HL 98: Nitrides: Bulk material, films, surfaces and quantum wells

Time: Friday 9:30–12:30 Location: EW 201

HL 98.1 Fri 9:30 EW 201

Valence band tomography in wurtzite GaN — •Martin Feneberg, Karsten Lange, Michael Winkler, Matthias Wieneke, Hartmut Witte, Jürgen Bläsing, Armin Dadgar, and Rüdiger Goldhahn — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Effective masses describe the curvature of the conduction and valence bands. These masses are extremely important input parameters for device design, understanding optical or transport phenomena, and evaluating theoretical results. However, especially the hole masses are experimentally largely unexplored.

Here, we present valence band tomography performed by analyzing spectroscopic ellipsometry data of a-plane wurtzite GaN with free electron concentrations up to $10^{20}\mathrm{cm}^{-3}$. The conduction band curvature of the same set of samples is already known from infrared studies [1]. By taking into account Burstein-Moss shift and band gap renormalization, the onset of the anisotropic interband absorption reveals the valence band edges for $k > 0$ in certain directions. This analysis yields the valence band curvature for the upper two valence bands.

[1] M. Feneberg, K. Lange, C. Lidig, M. Wieneke, H. Witte, J. Bläsing, A. Dadgar, A. Krost, and R. Goldhahn, Appl. Phys. Lett. 103, 232104 (2013).

HL 98.2 Fri 9:45 EW 201

Interaction of GaN(0001) surfaces with potassium and water — •Marcel Himmerlich, Vladimir Irkha, Anja Eisenhardt, Stephanie Reiss, and Stefan Krischok — Institut für Physik and Institut für Mikro- und Nanotechnologien, TU Ilmenau, Germany

Due to its high physical and chemical stability, gallium nitride (GaN) is a promising material for the use in chemical or biological sensor devices. For device optimization and clarification of degradation mechanisms, a profound understanding of the interaction between the GaN surface and the species of the surrounding environment that are aimed to be analysed is essential. Here we present a study on the interaction of GaN(0001) surfaces with potassium and water, motivated by K ions in aqueous environment being important for biosensor applications due to its involvement in fundamental cell metabolism processes. Changes in the chemical and surface electronic properties during the adsorption and coadsorption of K and water on the epitaxial grown GaN surfaces were in-situ characterized by X-ray and ultraviolet photoelectron spectroscopy. The measurements show the formation of K and oxygen related electron states as well as significant changes in the sample work function Φ and surface band bending V_{bb}. Water adsorption leads to a slight increase in Φ, while K adsorption and coadsorption of K and water induce a pronounced work function decrease. Furthermore, K increases the surface upward band bending of GaN(0001), while during the interplay of K with water a reduction in V_{bb} is observed. The interplay between surface and adsorbate electron states and the occurring chemical and charge transfer processes will be discussed.

HL 98.3 Fri 10:00 EW 201

Ultrafast to slow time-resolved defect luminescence studies of rare earth doped AlN — •Tristan Koppe[1], Oliver Beck[1], Takashi Taniguchi[2], Hans Hofsäss[1], and Ulrich Vetter[1] — [1]2. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]National Institute for Materials Science, Namiki 1 - 1, Tsukuba, Ibaraki 305-0044, Japan

We report on studies of fast and slow defect luminescence processes in undoped and rare earth doped AlN. It was synthesized by the temperature gradient method in a belt-type HP-HT apparatus using e.g. Li_3AlN_2 as solvent which was then mixed with EuF_3 before synthesis for rare earth doped AlN.

In this work a general overview is given on the known defect types in AlN reported in literature so far, and the interaction of defects and rare earth ions in the host are discussed based on luminescence studies. Time-resolved luminescence studies were performed using a Coherent MIRA 900-F Ti:Sa laser in combination, a pulse picker and an APG HarmoniXX FHG 3+1 harmonics generator with the luminescence light collected with a 0.3 m spectrograph and a streak camera.

