HL 44: Nitrides: Preparation and characterization II

Time: Thursday 14:00–17:00 Location: EW 015

HL 44.1 Thu 14:00 EW 015

Low-temperature plasma-enhanced atomic layer deposition of tunable cobalt nitride thin films — •Lukas Alexander Kohlmaier[1,2], Matthias Kuhl[1,2], Ian D. Sharp[1,2], and Johanna Eichhorn[1,2] — [1]Walter Schottky Institute, Technische Universität München, Germany — [2]Physics Department, TUM School of Natural Sciences, Technische Universität München, Germany

Transition metal nitrides are an interesting class of materials due to their high mechanical hardness, as well as magnetic and catalytic properties. In this context, cobalt nitride is especially promising for applications in the semiconductor industry and for electrochemical energy conversion. However, the synthesis of uniform cobalt nitride thin films with controlled composition by atomic layer deposition (ALD) is still rather unexplored. Here, we deposit cobalt nitride thin films by plasma-enhanced (PE) ALD using a cobaltocene precursor. Specifically, we analyzed the impact of different co-reactants and their combinations, as well as deposition temperatures, on the growth characteristics and material properties. The deposition at low temperatures (< 200 °C) is only enabled by introducing an additional nitrogen plasma pulse at the end of each PE-ALD cycle to regenerate surface sites for the subsequent precursor adsorption. Increasing deposition temperatures can be leveraged to tune the Co/N ratio and thus the material properties from semiconducting to metallic. Overall, this work puts forward PE-ALD as a promising approach for tuning the material properties of metal nitrides.

HL 44.2 Thu 14:15 EW 015

High temperature growth of cubic gallium nitride by PAMBE — •Pascal Mahler[1], Dirk Reuter[1,2], and Donat J. As[1] — [1]Paderborn University, Department of Physics, Warburger Strasse 100, 33098 Paderborn — [2]Institut für Photonische Quantensysteme (PhoQS), Warburger Strasse 100, 33098 Paderborn

State of the art cubic gallium nitride layers when grown using plasma assisted molecular beam epitaxy (PAMBE) are usually deposited at a substrate temperature of around 720°C under slightly gallium rich conditions with one monolayer gallium present on the surface during growth. This allows to grow layers with <1% hexagonal GaN content and a roughness of 2-5nm. However, it was shown that for selective area growth of c-GaN higher substrate temperatures of at least 870°C are necessary and that growth of c-GaN can be stabilized at this temperature. Based on these findings, growth of c-GaN on un-patterned 3C-SiC (001) substrates at temperatures from 720°C to 900°C has been investigated. HRXRD measurements reveal that samples grown at a substrate temperature of 860°C showed a decrease in the ω-FWHM of the (002) c-GaN reflection compared to samples optimized for growth at 720°C which according to the Ayers model is linked to a decrease in dislocation density.

HL 44.3 Thu 14:30 EW 015

uniform large-area top-down GaN nanowire array fabrication with independently tunable diameter and spacing — •jingxuan kang, rose-mary jose, thomas auzelle, oliver brandt, and lutz geelhaar — Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany

Top-down approaches to nanowire fabrication offer advantages in controllability over bottom-up growth. However, achieving large-area nanoscale patterning with high throughput poses challenges. This study explores the use of nanoislands resulting from the dewetting of a metal film as mask for GaN nanowire fabrication. To optimize size and shape homogeneity, we have extensively varied the annealing conditions for Pt films of different thicknesses. A thermodynamic model accurately describes the experimental dependencies of island diameter and density on film thickness, as well as the linear relation between island spacing and diameter.

To overcome the fixed spacing-diameter relation imposed by dewetting, we employ digital etching of the GaN nanowires fabricated with the above islands. O_2 plasma oxidation followed by KOH wet etching enables a precise reduction of the nanowire diameter, increasing at the same time the spacing. Hence, additional freedom is gained for tailoring the nanowire array properties. Combining metal dewetting with controlled lateral nanowire etching offers a pathway for large-scale top-down nanowire fabrication with both high throughput and flexibility in dimension control.

HL 44.4 Thu 14:45 EW 015

Metal modulated growth of cubic InGaN by Molecular Beam Epitaxy — •Silas A. Jentsch[1], Mario F. Zscherp[1], Nicolai M. Gimbel[1], Anja Henss[2], Donat J. As[3], Sangam Chatterjee[1], and Jörg Schörmann[1] — [1]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Germany — [2]Institute of Physical Chemistry, Justus-Liebig-University Giessen, Germany — [3]Department of Physics, University Paderborn, Germany

Cubic InGaN alloys are candidate materials for next-generation optoelectronic applications as they lack internal fields and promise to cover large parts of the electromagnetic spectrum from the deep UV towards the mid infrared. However, there still exist many challenges with the growth of indium-bearing cubic nitrides. Here we apply a metal-modulated growth approach to improve the morphological and structural quality of the epitaxially grown nitride films as compared to the conventional growth in molecular beam epitaxy.

