HL 27: GaN: preparation and characterization I

Time: Wednesday 9:30–13:00 Location: BEY 81

HL 27.1 Wed 9:30 BEY 81

SNOM measurements of GaInN/GaN and GaN/AlGaN light emittting quantum well structures — •Peter Clodius, Holger Jönen, Lars Hoffmann, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technische Universität Braunschweig, Institut für Angewandte Physik, Braunschweig

Today Group-III-Nitride based light emitting quantum well (QW) structures are used in a wide range of applications, from near green to blue and (ultra)violet LEDs and LDs. The high efficiency of the GaInN/GaN-QW structures in the blue and violet region is still a matter of discussion. Our explanation is based on the fact that, in high efficiency structures, nearly every dislocation in growth direction for c-plane surfaces, is decorated by a so called V-pit (hexagonal V-shaped structures with $(10\bar{1}1)$ sidewalls). On these sidewalls the growth rate of the QWs is reduced, compared to the growth on c-plane, which leads to thinner QWs with an increased bandgap, causing a potential which prevents charge carriers from reaching possible centers of non-radiative recombination at these defects. Recent SNOM-measurements showed a high energy emission from areas surrounding these pits even at room temperature. In this talk we will present the results of further experiments, trying to clarify the origin of this unusual emission. We will also present first measurements of GaN/AlGaN based QW structures emitting in the ultraviolet, investigating if V-pits play a role in these structures as well.

HL 27.2 Wed 9:45 BEY 81

Time-resolved measurements on blinking dots in InGaN/GaN quantum wells — •Anne Kuhnert[1], Clemens Vierheilig[1], Tobias Meyer[2], and Ulrich T. Schwarz[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany

In some InGaN/GaN quantum well samples the quantum well photoluminescence under cw laser excitation is not homogenously distributed, but shows dots with different emission wavelengths. The colors of the dots vary from red over green to blue. Some of these dots show a switching behavior between two intensity levels. The timescale of the blinking phenomenon is of the order of 10^{-2} s up to some seconds. At low excitation densities the time slices of on-state and off-state are mainly the same. With increasing excitation density the percentage of the off-state decreases and at high excitation intensities the dots stay permanently on. The photoluminescence of these samples is measured with a confocal microscope with high spatial resolution. The signal is detected time resolved by a photomultiplier tube.

HL 27.3 Wed 10:00 BEY 81

Korrelation von Raster-LBIC (Light Beam Induced Current), μ-EL und μ-PL-Spektroskopie an InGaN-MQW LEDs auf Silicon-On-Insulator (SOI)-Substrat — •T. Fey[1], L. Reissmann[1], J. Christen[1], A. Dadgar[1,2], A. Krost[1,2], V.K.X. Lin[3], S.L. Teo[3] und S. Tripathy[3] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität, 39106 Magdeburg — [2]AZZURRO Semiconductors AG, Magdeburg — [3]Institute of Materials Research and Engineering, 3 Resarch Link, 117602 Singapore

Es wurden MOVPE-gewachsene InGaN-MQW LEDs auf SOI-Substrat mittels LBIC, μ-EL- und μ-PL-Spektroskopie untersucht. Der Messaufbau besteht aus einem optischen Mikroskop mit motorgetriebenem xy-Tisch und einem 500 mm Spektrometer mit N_2 gekühlter CCD Kamera. Die gesamte LED Oberfläche von 300x300 μm^2 wurde mit einer Schrittweite von 3 μm gerastert. Die Spektren zeigten klar Fabry-Perot-(FP)-Moden, welche Schichtdickeninterferenzen darstellen. Die PL-Peakwellenlänge ist im Vergleich zur EL-Peakwellenlänge für alle Ströme um ca. 35 nm blauverschoben. Außerdem zeigt sich eine Verschiebung der Peaks der FP-Interferenzen unter Strominjektion gegen über der optischen Anregung. Daraus lässt sich eine Veränderung des Brechungsindex aufgrund veränderter Ladungsträgerdichte ableiten. Die Intensitätsverteilungen der PL und EL unterscheiden sich deutlich. Jedoch kann eine eindeutige mikroskopische Korrelation zwischen LBIC und EL festgestellt werden. Das LBIC-Signal dient der Visualisierung lokaler Unterschiede der elektrischen Eigenschaften der LED sowie deren Einfluss auf die EL-Intensitätsverteilung

