HL 52: Nitrides: Devices

Time: Friday 9:30–12:00 Location: EW 015

HL 52.1 Fri 9:30 EW 015

Heterostructure optimization of far-ultraviolet C light emitting diodes for improved efficiency and lifetime — •Tim Kolbe, Sylvia Hagedorn, Jens Rass, Hyun Kyong Cho, Jan Ruschel, Sven Einfeldt, and Markus Weyers — Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

The development of AlGaN-based light emitting diodes (LEDs) with emission wavelength in the far-ultraviolet-C (far-UVC) spectral region (< 240 nm) is driven by various applications like monitoring of gas concentrations (e.g. NO, NH3), the measurement of nitrates in water, or skin-friendly UVC-antisepsis. Although these LEDs have been improved over the recent years, the maximum emission power of the devices and their lifetimes are still low compared to UV LEDs in the longer wavelength range. In this presentation, an overview of our far-UVC LED development will be given. The influence of the heterostructure design and optimization of the epitaxial growth processes on voltage, emission power, and reliability of far-UVC LEDs will be discussed. Among other things, it will be shown how the design of the active region (e.g. quantum well numbers and quantum well barrier height) influences the voltage, optical power, and lifetime of the LEDs. Based on these optimizations, 233 nm LEDs with a maximum peak external quantum efficiency (EQE) of 1.13 % (wall plug efficiency of 0.82 %), an emission power of 9.7 mW and an operation voltage of 7.9 V at 200 mA were realized.

HL 52.2 Fri 9:45 EW 015

Hole transport in AlGaN-based far-UVC LEDs with multiple quantum wells — •Franz Biebler[1], Marcel Schilling[1], Jakob Höpfner[1], Massimo Grigoletto[2], Tim Wernicke[1], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institute of Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Understanding the hole transport in AlGaN-based far-UVC LEDs with wavelengths below 240 nm is crucial for improving the efficiency of these devices. In order to obtain an insight into this topic far-UVC LEDs with mixed wavelength AlGaN multiple quantum wells (MQW) were grown by metal organic vapor phase epitaxy (MOVPE), consisting of multiple QWs emitting at 233 nm and a single QW emitting at 250 nm. When the 250 nm wavelength QW is grown close to the n-side, it acts as an indicator for the presence of holes. In addition, the number of 233 nm QWs was varied between two and twenty. Temperature dependend electroluminescence-measurements have been performed on all samples. Analysis of the spectra shows a decrease in 250 nm intensity with increasing number of 233 nm QWs, due to capturing and confinement of the holes by 233 nm QWs. Comparing pulsed with continuous wave measurements for different current densities shows a significant decrease of intensity due to heating for the short wavelength QWs. Cooling of the LEDs down to 100 K reduces mobility of holes, which leads to a increase of the power ratio of 233 nm radiation to 250 nm radiation.

HL 52.3 Fri 10:00 EW 015

Impact of overgrowth conditions on characteristics of tunnel-junction LEDs — •Christoph Berger, Armin Dadgar, and André Strittmatter — Otto-von-Guericke-Universität Magdeburg

The implementation of tunnel-junctions (TJs) on the p-side of blue light emitting diodes (LEDs) offers an exciting way to realize transparent, highly conductive electrodes for enhanced hole injection, better current spreading and higher efficiency. We realized TJ-LEDs by growth of a 100 nm thick GaN:Ge layer with an electron concentration of $1\text{x}10^{20}$ cm^{-3} on top of the GaN:Mg layer in a continuous growth process by MOVPE. No in-situ or ex-situ activation steps were carried out and even 1 mm^2 LEDs show homogeneous light emission with improved output power. We propose that the activation of the p-GaN occurs during overgrowth with the GaN:Ge layer. Although n-doped GaN is known to block hydrogen diffusion, we assume an out-diffusion of H_2 promoted by V-pits that are formed during GaN:Ge growth in nitrogen ambient. Growing an additional GaN:Si layer in H_2-ambient on top of the TJ-LED for surface smoothening detoriates the optical and electrical characteristics of the device, suggesting repassivation of p-GaN by H_2 diffusion through the GaN:Ge layer. We will show results of different overgrowth schemes to elucidate the activation process for further improvement of device characteristics especially with regard to cascaded LEDs

