HL 22: Nitrides: Preparation and characterization I

Time: Tuesday 14:00–15:30 Location: EW 203

HL 22.1 Tue 14:00 EW 203

GaN as a photo-catalyst for carbon dioxide reduction — •Andreas Zeidler, Viktoria Kunzelmann, and Martin Stutzmann — Walter Schottky Institut, Technische Univeristät München, Deutschland

Carbon dioxide (CO_2) has reached a critical level in the atmosphere and counts as one of the main reasons for global warming. Reducing this greenhouse gas to hydrocarbon fuels would help solving environmental issues and simultaneously address challenges such as energy storage and energy resource shortage. Converting CO_2 into usable fuels via photo-catalytic reactions is one way to address this issue. Using gallium nitride (GaN) as a photo-electrode is promising, since GaN is relatively stable under operating conditions and provides electrons with sufficient energy for CO_2 reduction. A critical aspect for the use of GaN as a cathode material is the electronic band level profile at the surface of the material. Different doping of GaN will influence this level profile. Therefore, p-type doped and p/n-structured GaN, grown by molecular beam epitaxy, is studied via open-circuit voltage measurements, surface photovoltage and Kelvin probe force microscopy. In addition, X-ray diffraction, Raman spectroscopy, temperature-dependent photoluminescence and atomic force microscopy measurements give insights into the role of defects in the grown material and the topography of the sample surfaces.

HL 22.2 Tue 14:15 EW 203

Microscopic interface and composition analysis of one-directionally lattice-matched AlInN — •Philipp Horenburg, Heiko Bremers, Ronald Korn, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, TU Braunschweig, Germany

We present microscopic evidence of interfacial indium depletion in c-lattice-matched AlInN grown by metalorganic vapor phase epitaxy on m-plane GaN. Further, in contrast to reports from the literature, we see no hints at parasitic gallium incorporation into the AlInN.

It is well known that lattice matching to GaN can be achieved in various crystal orientations. However, as the ideal growth conditions of its binary constituents AlN and InN are fairly different, epitaxy of AlInN remains a complex endeavour with a small window of suitable growth parameters. We performed a series of high-angle annular dark field (HAADF) and energy-dispersive X-ray spectroscopy (EDS) measurements at the AlInN/GaN interface. In a quantitative analysis, it becomes evident that the nominal In composition of 28% is reached at later instant of the AlInN growth process as compared to Al. This leads to a 0.4 nm thick In-depleted phase at the initial stage of growth accompanied by a slight spreading of Ga beyond the interface with no auto-incorporation into the bulk AlInN. These observations are consistent with X-ray diffraction studies on c-plane AlInN/GaN super lattice structures. We conclude the intrinsic tendency of AlInN to form an Al-rich phase in the early stage of growth independent of the crystal orientation. We thank FEI for providing HAADF and EDS data.

HL 22.3 Tue 14:30 EW 203

Correlation of structural and optical properties of GaN/AlN quantum disks embedded in nanowires by highly spatially cathodoluminescence microscopy — •Bowen Sheng[1,2], Frank Bertram[2], Ping Wang[1], Xiaoxiao Sun[1], Gordon Schmidt[2], Marcus Müller[2], Peter Veit[2], Thomas Hempel[2], Jürgen Christen[2], and Xinqiang Wang[1] — [1]PKU, Beijing, China — [2]IEP, OvGU, Magdeburg, Germany

Single photon emitters are the fundmental device applications in quantum optics and quantum information processing. Due to their large band offset and high binding energy of the excitons, III-nitrides quantum structures are most promising candidates for such devices. Despite the success in growing quantum dots, operating up to 300 K in 2014, the inherent piezoelectric fields, alloy fluctuations, shape and size control of the active region pose severe challenges with respect to fast and efficient generation of a single photon flux at a well-defined wavelength.

In this work, self-assembled hexagonally shaped GaN nanowires (NWs) with AlN/GaN/AlN quantum disk on top have been grown on Si (111) substrate in a dense array by plasma-assistant molecular beam epitaxy. To correlate the structural and optical properties of individual nanowires, highly resolved cathodoluminescence spectroscopy (CL) inside a scanning transmission electron microscope has been performed at 18 K along single NWs. CL linescans along the NWs clearly identify the emission coming from GaN bottom part around 359 nm and the GaN Q-disks around 347 nm with smallest FWHM of 60 meV, respectively. Other detailed analysis will be reported as well.