Two distinct luminescence bands at 2.7 eV and 3.9 eV in undoped AlN with lifetimes in the range from several ps to several μs are found and their origin is discussed. In rare earth doped AlN energy transfer between rare earth ion and defects in the AlN host is discussed based on temperature dependent time-resolved luminescence measurements.

HL 98.4 Fri 10:15 EW 201

Aberration-corrected-STEM investigation of epitaxial GaN thin films formed by ion-beam based post-nitridation of Ga droplets — •David Poppitz, Andriy Lotnyk, Jürgen W. Gerlach, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, D-04318 Leipzig

GaN is a widely used semiconductor material in optoelectronics applications due to its optical properties. By increasing the crystalline quality, the emission efficiency for light emitting devices can be improved. Here, GaN thin films were produced in a system usually used for ion-beam assisted molecular-beam epitaxy (IBA-MBE) on 6H-SiC-, Al_2O_3- and γ-$LiAlO_2$-substrates. In the first step of the deposition process, Ga-droplets were deposited on the substrates. In the second step, a post-nitridation process of Ga droplets by a hyperthermal nitrogen ion beam with ion energies less than 25 eV was used to form the GaN thin films.

The thin films characterization was done by using a state of the art FEI Titan^3 G2 60-300kV probe aberration-corrected scanning transmission electron microscope (STEM). It was found that coalesced GaN thin films with film thicknesses less than 30 nm can be achieved by this preparation method. The detailed investigation shows different types of defects such as grain boundaries and stacking faults in the epitaxial, differently oriented films. However, the crystalline quality of GaN thin films was dependent on the substrate material.

HL 98.5 Fri 10:30 EW 201

Towards an understanding of (11$\bar{2}$2) InGaN quantum wells — •Markus Pristovsek, Tongtong Zhu, Yisong Han, and Colin J. Humphreys — Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge, CB3 0FS, UK

InGaN quantum wells (QWs) are at the heart of every light emitting diode. The drop of their photoluminescence (PL) emission towards green is mostly attributed to the piezo-electric fields which separate electron and hole wave functions. Semi- and non-polar orientations are investigated since the resulting fields are strongly reduced. Especially the stable (11$\bar{2}$2) orientation offers high indium incorporation.

We have grown and characterized (11$\bar{2}$2) InGaN QWs from 400 to 600 nm and compared with (0001) QWs. The indium desorption on the (11$\bar{2}$2) is slightly higher, hence QW growth rates and temperatures have a stronger influence and indium concentration are slightly lower. The critical thickness for full relaxation was comparable to (0001).

A QW thickness series showed indeed less wavelength shift for (11$\bar{2}$2) QWs from 2.0 to 4.5 nm. However, all the wavelengths were not close to the expected positions. Furthermore, the PL intensities of all QWs were less than a third of that of simultaneously grown (0001) QWs. Systematic variation of the barrier width showed that carriers generated more than ≈3 nm away from the (11$\bar{2}$2) QWs do not contribute to the PL. Electroluminescence is currently under investigation.

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Coffee break

HL 98.6 Fri 11:00 EW 201

Growth and characterization of InN on Si (111) by molecular beam epitaxy — •Saskia Weiszer, Andreas Zeidler, Fabian Schuster, and Martin Stutzmann — Walter Schottky Institut and Physics Department, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany

Multi-junction solar cells have received wide attention as the energy conversion efficiency can be increased significantly compared to single-junction solar cells. Theoretical considerations show that an InGaN/Si tandem solar cell could be an optimal implementation of a double-junction solar cell, as two different wavelength regions of the broad solar spectrum can be utilized by each junction connected via a resonant tunnel junction which is expected to form at an indium content of 46 %. As a first step towards such an InGaN/Si tandem solar cell, the growth of high quality InN directly on Si (111) substrates by molecular

beam epitaxy (MBE) has been investigated. First attempts of growing InN as a homogeneous thin film suffered from an insufficient quality. The obtained layer-like structures showed high surface roughness in atomic force microscope and various epitaxial orientations measured by high resolution X-ray diffraction. A possible alternative to layer growth is the growth of nanowires to reduce structural defects, since the lattice mismatch induced strain can relax through the nanowire sidewalls. By a varying the applied growth parameters, namely substrate temperature and III/V-ratio, the InN nanowire growth has been optimized and recent results will be presented.

