HL 10: Nitrides

Time: Monday 15:00–18:30 Location: H34

HL 10.1 Mon 15:00 H34

Degradation of the electrooptical properties of UVB LEDs observed by temperature dependent electroluminescence spectroscopy — •Jakob Höpfner[1], Priti Gupta[1], Martin Guttmann[1], Jan Ruschel[2], Johannes Glaab[2], Tim Kolbe[2], Arne Knauer[2], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

The operation of UVB-LEDs induces changes in their electrooptical characteristics, especially a gradual reduction in the emission power. As the lifetime of a device is a key property for its application, it is important to understand the microscopic processes governing their degradation behavior. We report an investigation on UVB-LEDs emitting at 310 nm before and after aging for 1000 h at 100 mA (67 Acm^{-2}) and a heatsink temperature of 70 °C using temperature(T)-dependent electroluminescence spectroscopy from 20 K - 340 K. Before aging, the external quantum efficiency (EQE) at 10 mA gradually increases with decreasing temperature from 0.8 % at 340 K to 1.8 % at 150 K and stays at that level for lower temperatures, indicating that EQE(T) is dominated by the radiative recombination efficiency. After 1,000 h of operation, the EQE has reduced to 0.45 % at 340 K and it shows a maximum of 1.4 % at 80 K. Also below 80 K, the EQE again decreases. These findings suggest a stress-induced reduction of both the radiative recombination efficiency and the carrier injection efficiency.

HL 10.2 Mon 15:15 H34

Short pulse operation of (Al,In)GaN laser diodes to increased linewidth and decreased coherence for laser displays — •Jannina J. Tepass[1], Lukas Uhlig[1], Dominic Kunzmann[1], Georg Brüderl[2], and Ulrich T. Schwarz[1] — [1]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]ams OSRAM Group, 93055 Regensburg, Germany

Red, green, and blue (RGB) laser diodes are used as the light source in laser displays in particular laser glasses for augmented, virtual, and mixed reality (AR/VR/MR). A narrow linewidth and corresponding high coherence will lead to speckles and non-uniform scattering at the gratings used for the projection into the eye box. Therefore, it is necessary to enhance the spectral linewidth of each laser diode to about 10 nm.

Mode competition causes a dynamic broadening of the laser spectrum already to about 1 nm. Here, we explore short pulse modulation to further increase the linewidth. A wavelength chirp at the beginning of each pulse is generating additional broadening at a pulse length of the order of a few nanoseconds. This chirp is the consequence of overshooting the carrier density above the threshold carrier density, resulting in a blue-shifted gain spectrum.

We investigate these broadening effects in blue and green (Al,In)GaN and red (Al,Ga)InP laser diodes with the help of a streak camera experiment. We took measurements for varying pulse length to analyse the spectral changes of those laser diodes and the behaviour with different pulse length.

HL 10.3 Mon 15:30 H34

Investigation of lateral charge carrier diffusion via micro-photoluminescence in InGaN MQWs and SQWs — •Conny Becht[1], Ulrich T. Schwarz[1], Michael Binder[2], Bastian Galler[2], Jürgen Off[2], Maximilian Tauer[2], Alvaro Gomez Iglesias[2], Heng Wang[2], and Martin Strassburg[2] — [1]Institute of Physics, Chemnitz University of Technology, 09126, Chemnitz, Germany — [2]ams-OSRAM International GmbH, Leibnizstr. 4, 93053 Regensburg, Germany

InGaN multi-quantum well (MQW) structures are used to obtain highly efficient blue light emitting diodes (LED). After the injection of carriers into the active layer of blue LEDs, a part of the carriers diffuses laterally before recombining (non-)radiatively. The diffusion behaviour in InGaN MQWs is up to now poorly understood.

In this study InGaN MQWs and single QWs (SQW) are investigated by micro-photoluminescence at room temperature. To study the diffusion behaviour, the excitation spot is decoupled from the detection area, which we call a pinhole scan. With the size of the excitation spot known, conclusions about the diffusion length of the charge carriers after optical pumping can be drawn. For deeper analysis of the diffusion behaviour the excitation density is varied and an external bias can be applied in addition.

The results show a long-range diffusion up to several 10 μm's. The energy shows a increasing blue shift with higher excitation power at the center (i.e. excitation spot).