HL 52.4 Fri 10:15 EW 015

A pressure sensitive silicon field effect transistor comprising a buffer-free piezoelectric $Al_{0.72}Sc_{0.28}N$ layer — •Rafael Ashkrizzadeh[1], Ole Gronenberg[2], Adrian Petraru[1], Lorenz Kienle[2,3], and Hermann Kohlstedt[1,3] — [1]Nanoelectronics, Faculty of Engineering, Kiel University, Germany — [2]Synthesis and Real Structure Group, Faculty of Engineering, Kiel University, Germany — [3]Kiel NanoSurface and Interface Science KiNSIS, Kiel University, Germany

In this work, we present a n-channel MISFET which consist of a 100 nm thick piezoelectric $Al_{0.72}Sc_{0.28}N$ layer in the gate stack. The functional $Al_{0.72}Sc_{0.28}N$ layer was deposited by dc/rf sputtering directly, i.e. buffer-free, on the Si-channel. The structure of the piezoelectric $Al_{0.72}Sc_{0.28}N$ layer as deposited on Si was investigated by wide-range reciprocal space mapping (RSM) and pole figures. Cross-sections taken of the gate stack were analyzed by Transmission Electron Microscopy (TEM) and chemical analyses by Energy Electron Loss Spectroscopy (EELS) line-scans, showed no indication of a residual interfacial layer.

HL 52.5 Fri 10:30 EW 015

Heterostructure design of 233 nm far-UVC LEDs with varied DPD layer thickness — •Paula Vierck[1], Jakob Höpfner[1], Marcel Schilling[1], Massimo Grigoletto[2], Tim Wernicke[1], and Michael Kneissl[1] — [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 have applications in skin safe disinfection and gas sensing. However, their internal quantum efficiency (IQE) is still low compared to LEDs emitting in the visible spectral range. Magnesium is commonly used as the p-type dopant in AlGaN materials. It has a high ionization energy which increases even more with rising aluminum content resulting in low hole concentrations and high series resistances particularly in devices with short emission wavelengths. Instead of doping the p-AlGaN layers with magnesium, a distributed-polarization doping (DPD) layer can be used to realize a Mg-free p-side. By composition grading from an AlN-layer to an 80% AlGaN, fixed negative space charges are introduced generating free holes in the DPD-AlGaN layer which enables a highly conductive and UV-transparent p-side. In this work, a series of 233 nm LEDs was simulated comparing two different drift diffusion simulation tools while varying the DPD thickness between 50 nm and 350 nm. The impact of the DPD thickness on the devices performance and its band structure were investigated, indicating a rising IQE with decreasing DPD thickness with a maximum value of 0.28 % at 54 A/cm^3 for a 50 nm thick DPD.

15 min. break

HL 52.6 Fri 11:00 EW 015

Optically pumped UVC VCSELs — •Estrella Torres Vasquez[1], Joachim Ciers[1], Nelson Rebelo[1], Filip Hjort[1], Michael Bergmann[1], Sarina Graupeter[2], Giulia Cardinali[2], Johannes Enslin[2], Tim Wernicke[2], Michael Kneissl[2,3], and Åsa Haglund[1] — [1]Chalmers University of Technology, Gothenburg, Sweden — [2]Technical University of Berlin, Berlin, Germany — [3]Ferdinand-Braun-Institut (FBH), Berlin, Germany

We demonstrate optically pumped ultraviolet-C (UVC <280 nm) vertical-cavity surface-emitting lasers (VCSELs) with an accurate cavity length control including a smooth etched N-polar surface. This was enabled by photo-assisted electrochemical etching of an $Al_{0.45}Ga_{0.55}N$ sacrificial layer with a Si doping of 4×10^{19} cm^{-3}. The VCSEL consists of an AlN cavity with 5 $Al_{0.30}Ga_{0.70}N/Al_{0.70}Ga_{0.3}N$ quantum wells and SiO_2/HfO_2 distributed Bragg reflectors. Photoluminescence measurements show a non-linear output power vs. pump power with a threshold pump power density down to 2 MW/cm^2 (incident power density) and a strong spectral narrowing down to 50 pm linewidth above threshold. The angular-resolved far-field spectrum changes from parabolic to non-dispersive around threshold with a 9° full width at half maximum. The main lasing wavelength only varies ∼1.2 nm between different UVC VCSELs across a 1.4 mm x 0.9 mm area, indicating an excellent cavity length control.