HL 98.7 Fri 11:15 EW 201

Molecular beam epitaxy of GaN quantum dots — •Christopher Hein[1], Andreas Kraus[1], Heiko Bremers[1], Fedor Alexej Ketzer[1], Kamran Forghani[2], Uwe Rossow[1], Ferdinand Scholz[2], and Andreas Hangleiter[1] — [1]Institute of Applied Physics, TU Braunschweig, Germany — [2]Institute of Optoelectronics, Universität Ulm, Germany

Quantum dots are desired nanostructures for laser diodes and non classical light generation. The III-nitride material system constitutes a valuable material for such applications due to their high bandgap and thermal stability. Our samples are grown in a RIBER 32P molecular beam epitaxy system in Stranski-Krastanov self assembled growth. Templates are c-oriented 300μm sapphire substrates on top of which MOVPE GaN (2.5μm) or AlN (500nm) is grown. Our experiments cover temperature dependent (675-725°C) deposition and subsequent characterization of uncapped and capped GaN QD. Growth on MOVPE GaN started with a 100 nm tick AlN (700°C) buffer. Afterwards 2 min GaN was deposited during which in situ RHEED developed from streaky to a dotty pattern, indicative for Stranski-Krastanov growth. AFM of the samples showed dots with 1.4 nm (700°C) up to 2 nm height with densities ranging from $1.3 \cdot 10^{10}/\mathrm{cm}^2$ (725°C) up to $6.0 \cdot 10^{10}/\mathrm{cm}^2$ (675°C). At higher temperatures dots reorganize in a way such that smaller dots coalesce due to higher mobility thus reducing the overall density. The QD sample grown at 700°C was reproduced on MOVPE AlN and capped with a 30 nm AlN layer to allow for optical characterization.

HL 98.8 Fri 11:30 EW 201

Investigation of the optical properties of Zn doped GaN/AlGaN quantum wells for future single photon applications — •Johannes Dühn[1], Matin Mohajerani[2], Xue Wang[2], Andreas Waag[2], Kathrin Sebald[1], and Jürgen Gutowski[1] — [1]Institute for Solid State Physics, University of Bremen, Germany — [2]Institute for Semiconductor Technology, Technical University of Braunschweig, Germany

Efficient single photon sources are a fundamental requirement for experimental quantum optics and cryptography. Established single photon sources often provide low intensities and have to be operated at cryogenic temperatures. A promising approach to this problem is the usage of bound excitons in wide-band-gap materials, because they possess large exciton binding energies and are therefore applicable at elevated temperatures. The position of the bound exciton emission is only determined by the type of defect and the emission exhibits a narrow line width, as it is favourable for device applications. In this work we investigate the micro-photoluminescence of a quantum well of zinc doped GaN embedded in AlGaN. Incorporation of zinc dopants is proven by identifying the acceptor bound exciton emission line at 3.455eV. To reveal the properties of individual emitters we investigate the luminescence properties of mesa etched structures on the sample. The single-photon properties of these emitters will be characterised by using a Hanbury-Brown-Twiss interferometer.