HL 27.4 Wed 10:15 BEY 81

Electro-optical properties of InGaN-based LED structures on the sub-μm length scale — •Clemens Vierheilig[1], Ulrich T. Schwarz[1], Nikolaus Gmeinwieser[2], Ansgar Laubsch[2], and Berthold Hahn[2] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany

The optical properties of InGaN-based quantum wells show strong fluctuations on different length scales. With pure optical measurements of the photoluminescence signal of the quantum wells it is not possible to separate effects of fluctuations of the quantum well width or indium content from local nonradiative recombination of the excited charge carriers. For this reason, we perform photoluminescence measurements with high spatial resolution (μPL) under external bias in combination with measurements of the laser beam induced photocurrent (LBIC). The strong fluctuations of the PL intensity on a length scale of several μm are also observed in the spectral position of the quantum well and the LBIC under reverse external bias. This indicates fluctuations of the quantum well width. An additional strong intensity fluctuation of the PL intensity on the sub-μm length scale is not observed in the LBIC signal. These short-range fluctuations are interpreted in terms of local nonradiative recombination.

15 min. break

HL 27.5 Wed 10:45 BEY 81

Structure and electronic properties of dislocations in GaN — •Philipp Ebert[1], Lena Ivanova[2], Svetlana Borisova[1], Holger Eisele[2], Ansger Laubsch[3], and Mario Dähne[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [3]OSRAM Opto-Semiconductors GmbH, 93055 Regensburg, Germany

Group-III nitrides developed rapidly toward the materials of choice for green to ultraviolet optoelectronics. Unfortunately, GaN substrates are still suffering from high dislocation densities, far above that of zincblende type III-V semiconductor substrates. This presence of high dislocation densities is detrimental for optoelectronics, because dislocations can act as recombination centers. Therefore, we investigated the type, spatial distribution, the projected line direction, and electronic properties of dislocations in n-type GaN by scanning tunneling microscopy. The dislocations were found to form localized bunches of entangled non-parallel dislocation lines. Within these bunches perfect dislocations with $a/3\left\{11\bar{2}0\right\}$ Burgers vectors were uncharged, while Shockley partials with $a/3\left\{11\bar{2}0\right\}$ Burgers vector and the related intrinsic type-2 stacking fault were negatively charged. The charges are traced to different charge transfer levels associated to the particular core structure. The observations suggest that the dissociation of dislocations may be responsible for the insertion of detrimental gap states in n-type GaN.

This work is supported by the DFG through SFB 787 and Eb 197/3-1.

HL 27.6 Wed 11:00 BEY 81

Sub micrometer photoluminescence fluctuations in green light emitting InGaN/GaN quantum wells — •Julia Danhof[1], Clemens Vierheilig[1], Ulrich Theodor Schwarz[1], Tobias Meyer[2], Matthias Peter[2], Berthold Hahn[2], Markus Maier[3], and Joachim Wagner[3] — [1]Institute for Experimental and Applied Physics, University of Regensburg, D-93040 — [2]Osram Opto Semiconductors GmbH, Leibnizstr. 4, D-95055 — [3]Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Tullastrasse 72, D-79108

For green light emitting InGaN/GaN multiple quantum well samples a correlation of surface morphology and photoluminescence measurements has been established by comparing atomic force microscopy images with PL maps. Of main interest here are threading dislocation. Three samples with nominally the same quantum well (QW) structures but different substrates and threading dislocation densities are compared. Emitted wavelengths lay between 510 nm and 520 nm. Green light emitting QWs usually show a meandering structure on micro photoluminescence maps. For the sample the lowest dislocation density pinhole scans were performed in order to address the issue of charge carrier diffusion length within the meandering structure.

