HL 53: Nitrides: Preparation of nonpolar and semipolar orientations

Time: Tuesday 14:00–16:15 Location: POT 151

HL 53.1 Tue 14:00 POT 151

Analytic solutions of kp-Hamiltonian for III-nitride semicondutors with arbitrary strain situation — •Michael Winkler, Rüdiger Goldhahn, and Martin Feneberg — Otto-von-Guericke-Universität, Magdeburg, Germany

Calculation of transition energies and optical polarization degrees in semi- and nonpolar wurtzite semiconductors demand new analysis schemes within **kp**-theory. We demonstrate that the Bir-Pikus Hamiltonian for nonpolar or semipolar material with *arbitrary strain situation*, following Hooke's law, is analytically solvable for eigenenergies and eigenvectors. These results contribute to an in-depth understanding of valence band distances and relative oscillator strengths. We discuss valence band crossing and anticrossing behavior under symmetry not preserving strain at the Γ-Point.

The fully analytical parametrization of eigenvalues for semipolar wurtzite layers allows finally for a quick qualitative analysis of oscillator strengths and band order. The methodology allows for an easy expansion to pressure-dependent optical experiments. Calculational results are put in relation to experimental data. We find that valence band crossings are exotic events occuring under special conditions only, which is discussed in detail.

HL 53.2 Tue 14:15 POT 151

The impact of silicon doping on the optical properties of the stacking fault emission in a-plane GaN — •Gordon Schmidt, Christopher Karbaum, Sebastian Metzner, Frank Bertram, Peter Veit, Matthias Wieneke, Hartmut Witte, Armin Dadgar, Martin Feneberg, Rüdiger Goldhahn, Alois Krost, and Jürgen Christen — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

In GaN the basal plane stacking fault (BSF) type I_1 is a two dimensional defect characterized by a cubic inclusion within the wurtzite structure. Excitons are bound at the BSF I_1 similar to the localization in a quantum well heterostructure leading to an efficient radiative recombination.

We present a study of the BSF I_1 emission from a-plane GaN layers with a systematic variation of the silicon doping level. Using metal-organic vapor phase epitaxy the a-plane GaN layers were grown on r-plane sapphire substrates with an AlGaN seeding layer. Varying the silane flow rate the electron concentration (n_e) was changed between nominally undoped and $3 \cdot 10^{19}$ cm^{-3}.

In cathodoluminescence (CL) experiments at 5 K the BSF I_1 emission is the most intense recombination whose peak energy exhibits a strong blueshift from 3.423 eV to 3.473 eV with increasing n_e. The recombination kinetics of the dominant CL show a monoexponential decay with initial lifetimes of the BSF I_1 emission decreasing with higher n_e from 2.9 ns to 470 ps. Our results will be discussed in terms of reduction of the quantum confined Stark effect within the BSF I_1.

HL 53.3 Tue 14:30 POT 151

In-situ analysis of the surface electronic properties of polar and nonpolar InN and GaN films — •Marcel Himmerlich, Anja Eisenhardt, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, PF 100565, 98684 Ilmenau, Germany

Intrinsic surface electronic properties of nitrides are still under debate especially due to a lack of in-situ analyses that allow the characterization of clean surfaces commonly considered in electronic structure calculations. Here we present in-situ studies on the surface properties of polar and nonpolar configurations of GaN and InN thin films prepared by plasma-assisted molecular beam epitaxy utilizing ultraviolet and X-ray photoelectron spectroscopy [1,2]. It will be shown that especially surface reconstructions or relaxations are responsible for the existence of occupied and unoccupied electron states that determine the band alignment at surfaces and interfaces. For both group III nitrides, GaN and InN, the metal-polar surface exhibits different band bending V_{bb} compared to the N-polar, m-plane and a-plane surface. Thereby V_{bb} depends on the position of surface states that induce a pinning of the Fermi level. Furthermore, the GaN and InN surface states are easily saturated by adsorbates due to exposure to reactive gases like oxygen or water, partly combined with strong changes in the surface band bending.

[1] M. Himmerlich et al., Phys. Rev. B 88 (2013), 125304.
[2] A. Eisenhardt et al., Appl. Phys. Lett. 102 (2013), 231602.