We report cubic InGaN layers (x(In) = 0.27) grown by metal-modulated plasma-assisted molecular beam epitaxy on c-GaN/AlN/3C-SiC/Si templates which should nominally causes the formation of alternating GaN and InN layers. Surprisingly, we found the formation of a InGaN/GaN superstructures for short InN growth times and a complete mixture of GaN and InN resulting in homogeneous c-InGaN layers for long InN growth times. High-resolution X-ray diffraction (HR-XRD), Atomic Force Microscopy (AFM) and photoluminescence studies reveals the structural and optical properties of our c-InGaN layers.

HL 44.5 Thu 15:00 EW 015

Molecular beam epitaxy of (Al,Sc)N nanowires — •Philipp John, Oliver Brandt, Achim Trampert, Lutz Geelhaar, and Thomas Auzelle — Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Hausvogteiplatz 5-7, 10117 Berlin, Germany

To extend the functionalities of classical III-nitride devices, combinations with transition metal nitrides are sought. Alloying AlN with ScN, for instance, can enhance its piezoelectric coefficient by up to a factor of 5, provided that the hexagonal wurtzite phase is maintained. Wurtzite (Al,Sc)N is thus a promising material for new types of surface/bulk acoustic devices, piezoelectric energy harvesters and high electron mobility transistors.

In this contribution, we demonstrate (Al,Sc)N growth on self-assembled AlN and GaN nanowire stems by molecular beam epitaxy for a wide range of concentrations. Wurtzite (Al,Sc)N is stabilized at low to moderate Sc concentrations, while a phase transition to the cubic rocksalt structure is found for high Sc concentrations. We will discuss the possibility of growing either axial or core/shell nanowire structures, depending on the (Al,Sc)N growth conditions. Axial nanowire structures offer the preferred geometry for piezoelectric devices, while core/shell nanowires are promising for realizing heterostructures combining group III-nitrides and transition metal nitrides.

HL 44.6 Thu 15:15 EW 015

Alloying and demixing in AlGaN/GaN nanowire heterostructures — •Rudolfo Hötzel[1], Lukas Lübken[1], Anton Schäning[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, University of Bremen, 28359 Bremen, Germany

Contrary to common knowledge that GaN nanowires (NW) only grow in the nitrogen-rich (N-rich) regime, a precise evaluation of the growth stoichiometry on the growth surface shows a growth window extending into the metal-rich regime. The AlGaN/GaN NW heterostructures grown by molecular beam epitaxy were analyzed by scanning transmission electron microscopy (STEM) and energy dispersive X-ray spectroscopy (EDX) as well as X-Ray diffraction (XRD). In that line, the influence of the III/V-ratio on the alloy formation of the ternary material for N-rich as well as metal-rich growth conditions is studied. In N-rich growth conditions the concentration in the alloy follows a linear trend up to close to the stoichiometric point of GaN, where the increased presence of Al leads to a change of surface adsorption which tips the growth over to the metal-rich regime, where we observe instantaneous growth of pure AlN despite the available Ga flux. However, after some time the growth switches over to incorporate Ga, forming an AlGaN alloy. In other words, even though Al possesses a higher reaction enthalpy and AlN forms, Ga accumulates on the growth surface resulting in another tip-over of the growth regime leading to AlGaN formation.

15 min. break

HL 44.7 Thu 15:45 EW 015

Highly spatially resolved investigation of structural and optical properties of a GaN-based p-n-diode — •Luca Greczmiel, F. Bertram, G. Schmidt, P. Veit, H. Eisele, A. Dempewolf, S. Petzold, J. Christen, A. Strittmatter, and A. Dadgar — Otto-von-Guericke-University Magdeburg, Magdeburg, Germany

GaN based devices are promising candidates for the next generation of high power electronics due to its high breakdown voltage, high electron mobility and highthermal conductivity. To understand the physics of these complex devices, the fundamental structural, electronic and material properties have to be investigated. In this study, we investigated a GaN based p-n-structure by cathodoluminescence microscopy (CL) directly performed in a scanning transmission electron microscope (STEM). The diode was grown by metal organic vapor phase epitaxy on top of an optimized template. An n-doped GaN layer with nominal 8x10^{18} cm^{-3} Si doping serves as current spreading layer. The p-n-junction is formed by a 970 nm thick GaN:Si layer and a 280 nm GaN:Mg layer with nominal doping concentration of 7x10^{17} cm^{-3} and 1-3x10^{19} cm^{-3}, respectively. In scanning electron micrsocopy images, we were able to determine the thickness of the GaN:Mg layer to 280 nm due to the distinct doping contrast. In STEM-CL linescans, we observe a drastic change of the recombination channels. The donor bound exciton emission is dominant at 357.2 nm in the n-GaN layer. Towards the p-n-junction, donor-acceptor-pair recombination (DAP) increases mono-exponentially in intensity and reaches its maximum at the p-n-interface.

