ≈ 0.3 is obtained.

HL 64.5 Wed 17:30 EW 202

Determination of indium content in semipolar GaInN multiple quantum well samples using XRD — •Heiko Bremers[1], Holger Jönen[1], Uwe Rossow[1], Stefan Schwaiger[2], Ferdinand Scholz[2], and Andreas Hangleiter[1] — [1]TU Braunschweig, Institute of Applied Physics, Braunschweig — [2]Universität Ulm, Institute of Optoelectronics, Ulm

X-ray diffraction is one of the most important tools to determine the structural properties of solids. In the III-nitrides it has been used very successfully to determine compositions of ternary layers in polar as well as in non-polar samples. In semipolar samples additional shear stresses result in a change of the angles between base vectors. In order to quantify these changes we have to rotate the tensors describing Hookes law to a new coordinate system S'. By using the fact that in growth direction the normal stress equals zero, one in principle is able to determine the composition.

For the example of $(11\bar{2}2)$ semipolar samples we will discuss the difficulties in really determining the composition. The properties of this particular orientation can be achieved by a rotation around the m-axis by an angle of approximately 58.4°. The rotation changes the base system S (x, y, z) from $[2\bar{1}\bar{1}0]$, $[01\bar{1}0]$, $[0002]$ direction towards the new system S' (x', y', z') $[\bar{1}\bar{1}23]$, $[01\bar{1}0]$, $[2\bar{1}\bar{1}2]$ direction. Unfortunately there are no lattice planes available to directly measure the strain component in the new x-direction. We will discuss a way out of this dilemma by using relations between the old and new base system.

HL 64.6 Wed 17:45 EW 202

STEM and XRD investigations of ultra thin GaInN/GaN quantum wells with high indium content — •Lars Hoffmann[1], Heiko Bremers[1], Holger Jönen[1], Uwe Rossow[1], Thorsten Mehrtens[2], Marco Schowalter[2], Andreas Rosenauer[2], and Andreas Hangleiter[1] — [1]TU Braunschweig, Institute of Applied Physics, Braunschweig, Germany — [2]Universität Bremen, Institute of Solid State Physics, Bremen, Germany

While GaN-based blue light emitting devices exhibit exceptionally large internal quantum efficiencies (up to 90% at room temperature) their green counterparts quickly become less efficient at longer wavelength ("green gap"). Using Transmission Electron Microscopy (TEM) and X-ray diffraction (XRD) we have studied ultrathin (< 2nm) quantum well (QW) structures with high indium content suitable for blue-green laser and light emitting diodes. We investigate the homogeneity of indium incorporation into the quantum well and its interface roughness. In order to obtain high indium content quantum wells we need to decrease the growth temperature, leading to poorer optical and structural quality of the GaN barriers. In our XRD and TEM measurements we observe in some cases that indium is also incorporated into the barriers. Depending on growth conditions, we observe an indium tail or even step-like structures in the barriers, caused by excess indium supplied during quantum well growth. Therefore the temperature profile and the gallium/indium ratio during growth need to be optimized to avoid indium segregation and unwanted incorporation into the barriers.

HL 64.7 Wed 18:00 EW 202

Optimierung der Präparation von GaN-basierten Proben mittels Niedrigenergie-Ionendünnung für (S)TEM — •Stephanie Bley[1], Thorsten Mehrtens[1], Andreas Rosenauer[1] und Satyam Parlapalli[2] — [1]AG Elektronenmikroskopie, Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Deutschland — [2]Institute of Physics, Bhubaneswar 751005, India

Die Präparation von TEM-Proben mittels hochenergetischer Ionenstrahlen (Energie > 5keV) bewirkt die Bildung von Punktdefekten bzw. die Amorphisierung der Probenoberfläche. Die amorphe Oberflächenschicht führt im TEM zu einem fleckigen, inhomogenen Bildkontrast, wodurch eine quantitative Analyse der Probe erschwert wird. Anhand von (S)TEM-Untersuchungen an GaN-basierten Proben wird gezeigt, dass durch die Präparation mittels Niedrigenergie-Ionendünnung (Energie < 1keV) die amorphe Oberflächenschicht deutlich reduziert und der Bildkontrast verbessert wird. Dazu werden die experimentell ermittelten Daten für verschiedene Ionendünnungsverfahren mit simulierten Daten (Monte Carlo Simulation, SRIM) verglichen. Außerdem werden Dickenprofile der Probe durch den Vergleich der normierten Intensität aus STEM-Bildern mit einer durch die Frozen Lattice-Methode simulierten Referenzintensität erzeugt. Anhand der Änderung der Probendicke vor und nach der Behandlung mit niederenergetischen Ionen wird die Ätzrate bestimmt.

HL 64.8 Wed 18:15 EW 202

Bestimmung der Gitterparameter in orthorombisch verzerrten semipolaren und unpolaren Wurtzitstrukturen — •Martin Frentrup, Tim Wernicke, Markus Pristovsek und Michael Kneissl — TU Berlin, EW 6-1, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

Heteroepitaktisch gewachsene Nitridhalbleiterschichten mit semi- oder nichtpolarer Orientierung werden durch anisotrope Gitterfehlanpassungen rhomboedisch verzerrt. Dies macht die exakte Bestimmung der Gitterparameter und somit der Stöchiometrie in solchen Schichten mit hochauflösender Röntgenbeugung schwierig.

Wir haben ein Model entwickelt, das diese orthorombische Verzerrung berücksichtigt und mit dessen Hilfe es möglich ist die Gitterparameter und die Verzerrung an Hand nur weniger Röntgenreflexe zu bestimmen. Durch günstige Wahl der Koordinatenachsen und Ausnutzung von Symmetrien konnten wir die Zahl der unabhängigen Parameter von sechs auf vier reduzieren. Unter der Annahme, dass die Verzerrung nur zu einer kleinen Abweichung von der idealen Wurtzitstruktur führt, lässt sich die verallgemeinerte Gleichung für den Netzebenabstand d_{hkl} linearisieren. Dadurch reichen bereits vier voneinander unabhängige XRD-Reflexe aus, um das Gleichungssystem zu lösen und die vier Parameter eindeutig zu bestimmen. Hieraus können mit Hilfe unseres Models weitere Informationen zur Kristallschicht, wie die Gitterfehlanpassug, der Verspannungszustand und die stöchiometrische Zusammensetzung berechnet werden.