HL 53.4 Tue 14:45 POT 151

Luminescence characteristics of pyramidal InGaN/GaN light emitter — •Jan Wagner, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

The green spectral range is an important topic for the field of semiconductor light emitters nowadays. The lack of efficient InGaN/GaN green emitters due to the Quantum Confined Stark Effect (QCSE) limits the use of semiconductors in optical devices. The QCSE reduces the recombination efficiency for electrons and holes in these emitter drastically by shifting the wavefunctions away from each other. To overcome this we grow semipolar InGaN quantum wells on top of three dimensional GaN pyramids. The use of semipolar facets instead of c-plane GaN as growth surface reduces the QCSE by a large amount and should increase the efficiency of green InGaN/GaN emitter. Since up to now semipolar and nonpolar GaN substrates are not widely available we use the method of epitaxial lateral overgrowth (ELO) to force a three-dimensional growth of the GaN. This provides us with easy accessible semipolar growth surfaces for the InGaN quantum well. In this contribution we would like to show our latest results in the control and growth of pyramidal GaN structures as well as the optical characteristics and the dynamics of the charge carriers of these structures.

HL 53.5 Tue 15:00 POT 151

Determination of polarisation fields in group III-nitride heterostructures by capacitance-voltage-measurements — •Monir Rychetsky[1], Ingrid Koslow[1], Jens Rass[1,2], Tim Wernicke[1], Konrad Bellmann[1], Veit Hoffmann[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

InGaN/GaN heterostructures exhibit strong piezoelectric and spontanous polarisation fields and sheet charges resulting in band bending. This leads to a reduction in the radiative recombination rate in light-emitting diodes (LEDs) and a red shift in the emission wavelength, due to the quantum-confined Stark effect.

There are several methods by which the magnitude and orientation of these polarisation fields have been measured. However, no exact values for the polarisation fields in semipolar planes have been reported.

In this contribution we propose a new approach to determine polarisation fields by using capacitance-voltage measurements. The sheet charges at the heterointerface influence the charge distribution in a PIN (positive intrinsic negative) junction and therefore the depletion width and the capacitance. In order to improve the accuracy of the method we compare the depletion width of two PIN junctions, one with an embedded InGaN layer and therefore influenced by the internal polarisation fields and one without it. First results of an $In_{0.08}Ga_{0.92}N$ quantum well on (0001) show an internal field strength in the range of 0.95 - 1.25 MV/cm in $[000\bar{1}]$ direction.

HL 53.6 Tue 15:15 POT 151

Optical and structural nano-characterization of GaN based LED structures with semipolar sub-μm patterned InGaN QWs — •Sebastian Metzner[1], Marcus Müller[1], Gordon Schmidt[1], Benjamin Max[1], Peter Veit[1], Silke Petzold[1], Frank Bertram[1], Robert Leute[2], Dominik Heinz[2], Junjun Wang[2], Ferdinand Scholz[2], and Jürgen Christen[1] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg — [2]Institute of Optoelectronics, University of Ulm

We present the nano-scale correlation of optical and structural properties of an LED structure with sub-μm semipolar InGaN quantum wells (QWs) using liquid helium temperature scanning (transmission) electron microscope cathodoluminescence (SEM/STEM-CL). The semipolar n-doped GaN structures were selectively grown on a SiN mask consisting of stripes with a period of 260 nm on top of a c-plane GaN/sapphire template using metalorganic vapour phase epitaxy. The $\{10\bar{1}1\}$ side facets were subsequently covered by InGaN and finally completely filled up and planarized by p-doped GaN. The InGaN QWs on top of the $\{10\bar{1}1\}$ GaN stripes are clearly resolvable in cross-section STEM images in high-angle annular dark field contrast and can directly be correlated to intense CL emitting at $\sim$ 440 nm. We will discuss the impact of e.g. systematic thickness changes of the QW on the luminescence properties as well as the effect of the mask patterning process and selective growth on the planarization during p-doped GaN growth.