HL 44.8 Thu 16:00 EW 015

Optical and chemical characterisation of $In_xGa_{1-x}N$ layers and nanowire arrays — •Aidan Campbell, Mikel Gómez Ruiz, Jingxuan Kang, Lutz Geelhaar, Oliver Brandt, and Jonas Lähnemann — Paul-Drude-Institut für Festkörperelektronik, Germany

$In_xGa_{1-x}N$ is an alloy with promising applications in solar water splitting, CO_2 conversion, and solar energy harvesting. Particular advantages are the tunable direct bandgap (0.7–3.5 eV), large absorption coefficient (10^5 cm^{-1}) and high mobility. In this study, we investigate $In_xGa_{1-x}N$ layers of nominal composition $0.025 < x < 0.12$ grown by plasma-assisted molecular beam epitaxy. A multi-spectroscopic approach is employed using cathodoluminscence and energy dispersive X-ray spectroscopy in a scanning electron microscope. Thereby, the chemical, optical, and structural properties can be analysed and correlated for the same local region of a specimen. Factors such as dislocation density, luminous intensity, spatial homogeneity of the composition, and the morphology will be discussed, as they are key properties in optimizing growth techniques enabling high efficiency devices. The dislocation density increases by a factor of 6 over this compositional range, reaching 1.5×10^9 cm^{-2} at $x = 0.12$. Compositional variations are evidenced by the spatial distribution of emission energies, which for different samples suggest local in-plane variations of $\Delta x = \pm 0.005$–0.008. Finally, the investigation is extended to $In_xGa_{1-x}N$ nanowires obtained from these layers by top-down processing.

HL 44.9 Thu 16:15 EW 015

MBE growth of cubic InxGa1-xN over the entire GaN/InN composition range — •Mario F. Zscherp[1], Silas A. Jentsch[1], Marius J. Müller[1], Vitalii Lider[2], Celina Becker[2], Limei Chen[1], Mario Littmann[3], Falco Meier[3], Andreas Beyer[2], Detlev M. Hofmann[1], Donat J. As[3], Peter J. Klar[1], Kerstin Volz[2], Sangam Chatterjee[1], and Jörg Schörmann[1] — [1]Institute of Experimental Physics I and Center for Materials Research, Justus-Liebig-University Giessen — [2]Materials Science Center and Faculty of Physics, Philipps-University Marburg — [3]Department of Physics, University Paderborn

Cubic InxGa1-xN is a candidate material for optoelectronic applications because they lack internal fields and promise to cover a vast range of emission wavelengths. However, the large discrepancy in interatomic spacing and growth temperatures of GaN and InN hinder the growth of c-InxGa1-xN with x(In) > 0.3. Several publications even report spinodal decomposition for intermediate In contents.

We overcome this perceived miscibility gap of c-GaN and c-InN using molecular beam epitaxy. The c-InxGa1-xN layers are grown on smooth c-GaN/AlN/3C-SiC/Si templates. Reciprocal space maps precisely monitor the composition, phase purity, and strain relaxation of the thin films. The photoluminescence data clearly demonstrate the full tunability of the emission energy from 0.71 to 3.24 eV. Furthermore, scanning transmission electron microscopy, photoluminescence data, and Raman spectroscopy infer a CuPt-type ordering for intermediate In contents as well as short-range ordering for all compositions.

HL 44.10 Thu 16:30 EW 015

Influence of Surface and Subsurface Damage on GaN Wafer Processing and Laser Facet Fabrication — •Saad Makhladi — Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Backside wafer thinning is an inherent part of the process chain to fabricate diode laser chips, enabling precise wafer cleavage with a high structural quality of the laser facets. However, in the case of gallium nitride (GaN) wafers, their brittleness poses challenges for process control, limiting the process yield. To optimize the backend processing of GaN ridge waveguide laser chips, GaN laser wafers underwent backside thinning employing two different technologies, namely lapping and grinding. The laser chips from these wafers were compared. The investigation included a detailed evaluation of backside surface morphology, wafer edge conditions, and subsurface damage (SSD), with respect to crystallinity, stress and wafer bow. As a result of this study, the probability of unintentional breakage of the wafers during processing has been reduced by a factor of two. The bow radius of thinned chips increases from 0.35 m to 0.65 m, and the depth of the SSD is reduced from 2.1 m to 0.8 m by employing Grinding instead of lapping. Certain wafer backside features were found to lead to cracks, which have the potential to propagate during cleavage to enhance terrace formation. i.e., to reduce the facet quality. Further investigations involve subsequent polishing of the GaN wafer backside and studying its impact on the facet formation of GaN Lasers.

HL 44.11 Thu 16:45 EW 015

HfN as conductive buffer for GaN epitaxy — •Christopher Lüttich, Florian Hörich, Jürgen Bläsing, André Strittmatter, and Armin Dadgar — Otto-von-Guericke Universität, Magdeburg

Hafniumnitrid-Schichten wurden mittels eines reaktiven DC magnetron Sputterprozess auf Si gewachsen unter verschiedenen Bedingungen. Diese Schichten wurden mit Galliumnitrid überwachsen, mit dem Ziel, vertikale Leitfähigjeit vom Substrat durch die Pufferschicht zum Galliumnitrid zu erreichen.