HL 27.7 Wed 11:15 BEY 81

Screening Dynamics of the Spontaneous Polarisation Field in GaInN/GaN Quantum Well Structures — •Martina Finke, Daniel Fuhrmann, Holger Jönen, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institut für Angewandte Physik, Braunschweig

In GaN-based quantum well structures, the spontaneous and piezoelectric fields lead to the quantum confined Stark effect, which causes a decrease in the effective bandgap and a reduction of the oscillator strength and therefore the intensity of emitted light. The piezoelectric polarization was measured experimentally by various methods, but the spontaneous field as a bulk property is usually screened by charged species on the surface and was not accessible to direct experimental determination up to now. We use GaInN quantum wells as a sensitive probe for the magnitude and changes of the spontaneous field. The samples are investigated by cathodoluminescence and photoluminescence in an UHV environment. One the one hand the electron beam activates the spontaneous field by removal of charges at the surface. On the other hand, electron hole pairs generated in the bulk tend to screen the field. The complex dynamics are observed as a shift of spectral position and an intensity variation. By variation of electron beam penetration depth, cap thickness and doping level we study the different time dependent behaviour in screening and descreening of the spontaneous field.

HL 27.8 Wed 11:30 BEY 81

Spatially resolved X-ray diffraction measurements on AlInN/GaN distributed Bragg reflectors — •Christoph Berger, Pascal Moser, Jürgen Bläsing, Armin Dadgar, Thomas Hempel, and Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Deutschland

As a high-index-contrast and high-band gap material, which can be grown lattice-matched on GaN, AlInN is very promising for the fabrication of GaN-based optoelectronic devices. In vertical-cavity surface-emitting lasers (VCSELs) very high reflectivities are needed, which can be achieved by distributed Bragg reflectors (DBRs). For that purpose the layers need to have a quarter wave thickness and good crystalline quality. The DBRs were grown on GaN by metalorganic vapor phase epitaxy (MOVPE) on c-plane sapphire substrates and characterized by different X-ray diffraction (XRD) techniques, as symmetrical $\theta/2\theta$-scans, grazing-incidence in-plane diffraction (GIID) and reciprocal space mapping. Layer thicknesses and concentrations were determined and it could be shown, that the layers are grown fully strained on GaN. In $\theta/2\theta$-scans lots of satellite-peaks are observed, which implies a good periodicity and abrupt interfaces. However, spatially resolved XRD measurements revealed that the thickness ratio of the layers changes with the radial position on the wafer, which causes a shift of the corresponding optical stop band and a decrease of the maximum optical reflectivity.

15 min. break

HL 27.9 Wed 12:00 BEY 81

Radiative recombination in GaInN quantum wells investigated via time-resolved photoluminescence — •Torsten Langer, Holger Jönen, Carsten Netzel, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig

The optical properties of group-III-nitrides are strongly influenced by an interplay between radiative and nonradiative recombination processes. For our high internal efficiency c-plane GaInN/GaN quantum wells, the effective lifetime, determined by time-resolved photoluminescence(PL)-spectroscopy, is dominated by radiative recombination nearly up to room temperature. This is evidenced by an increase of the effective lifetime with increasing temperature, which is tantamount to a high internal quantum efficiency, proving the results from temperature and excitation power dependent PL-measurements (continuous wave excitation). While radiative lifetime increases almost linearly at higher temperatures, the nonradiative lifetime drops due to thermal activation of nonradiative processes. The influence of excitons is clearly visible too, when fitting the intensity transients with a model based on radiative excitonic and nonradiative recombination. In this model, the ratio between excitons and free carriers are described by the law of mass action. Furthermore, we observe higher effective lifetimes with increasing quantum well thickness, due to a decreased oscillator strength caused by piezoelectric fields. In m-plane GaInN quantum wells, the interplay between radiative and nonradiative recombination processes is present as well. Here we observe a higher oscillator strength and therefore a shorter effective lifetime.

HL 27.10 Wed 12:15 BEY 81

Wachstum von GaN auf hochindizierten Silizium-Substraten — •Roghaiyeh Ravash, Jürgen Bläsing, Matthias Wieneke, Armin Dadgar und Alois Krost — Institut für Experimentelle Physik (IEP), Magdeburg, Deutschland

