HL 32: Nitrides: Preparation and Characterization I

Time: Wednesday 9:30–11:00 Location: H15

HL 32.1 Wed 9:30 H15

Optical properties of asymmetric cubic AlGaN/GaN quantum wells — •Erik Graper[1], Elias Baron[1], Martin Feneberg[1], Tobias Wecker[2], Donat J. As[2], and Rüdiger Goldhahn[1] — [1]Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Germany — [2]Department Physik, Universität Paderborn, Germany

Group III-nitrides, particularly AlGaN and GaN, are essential materials for high-performance electronic and optoelectronic devices. While conventional hexagonal AlGaN/GaN high-electron-mobility transistors (HEMTs) operate in normally-on mode, cubic AlGaN/GaN structures enable normally-off operation - a crucial advantage for energy-efficient power electronics. These cubic AlGaN/GaN heterostructures offer additional benefits such as the absence of internal polarization fields in (001) orientation.

In this study, we investigate asymmetric cubic AlGaN/GaN double quantum wells (2.5 nm and 0.6 nm) with varying barrier thicknesses, grown by plasma-assisted molecular beam epitaxy on 3C-SiC/Si substrates in (001) orientation. We employed complementary spectroscopic techniques to analyze quantum well coupling, combining photoluminescence (PL) measurements using continuous-wave lasers (266 nm and 325 nm) with photoluminescence excitation (PLE) spectroscopy using a tunable pulsed laser (325 - 354 nm). The acquired spectra were analyzed to determine wavelength dependent luminescence of the 2.5 nm quantum well.

HL 32.2 Wed 9:45 H15

Nanoscale characterization of cascaded GaN/InGaN LEDs with tunnel junction — •Konstantin Wein, Gordon Schmidt, Frank Bertram, Holger Eisele, Peter Veit, Olga August, Christoph Berger, Armin Dadgar, André Strittmatter, and Jürgen Christen — Otto-von-Guericke-University Magdeburg, Germany

In this work, comprehensive cathodoluminescence (CL) and electron beam induced current (EBIC) characterization directly performed in a scanning transmission electron microscopy (STEM) were performed on an InGaN/GaN double cascaded LED using a GaN:Ge/GaN:Mg tunnel junction (TJ). Cascaded LEDs benefit from monolithic multi-wavelength emission, lower injection current density (lower droop), and smaller chip sizes compared with standard LEDs. In low temperature (T = 17 K) highly spatially resolved CL, each individual layer is identified by its characteristic emission. The GaN:Si layers exhibit NBE emission at 365 nm corresponding to donor-bound exciton recombination, in contrast to the GaN:Mg layers which exhibit donor-acceptor pair recombination emitting at 380 nm. The intensity profile across the InGaN MQWs of both active regions gives access to the transport and capture of the excess carriers and excitons. The direct comparison of the local CL emission with the EBIC signal exhibits not only the local quantum efficiency as well as transfer of carriers (diffusion/drift) but also the current spreading/injection distribution of the vertical device. The impact of functional layers like electron blocking layers or TJs on the transport of carriers is directly visualized on the nano-scale.

HL 32.3 Wed 10:00 H15

Understanding the Effect of Defects in Ta3N5 Thin Films on Charge Carrier Dynamics — •Jan Luca Blänsdorf[1], Lukas M. Wolz[1], Matthias Kuhl[1], Johannes Dittloff[1,2], Nina Miller[1], Gabriel Grötzner[1,2], Ian D. Sharp[1,2], and Johanna Eichhorn[1] — [1]Physics Department, TUM School of Natural Sciences, Technische Universität München, Germany — [2]Walter Schottky Institute, Technische Universität München, Germany

Transition-metal nitrides are a highly interesting material space for solar-energy conversion due to their suitable bandgap for visible light absorption and high theoretical solar-to-hydrogen efficiencies. An intensively studied example is Ta3N5, with a bandgap of 2.2 eV and favorable band alignment for solar water splitting. However, its photoelectrochemical performance is limited by oxygen impurities and nitrogen vacancies. Here, we used transient absorption spectroscopy on the microsecond timescale to reveal the impact of different defects on charge carrier dynamics in Ta3N5. Therefore, we synthesized Ta3N5 thin films with different concentrations of nitrogen vacancies and oxygen impurities. Their structure, defect and photoelectrochemical properties were correlated with charge carrier dynamics to identify current performance limitations.