HL 52.7 Fri 11:15 EW 015

Temperature dependent electroluminescence studies of the influence of the electron blocking layer thickness on the emission characteristics of deep ultraviolet light emitting diodes — •Jakob Höpfner[1], Fabio Steyer[1], Marcel Schilling[1], Anton Muhin[1], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Earlier studies have shown that a low current injection efficiency (CIE) is partly responsible for the poor external quantum efficiencies (EQE) of AlGaN-based deep ultraviolet light emitting diodes (DUV-LEDs). In particular, the hole injection and the carrier distribution in the AlGaN multi quantum well (MQW) active region is not well understood. In order to get a better insight we have performed temperature dependent electroluminescence (EL) investigations of three-fold AlGaN MQW LEDs with a variation of the electron blocking layer (EBL) thickness. We found an optimal EBL thickness of 12 nm for the highest external quantum efficiency of our DUV-LEDs. Additionaly we observed no voltage penalty by increasing the EBL-thickness. Temperature dependent measurements revealed a difference in high temperature stability with changed electron blocking layer thickness of our devices. These experimental results are also supported by by drift diffusion simulations and enable us to further understand the carrier transport in DUV-LED heterostructures.

HL 52.8 Fri 11:30 EW 015

Facet degradation mechanisms of InGaN-based laser diodes emitting around 420 nm — •Erik Freier, Jos Boschker, Johannes Glaab, Anna Mogilatenko, Carsten Netzel, Martin Guttmann, Ji Hye Kang, Saad Makhladi, and Sven Einfeldt — Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

There are numerous possible applications for InGaN-based laser diodes in the field of metrology and sensing. One example is an external cavity diode laser for a rubidium-based optical atomic clock for use in space. In order to realize such an experiment, a diode laser with an emission wavelength of 420 nm with high reliability and stability in terms of emitted output power and beam direction is a basic prerequisite. The facet coating has a significant influence on the laser properties. In long-term cw operation, we tested the reliability of ridge waveguide lasers with various facet coating material systems consisting of Al_2O_3, SiO_2, TiO_2, and Ta_2O_5, respectively, in different atmospheres. The facet degradation was investigated using scanning and transmission electron microscopy combined with energy dispersive x-ray spectroscopy. As a general effect, we observe the formation of a SiO_x layer of several 100 nm thickness on the output facet during laser emission. This leads to fluctuations in the output power of the diode laser. We discuss several options to suppress this effect including the use of different coating material combinations, atmospheres and aging conditions. We present strategies to fabricate long-term stable facets of blue-violet lasers with a stable laser emission of 20 mW for thousands of hours.

HL 52.9 Fri 11:45 EW 015

Influence of the MQW heterostructure variations on the efficiency of AlGaN-based DUV LEDs — •Markus A. Blonski[1], Anton Muhin[1], Tim Kolbe[2], Sylvia Hagedorn[2], Hyun Kyong Cho[2], Jens Rass[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

Deep ultraviolet (DUV) light emitting diodes (LEDs) with emission wavelengths shorter than 235 nm exhibit an external quantum efficiency (EQE) below 2 %. The EQE is comprised by the product of carrier injection efficiency (CIE), light extraction efficiency (LEE) and radiative recombination efficiency (RRE). In this work we investigate the RRE of epitaxially grown DUV-LEDs emitting below 235 nm using the Titkov-Dai method through a fit of the EQE. The impact of AlGaN quantum well thickness, AlGaN barrier thickness and Al molar fraction on the RRE of DUV-LEDs is investigated. To apply the Titkov-Dai method, reliable EQE measurements across a wide range of current densities from few mA/cm^2 to few hundred A/cm^2 are required. Accurate measurements at low currents are performed in continuous wave (cw) operation. To exclude Joule heating of the device at high currents we use pulsed electroluminescence spectroscopy with the parameters being determined by varying the pulse width, frequency and delay time between pulsed measurements and comparing them to cw measurements. At currents above 5 mA, pulsed measurements are required to suppress heating and aging of the LEDs, and for currents below 1 mA cw measurements were used to achieve lower noise levels.