Bei den meisten bisher realisierten Bauelementen, die auf GaN basieren, ist die Wachstumsorientierung parallel zur c-Achse. In solchen Schichten tritt Ladungsseparation aufgrund der internen spontanen- und verspannungsinduzierten piezoelektrischen Polarisation auf, was sich u. a. im Quantum Confined Stark Effekt (QCSE) äußert. Eine mögliche Lösung, die Polarisationsfelder und den QCSE zu kontrollieren, ist das Wachstum polarisationsreduzierter Schichten. Um nicht- bzw. semipolar orientiertes GaN mittels MOVPE zu wachsen, wird hier durch Änderung der Prozessparameter wie z.B. dem Druck, der Wachstumstemperatur, dem V-III Verhältnis, etc. nach geeigneter Silizium-Substratoberfläche, wie z. B. (511), (711) gesucht Die Oberflächen der gewachsenen Proben sind im Vergleich zu c-achsenorientierten GaN-Schichten auf Si(111)-Substraten, die meist als Referenz-Proben im selben Wachstumsversuch benutzt werden, sehr rau. Aufgrund der nahezu pulverartigen Verteilung der GaN-Kristallite treten eine Vielzahl von Intensitätsreflexen auf. Zur Bestimmung der Textur der Kristallite werden Polfigurmessungen durchgeführt. Für einige GaN Orientierungen wird bei bestimmten Si-Kristallorientierungen eine deutlich erhöhte Intensität beobachtet. Diese bevorzugten Orientierungen werden im Zusammenhang mit der bekannten Oberflächenstruktur der verschiedenen Si-Substrate diskutiert.

HL 27.11 Wed 12:30 BEY 81

Spectral behaviour of semipolar GaInN/GaN on $\{11\bar{2}2\}$ and $\{1\bar{1}01\}$ semipolar facets — •Michael Wiedenmann[1], Martin Feneberg[1], Rolf Sauer[1], Klaus Thonke[1], Thomas Wunderer[2], Stephan Schwaiger[2], Frank Lipski[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

We present cathodoluminescence measurements on GaInN/GaN single quantum wells grown on different semipolar facets. These semipolar facets were formed via selective epitaxy on a GaN template with hexagonally ordered mask patterns. The intentionally grown inverse pyramids possess $\{11\bar{2}2\}$ and $\{1\bar{1}01\}$ crystal planes. The optical properties of the quantum well on the different facets are investigated by spatially resolved cathodoluminescence spectroscopy. Strong shifts of the quantum well luminescence are found within individual facets, which are discussed in terms of concentration gradients and quantum well thickness changes.

HL 27.12 Wed 12:45 BEY 81

Mikroskopische Lumineszenzuntersuchungen an grün-emittierenden InGaN/GaN MQWs auf semi-polaren $\{1\bar{1}01\}$ Facetten — •Sebastian Metzner[1], Frank Bertram[1], Jürgen Christen[1], Thomas Wunderer[2] und Ferdinand Scholz[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]Institut für Optoelektronik, Universität Ulm

Wir präsentieren hochortsaufgelöste Kathodolumineszenzmikroskopie (KL) von, für den grünen Spektralbereich optimierten, dreifach InGaN-MQWs, die selektiv auf $\{1\bar{1}01\}$ GaN-Facetten gewachsen wurden, welche mit MOVPE durch streifenförmige SiO_2-Maskierungen hergestellt wurden. Im auf Saphir gewachsenen GaN-Puffer dominiert die scharfe (FWHM < 5 meV) (D^0,X) Lumineszenzlinie bei 355,8 nm, was einer biaxialen kompressiven Verspannung von 0,5 GPa entspricht. Die GaN-Prismen zeigen im Querschnitt einen schwachen, scharfen (D^0,X)-Peak, der im lateral überwachsenen QW-Bereich stark rotverschoben (357,7 nm) und verbreitert ist. Die ortsintegrale KL des InGaN-MQW liegt im grünen Spektralbereich bei ca. 510 nm. Mikroskopisch ist ein QW-Lumineszenzverlauf zu identifizieren, der beginnend mit langwelliger KL (517 nm) in Maskennähe über eine kurzwellige KL ($<$ 505 nm) auf 1/3 Facettenhöhe in Richtung Dachfirst zu längeren Wellenlängen (bis 512 nm) schiebt. Unmittelbar am First geht eine intensive, kurzwellige InGaN-Emission mit einer perfekten Morphologie einher. Im Gegensatz dazu korreliert eine schwache InGaN-Intensität bei 515 nm, begleitet von GaN-Defektlumineszenz bei 390 nm - 450 nm, mikroskopisch mit morphologischen Defekten unmittelbar am First.