HL 33: Nitrides: Devices

Time: Wednesday 11:15–13:00 Location: H15

HL 33.1 Wed 11:15 H15

Influence of barrier height variations on the efficiency of AlGaN-based 225nm LEDs — •Markus A. Blonski[1], Jakob Höpfner[1], Tim Kolbe[2], Sylvia Hagedorn[2], Hyun Kyong Cho[2], Jens Rass[2], Paula Vierck[1], Tim Wernicke[1], Michael Kneissl[1,2], and Markus Weyers[2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Deep ultraviolet (DUV) light emitting diodes (LEDs) with emission wavelengths shorter than 225 nm exhibit low external quantum efficiencies (EQEs). Since the AlGaN multi-quantum well (MQW) active region remains a significant limiting factor for EQE, the effects of the barrier height in the MQW region on the radiative recombination efficiency (RRE), carrier injection efficiency (CIE) and light extraction efficiency (LEE) are examined. For this, the barrier composition is varied from $Al_{0.82}Ga_{0.18}N$ over $Al_{0.86}Ga_{0.14}N$ to $Al_{0.89}Ga_{0.11}N$. The lowest barrier leads to the highest peak EQE at 0.05 % and the highest barrier to an EQE peak below 0.02 %. The RRE, CIE and LEE are determined using continuous wave and pulsed electroluminescence measurements, determination of optical polarization and Monte Carlo raytracing simulations. The analysis shows that an increase in barrier height leads to an increase in RRE and LEE and a significant decrease in CIE for an overall decrease in EQE. Drift diffusion simulations indicate a notable increase in electron spillover across the $Al_{0.98}Ga_{0.02}N$ electron blocking layer to the p-side, attributable to a reduced band offset between barrier and electron blocking layer, reducing the CIE.

HL 33.2 Wed 11:30 H15

Homoepitaxy on AlN-bulk substrates with different offcut angles — •Sebastian Krüger[1], Sarina Graupeter[1], Massimo Grigoletto[1,2], Marcel Schilling[1], Sylvia Hagedorn[2], Carsten Hartmann[3], Thomas Straubinger[3], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [3]Leibniz-Institut für Kristallzüchtung, Berlin, Germany

Laser diodes in the UVC spectral range require high-quality AlN and AlGaN layers with low threading dislocation densities (TDD) and smooth surfaces. AlN substrates with a TDD of $< 10^4$ cm^{-2} are the ideal choice. In this work we investigate the influence of substrate off-cut (0.1° to 0.5°) and growth parameters (e.g. TMAl flow, V/III-ratio) on the morphology of homoepitaxially grown AlN buffer layers. A transition from step flow growth for a 0.2° miscut AlN substrate to step bunching for miscuts of 0.39° and above is observed for a growth temperature of 1070°C, a TMAl flow of 35 μmol/min and a V/III-ratio of 15. For a miscut of 0.27° step flow growth is still present but the terrace width shows significant variation. The RMS roughness increases from 0.11 nm (on 0.2°) to 0.45 nm (on 0.39°). For 0.5° miscut, the substrate terrace width is even smaller, i.e. the diffusion length must be reduced to avoid step bunching e.g. by increasing the V/III-ratio. Between V/III ratios of 15 and 60 we found morphologies such as island growth and step meandering with the lowest RMS roughness of 0.11 nm for a TMAl flow of 35 μmol/min and a V/III-ratio of 15.

HL 33.3 Wed 11:45 H15

Stabilizing Ta_3N_5 Thin Films Photoelectrodes by Defect Engineering — •Lukas M. Wolz[1], Gabriel Grötzner[1,2], Tim Rieth[1,2], Laura I. Wagner[1,2], Matthias Kuhl[1], Johannes Dittloff[1,2], Guanda Zhou[1,2], Saswati Santra[1,2], Verena Streibel[1,2], Frans Munnik[3], 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 — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Tantalum nitride (Ta_3N_5) is a highly investigated photoelectrode material due to its favorable optoelectronic properties for photoelectrochemical (PEC) energy conversion. However, intrinsic defects such as nitrogen vacancies and oxygen impurities play a crucial role in defining their optical, electronic, and photoelectrochemical properties. While the role of these defects in PEC activity is well investigated, their impact on material stability remains underexplored. We investigate the relationship between atomic-scale defects and macroscale PEC stability in Ta_3N_5 thin films. To reveal the impact of each defect type on the material properties, we introduced different defect concentrations in Ta_3N_5 by using three different precursors in the synthesis process. Low oxygen concentrations are found to increase long-range order but lead to high concentrations of deep-level defects, leading to increased charge recombination and decreased material stability. Conversely, higher oxygen contents result in reduced structural order but beneficially passivate deep-level defects, leading to improved stability.