HL 22.4 Tue 14:45 EW 203

Investigation of AlN layer growth evolution under a Ga surfactant effect — •Christopher Hein, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institute of Applied Physics, Braunschweig, Germany

A key problem for high quality growth of AlN in MBE are low growth temperatures as well as the tendency to droplet formation in a metal rich regime. The latter can be overcome by codeposition of gallium as a surfactant during growth. We will investigate the evolution of thin AlN epilayers (10nm to 40nm thickness) under gallium surfactant. The samples were grown on MOVPE 2.5μm thick GaN layers on c-oriented sapphire substrates. The MBE growth starts with a 20nm GaN buffer layer grown at 745°C followed by an AlN epilayer in a double-pulsed growth scheme. Metal pulses were 22s long, followed by 25s nitrogen. In case of surfactant samples, gallium was supplied in parallel to aluminum. The total ratio of gallium contributing to the group III flux was fixed at 26% in the gas phase. Symmetric 2θ-ω-scans around the (0002) and (10$\bar{1}$0) reflex for samples grown with gallium surfactant show a residual GaN surface layer, formed after growth from accumulated gallium. As a consequence a sample series was grown which implemented a desorption step for the surface gallium. AFM of samples shows the tendency to crack formation for all samples, indicative for an onset of relaxation as confirmed by XRD. The surfactant and desorption treated samples show an additional reduction in surface RMS roughness value. This is attributed to a benefiting effect of the gallium surfactant on lateral growth of the AlN layer.

HL 22.5 Tue 15:00 EW 203

Analysis of the low temperature internal quantum efficiency of GaInN/GaN quantum wells — •Fedor Alexej Ketzer[1], Torsten Langer[1], Philipp Henning[1], Heiko Bremers[1], Uwe Rossow[1], Dirk Menzel[2], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig

The internal quantum efficiency (IQE), one of the key parameters for light emitting devices, is often measured by temperature dependent photoluminescence spectroscopy. By normalizing the integrated intensities at different temperatures and excitation powers to the excitation power and dividing by the maximum value one can estimate the IQE. For this estimation it is assumed that nonradiative recombination gets suppressed at low temperatures, which may be indicated by a saturation of the measured IQE. But tunneling processes with no, or a weak dependence on temperature may reduce the IQE even at low temperatures, which results in an overestimation of the IQE. Therefore we studied the absolute intensities at low temperatures as well as the IQEs for samples with changed nonradiative recombination. For this purpose we introduced intentional defects inside the quantum well region by ion implantation with different doses and compared the data with an unimplanted sample. Furthermore we investigated a set of samples with various radiative recombination rates and similar nonradiative recombination rates. From both series we estimate the IQE at low temperatures to clarify if a low temperature saturation of the temperature behavior is sufficient to neglect nonradiative recombination.

HL 22.6 Tue 15:15 EW 203

Photoelectrochemical characterization of p-type GaN for application as a photocatalyst for CO_2 reduction — •Viktoria Kunzelmann, Andreas Zeidler, Ian Sharp, and Martin Stutzmann — Walter Schottky Institute and Physics Department, Technische Universität München, Garching, Germany

The photocatalytic conversion of CO_2 into useful hydrocarbons can provide an excellent sustainable way to store energy. Finding a suitable semiconductor for efficient CO_2 reduction is challenging as it must fulfill several requirements: it must provide high energy electrons to split the inert CO_2 molecule, the band edges must straddle the desired redox levels and it needs to be stable under operating conditions. Gal-

lium nitride (GaN) is promising as a photocatalyst as it fulfills most of these requirements. GaN is also known for its superior chemical stability, however, surface oxidation during photoelectrochemistry is still a major issue, especially for n-type GaN. To diminish oxidation effects, p-doped GaN could be used as it exhibits surface electrons during photoexcitation due to the downward surface band bending. Understanding the charge transfer processes across the p-GaN/electrolyte interface is essential to optimize the material properties. Hence, in this work we focus on the photoelectrochemical investigation of p-GaN electrodes and the effect of different surface treatments on the (photo)current-voltage characteristics as well as on the stability during operation. Changes in the chemical composition caused by photoelectrochemistry are studied by XPS, and changes in the surface photovoltage are monitored by contact potential difference measurements.