HL 53.7 Tue 15:30 POT 151

Cathodoluminescence mapping on differently inclined semipolar InGaN facets — •Matthias Hocker[1], Ingo Tischer[1], Benjamin Neuschl[1], Jeffrey Helbing[1], Junjun Wang[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, University of Ulm, D-89081 Ulm, Germany — [2]Institute of Optoelectronics, University of Ulm, D-89081 Ulm, Germany

Indium gallium nitride (InGaN) based converter structures are promising candidates for optical devices emitting in the green spectral range. They are realized by epitaxial overgrowth of three-dimensional semipolar gallium nitride (GaN) by InGaN multiple quantum wells. Besides structural deficiencies, differently inclined facets incorporate different amounts of indium, resulting in a broadening of the integral light output spectrum. To overcome these deficiencies, such converter structures were investigated in detail by spatially and spectrally resolved low-temperature cathodoluminescence (SEM-CL), which offers the possibility to distinguish the origin of the different spectral contributions locally. In the CL maps, dark areas and subfacets with blue shifted emission patterns were found. These emission features correlate with undesirable subfacets of the GaN templates. By suppressing these subfacets, it is possible to achieve a more homogenous luminescence distribution, resulting in a better performance of the final device.

HL 53.8 Tue 15:45 POT 151

Generalized ellipsometry of semipolar AlGaN — •Juliane Klamser[1], Martin Feneberg[1], Rüdiger Goldhahn[1], Joachim Stellmach[2], Martin Frentrup[2], Simon Ploch[2], Frank Mehnke[2], Tim Wernicke[2], and Michael Kneissl[2] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [2]Institut für Festkörperphysik, Technische Universität Berlin

We present generalized spectroscopic ellipsometry data obtained from the anisotropic semiconductor material system aluminum gallium nitride (AlGaN). The several micrometer thick AlGaN layers were grown by metal-organic vapor phase epitaxy on m-plane sapphire substrates. The samples cover the whole composition range between GaN and AlN. The (11-22) orientation of the AlGaN surface allows for alignment of the optical axis parallel to the plane of incidence, no perpendicular alignment is possible. The optical axis of the as well anisotropic sapphire substrate is pointing in a different direction. This challenging sample geometry requires careful measurement of the main and the secondary elements of the Jones matrix. As result of the evaluation of the measurements we present the successfully separated ordinary and extraordinary tensor components of the dielectric function. We not only succeeded in fitting model dielectric functions to experimental data but also present point-by-point fitted dielectric functions of several AlGaN samples. The valence band structure of AlGaN governing optical selection rules and thus the dielectric function is expected to show a crossing at certain but unknown Al concentration. Our study experimentally narrows the possible band crossing range in AlGaN.

HL 53.9 Tue 16:00 POT 151

Direct identification of luminescence from I1 type basal plane stacking faults in semipolar AlGaN layer with low Al content — •Ingo Tischer[1], Manuel Frey[1], Matthias Hocker[1], Robert A.R. Leute[2], Ferdinand Scholz[2], Heiko Groiss[3], Erich Müller[3], Dagmar Gerthsen[3], Willem van Mierlo[4], Johannes Biskupek[4], Ute Kaiser[4], and Klaus Thonke[1] — [1]Institut für Quantenmaterie, Gruppe Halbleiterphysik, Universität Ulm, 89081 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89081 Ulm — [3]Laboratorium für Elektronenmikrokopie, Karlsruhe Institute of Technology, 76131 Karlsruhe — [4]Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm, 89081 Ulm

For nitride-based laser diodes and LEDs high quality AlGaN electron blocking layers are required. Due to the lattice mismatch of AlGaN and GaN, the occurance of structural defects increases strongly, especially on semipolar surfaces. In this study, we assign distinct spectral luminescence features to structural defects of AlGaN layers on a semipolar GaN template. Spatially resolved cathodoluminescence (CL) recorded at temperatures below 10K using a scanning electron microscope, performed on the cross section and on the $\{10\bar{1}1\}$ side facet surface, allows to determine the spatial and spectral distribution of luminescence features. High resolution STEM investigations at the same sample area allow the direct assignment of optical bands to distinct structural features like basal plane stacking faults and regions with different Al content.