HL 33.4 Wed 12:00 H15

Studying the carrier distribution of multicolor far-UVC LEDs by temperature dependent electroluminescence measurements — •Jakob Höpfner[1], Franz Biebler[1], Florian Kühl[1], Marcel Schilling[1], Anton Muhin[1], Massimo Grigoletto[1,2], Martin Guttmann[2], Gregor Hoffmann[3], Friedhard Römer[3], Tim Wernicke[1], Berndt Witzigmann[3], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), 12489 Berlin, Germany — [3]Lehrstuhl für Optoelektronik, Department EEI, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The low current injection efficiency (CIE) is one of the root causes for the poor external quantum efficiency of AlGaN based far-UVC LEDs. To improve the CIE it is necessary to gain insights into the carrier distribution and transport in the AlGaN multiple quantum well active region. Therefore, heterostructures were grown by metalorganic vapour phase epitaxy (MOVPE) with a varying number of QWs (2 –20) emitting at 233 nm and one single QW with an emission wavelength of 250 nm. This allows us to probe the carrier transport with the help of temperature dependent electroluminescence measurements (100 K - 340 K). The experimental findings were correlated with drift-diffusion simulations and Monte-Carlo ray-tracing simulations. Experiment and simulations show that the holes are weakly confined in the 233 nm emitting QWs and exhibit a long diffusion length over many QWs mainly due to thermal escape from the shallow barriers.

HL 33.5 Wed 12:15 H15

Influence of strain reduced HTA-AlN/sapphire templates with different offcuts on the performance of UVC LEDs — •Sarina Graupeter[1], Finn Kusch[1], Paula Vierck[1], Sylvia Hagedorn[2], Markus Weyers[2], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany

High temperature annealing (HTA) of sputter dposited AlN layers on (0001) sapphire substrates allows for fabrication low threading dislocation densitiy templates (TDD of 4 x $10^8 cm^2$) enabling UVC LEDs with improved external quantum efficiency and lifetime. However, due to the thermal expansion mismatch of the sapphire and the AlN, the AlN layers are under high compressive strain after cooling down from HTA at 1700°C. This can lead to strain relaxation and formation of dislocation half-loops during the subsequent growth of AlN and AlGaN layers, thus decreasing the radiative recombination efficiency (RRE). By growing a Si-doped AlN layer on HTA-AlN the in-plane compressive strain ϵ_{xx} is reduced by around 30% from -0.3 to -0.2. The impact of such an interlayer on the electro-optical properties of UVC-LEDs has been investigated with focus on the RRE. The RRE has been determined using cw and pulsed EL-measurements with the Titkov-Dai method. Using an AlN:Si interlayer shows an increase of the EQE value from 0.8% to 1%. Emission powers as high as 1.9 mW at 50 mA can be realized for UVC LEDs on strain reduced templates.

HL 33.6 Wed 12:30 H15

Characterisation of a Pt on-chip counter electrode on a GaN/AlGaN-ISFET Wheatstone bridge as pH-sensor — •Alexander Hinz[1], Niklas Krantz[1], Stephan Figge[1], and Martin Eickhoff[1,2] — [1]Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany — [2]MAPEX Center for Materials and Processes, University of Bremen, Bibliotheksstraße 1, 28359 Bremen, Germany

The influence of a Pt on-chip counter electrode on field effect transistors as pH-sensors was investigated. The intention was to reduce the size of the complete sensor structure consisting of ISFET, counter and reference electrode. In addition, the function of the Pt on-chip electrode was be compared to setup using an external Pt counter electrode to discuss stability and leakage. Furthermore, a Wheatstone bridge design is used to compensate temperature drifts. A reduction of this drift to 0.02 mV/°C was achieved. The long-time behavior of the temperature drift and also of pH changes was also analysed.

HL 33.7 Wed 12:45 H15

Efficiency analysis of 233 nm far-UVC LEDs with varied DPD AlGaN layer thickness beyond 298 K — •Paula Vierck[1], Jakob Höpfner[1], Marcel Schilling[1], Massimo Grigoletto[1,2], Markus Blonski[1], Tim Wernicke[1,2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand Braun Institut (FBH), Berlin, Germany

Light emitting diodes (LEDs) emitting in the far ultraviolet-C (far-UVC) spectral range offer applications in skin safe disinfection and gas sensing. In this work we analyze far-UVC LEDs with a distributed-polarization doped (DPD) p-AlGaN layer as this offers a promising alternative to Mg-doping. By compositionally grading the Al content of the AlGaN layer, a 3D hole gas can be generated exceeding the free hole concentration of conventionally Mg doped samples. The theoretically calculated charge profile depends on the grading and can be controlled by changing the DPD layer thickness or the alloy composition. In this work, five samples with DPD layer thicknesses between 25 nm and 150 nm were investigated by electroluminescence spectroscopy and numerical simulations. With decreasing DPD layer thickness we find an increase in the peak external quantum efficiency (EQE) with a maximum EQE of 0.37 % for a DPD thickness of 25 nm due to an increased hole concentration. Further analysis at temperatures of up to 353 K revealed a notable decline in the devices EQE down to 0.15 % at 353 K for a 25 nm thick DPD. This work will provide an analysis of the different contributing factors to the EQE drop with insights provided by simulations.