HL 98.9 Fri 11:45 EW 201

Optical investigations of anisotropic strain of nonpolar GaInN quantum wells grown on AlInN/GaN buffer layers — •Fedor Alexej Ketzer, Ernst Ronald Buss, Philipp Horenburg, Holger Jönen, Heiko Bremers, Torsten Langer, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

We investigate the effect of different buffer layers on the anisotropic strain of nonpolar GaInN quantum well (QW) structures. Therefore we examine optical properties of QWs grown via low pressure MOVPE. We compare fully strained QWs grown on m-plane pseudobulk GaN substrates with similar samples with AlInN buffer layers of different composition. The effect of the strain of the active zone is investigated by temperature dependent and polarization resolved resonant photoluminescence spectroscopy. Since high strain is prominent in GaN/GaInN heterostructures, AlInN buffer layers provide a good possibility of changing overall strain and relaxation. Due to the deformation potentials which strongly affect the band energies, changing the indium content and relaxation of the buffer layer can further tune the emission wavelength and the degree of polarization of the emitted light. Our samples show good optical properties with narrow spectra but strong differences in the degree of polarization and transition energy compared to samples with regular GaN buffer. This is in good agreement with our calculations of the strain and valence band energies.

HL 98.10 Fri 12:00 EW 201

Photoluminescence of GaN grown by high temperature vapor phase epitaxy — •Friederike Zimmermann[1], Jan Beyer[1], Gleb Lukin[2], Olf Pätzold[2], Christian Röder[1,3], Michael Stelter[2], and Johannes Heitmann[1] — [1]Institut für Angewandte Physik, TU Bergakademie Freiberg, Leipziger Str. 23, D-09599 Freiberg, Germany — [2]Institut für Nichteisenmetallurgie und Reinststoffe, TU Bergakademie Freiberg, Leipziger Str. 34, D-09599 Freiberg, Germany — [3]Institut für Theoretische Physik, TU Bergakademie Freiberg, Leipziger Str. 23, D-09599 Freiberg, Germany

High temperature vapor phase epitaxy (HTVPE) is a promising process for chlorine-free growth of GaN. We report on a photoluminescence study on GaN samples grown in a modified HTVPE reactor, which was designed to overcome some of the drawbacks of HTVPE growth. All samples show an overall high luminescence efficiency increasing with III/V-ratio. At 15 K the spectra are dominated by a DAP-like transition at 3.27 eV indicating the presence of acceptors. The near band edge region shows two broad excitonic features which can be ascribed to the common residual donor bound excitons at 3.473 eV and an acceptor bound exciton at 3.462 eV. A carbon contamination cannot be ruled out. The HTVPE samples generally show a much lower variety of radiative defects compared to GaN grown by other methods.

HL 98.11 Fri 12:15 EW 201

Influence of off-cut on the surface morphology and defect distribution of epitaxial laterally overgrown (ELO)-AlN — •Johannes Enslin[1], Frank Mehnke[1], Tim Wernicke[1], Konrad Bellmann[1], Arne Knauer[2], Viola Kueller[2], Anna Mogilatenko[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Smooth AlN layers on sapphire with low defect densities are essential for efficient light emitters in the UV-C spectral region between 200 nm and 280 nm. By growing AlN on patterned sapphire substrates (ELO) the threading dislocation density can be significantly reduced from $10^{10}\mathrm{cm}^{-2}$ to $< 10^{9}\mathrm{cm}^{-2}$. However, the ELO-AlN surfaces often suffer from macrosteps with heights of 22 nm for an off-cut angle of 0.25° to the sapphire m-plane. In this paper, we study the influence of the sapphire substrate off-cut angle on the occurrence of macrosteps on ELO-AlN. For this purpose sapphire wafers with off-cut angles between $0.08° \pm 0.008°$ and $0.23° \pm 0.008°$ were overgrown. AFM analysis of the ELO-AlN surfaces revealed macrosteps for off-cut angles between 0.16° and 0.23° with step heights of 19 nm. For substrate off-cuts of $< 0.12°$ the surface exhibits a wavelike surface morphology with the periodicity of the ELO pattern and a peak to bottom ratio of 4 nm. The influence of the surface morphology on the defect distribution will be discussed.