HL 32.4 Wed 10:15 H15

Accessing and evaluating the full growth window of PAMBE grown AlGaN/GaN nanowires — •Rudolfo Hötzel[1], Marten Wilkens[1], Florian Krause[1], Andreas Rosenauer[1,2], Stephan Figge[1], and Martin Eickhoff[1,2] — [1]Institute of Solid State Physics, University of Bremen, 28359 Bremen, Germany — [2]MAPEX Center for Materials and Processes, 28359 Bremen, Germany

Typically group III/V nanowires synthesized by PAMBE are grown under a surplus of nitrogen. Under metal-rich conditions nanowire broadening is reported [1] leading to increased coalescence until self-stabilisation to stoichiometric conditions is reached. To establish stoichiometry single GaN nanowires consisting of multilayers of GaN grown with varying Ga fluxes were analyzed by STEM-EDX. The dependence of growth rates on temperature and fluxes could be consistently fitted with previously reported growth models [1] with the Ga desorption rate as the only free parameter. However a lateral broadening was not observed even for deep Ga-rich conditions. We attribute this to higher growth temperatures leading to an increased Ga desorption from the side facets. Based on these findings AlGaN/GaN nanowires were grown under deep metal-rich conditions. We observed that high Al/Ga fluxes lead to the formation of AlN regions due to the higher formation enthalpy of AlN with Ga accumulating on the c-face because of demixing. A homogenous incorporation of Al under deep metal-rich conditions was only possible for low Al/Ga flux ratios which are limited by the growth temperature. [1] S. Fernández-Garrido et al., Nano Lett. 13, 3274-3280 (2013)

HL 32.5 Wed 10:30 H15

Nanoscale multi-spectroscopic characterisation of InGaN pseudo-substrates grown on nanowire arrays — •Aidan Flynn Campbell, Jingxuan Kang, Huaide Zhang, Oliver Brandt, Lutz Geelhaar, and Jonas Lähnemann — Paul-Drude-Institut für Festkörperelektronik, Berlin, Deutschland

The efficiency of nitride light-emitting diodes (LEDs) in the amber and red spectral ranges is severely limited by the high strain in (In,Ga)N quantum wells with increasing In content when grown on GaN. Thus, reducing the lattice mismatch between the active region and adjacent layers is highly desirable. Our approach exploits the lateral elastic strain relaxation facilitated by nanowires fabricated top-down from a single-crystalline layer, epitaxial overgrowth of a subsequent layer achieves a strain free pseudo-substrate. In this study, we characterise the optical, chemical, and crystallographic properties of such overgrown layers, which are key in understanding and optimising our epitaxial overgrowth fabrication route.

We utilise experimental techniques such as continuous-wave and time-resolved cathodoluminescence (TRCL), energy-dispersive X-ray spectroscopy (EDX), and high-resolution electron backscatter diffraction (HR-EBSD). We demonstrate low dislocation densities, low compositional variations and low crystal misorientation across coalescence boundaries. Furthermore, the factors influencing defect formation and the relevance of dislocation propagation are investigated and correlated with the resulting luminescence efficiency of the overgrown layers.

HL 32.6 Wed 10:45 H15

Measuring solute concentrations in ammonothermal solutions via in situ X-ray absorption - estimating detection limits for novel nitrides — •Rajesh Chirala, Ege N. Civas, and Saskia Schimmel — Chair of Electron Devices (LEB), Dept. EEI, FAU Erlangen-Nürnberg, Cauerstr. 6, 91058 Erlangen, Germany

The ammonothermal method [1] is effective for producing high quality single crystals of binary and ternary nitrides [2], which are emerging semiconductor materials [3]. Despite the challenging process conditions (100 to 300 MPa, 400 to 800 °C), in situ measurement techniques such as X-ray imaging [4] allow to study reaction kinetics and solubilities, which are highly relevant to bulk crystal growth. In case of GaN, the quantitative determination of the concentration of Ga containing intermediates was already demonstrated [5].

By simulating the X-ray absorption of novel nitrides in an ammonothermal autoclave, we estimate element-specific detection limits for solute concentrations and derive strategies for detecting lighter elements or lower concentrations. Amongst the others, effectiveness of using a combination of lower X-ray energies and higher X-ray dose will be analyzed.

References :-

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[4] S. Schimmel et al., J. Cryst. Growth 418, 64, 2015.
[5] S. Schimmel et al., J. Cryst. Growth 498, 214, 2018.