HL 10.4 Mon 15:45 H34

Threshold and gain measurements of AlGaN-based UVC lasers — •Markus Blonski[1], Giulia Cardinali[1], Bernd Witzigmann[2], Norman Susilo[1], Daniel Hauer Vidal[1], Martin Guttmann[1], Tim Wernicke[1], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Department Elektrotechnik-Elektronik-Informationstechnik (EEI), University Erlangen-Nürnberg (FAU), Erlangen, Germany

Recently, first UVC laser diodes were demonstrated, with relatively high threshold current densities and pulsed operation. Critical parameters affecting the threshold are the electron and hole wavefunctions overlap and the optical confinement factor. While thicker quantum wells (QWs) yield higher confinement factors, the wavefunctions overlap in AlGaN QWs thicker than 3 nm is reduced due to the quantum-confined Stark effect (QCSE). In this work, the influence of QW thickness on lasing threshold and optical gain in AlGaN-based optically pumped lasers with SQWs between 3 nm and 12 nm emitting at 275 nm is studied. The lasing peak shifts to shorter wavelengths with respect to the spontaneous emission in thin wells, while the widest wells ex- hibit a red-shift. Similar lasing threshold power density was observed for all samples at around 1.4MW cm^{-2}. Variable stripe length method measurements showed positive net gain in all the samples with compa- rable values of differential net gain. Simulations of the material gain show that higher energy states contribute to the gain in wider wells, whereas in the 3 nm AlGaN QW the ground state provides the gain.

HL 10.5 Mon 16:00 H34

Drift-diffusion simulation of UVC-LEDs with varied emission wavelength — •F. Bilchenko[1], A. Muhin[1], M. Guttman[1,2], T. Wernicke[1], F. Römer[3], B. Witzigmann[3], and M. Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany — [3]Friedrich-Alexander-Universität Erlangen-Nürnberg, Lehrstuhl für Optoelektronik, Erlangen, Germany

The external quantum efficiency (EQE) of AlGaN-based deep ultraviolet (UVC) light emitting diodes (LEDs) decreases strongly for emission wavelengths (λ) below 240 nm by two orders of magnitude from 1% (240 nm) to 0.01% (217 nm). We showed that the light extraction efficiency (LEE) on wafer level decreases only by a factor of less than 3 from 4% (240 nm) to 1.5% (217 nm), leaving current injection efficiency (CIE) and radiative recombination efficiency (RRE) as possible major causes for the EQE decrease. In order to estimate the contribution of the CIE and RRE to the EQE we analyse measured electroluminescence characteristics by simulating an LED-series with nominally identical heterostructure but varying AlGaN composition in the active region in order to achieve λ ranging from 217 nm to 263 nm. Our results suggest that, in this wavelength range, the change in CIE contributes greatly to the decrease in EQE. For devices emitting at 263 nm and 249 nm the CIE stays roughly constant at around ∼50%, showing a significant decrease towards shorter λ, i.e. 48% at 240 nm and 2% at 217 nm. Based on these results, it appears that improvement of the CIE is paramount for achieving high-power UVC-devices.

HL 10.6 Mon 16:15 H34

Realizing tunnel junctions in AlGaN-based UVC light emitting diodes emitting at 232 nm — •Verena Montag[1], Frank Mehnke[1], Martin Guttmann[2], Luca Sulmoni[1], Christian Kuhn[1], Johannes Glaab[2], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

An ultraviolet C (UVC) -transparent p-AlGaN layer is needed to overcome the strong absorption of p-layers in deep UV light emitting diodes (LEDs). However, transparent p-AlGaN layers exhibit high sheet and contact resistances resulting in very large operating voltages. A promising alternative to standard p-contacts is the injection of holes into the AlGaN quantum well by tunnel heterojunctions (TJs). This allows for low resistivity n-layers and n-contacts on both sides of the device. We have successfully demonstrated fully transparent AlGaN-based TJ-LEDs emitting at 232 nm grown entirely by metal-organic vapor phase epitaxy. A thin GaN interlayer was implemented to enhance carrier tunneling at the TJ interface. Typically, the operating voltages, the output powers and the external quantum efficiencies of a 0.15 mm^2 TJ-LED featuring a 8 nm thick GaN interlayer are 24 V, 77 μW and 0.29%, respectively, measured on wafer at 5 mA in cw operation. This is the first reported TJ-LED in the wavelength range below 240 nm.

15 min. break

HL 10.7 Mon 16:45 H34

Influence of the AlGaN MQW growth temperature on the performance characteristics of DUV-LEDs with emission at 235 nm — •Marcel Schilling, Norman Susilo, Giulia Cardinali, Anton Muhin, Frank Mehnke, Tim Wernicke, and Michael Kneissl — Technische Universität Berlin, Institute of Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany

The realization of efficient deep ultraviolet light emitting diodes (DUV-LEDs) with emission wavelength near 235 nm is very challenging as the photon energy is very close to the band gap of AlN. For AlGaN layers with high Al mole fractions point defects like vacancies and impurities are easily incorporated during metal organic vapor phase epitaxy (MOVPE). Deep levels in the energy band gap associated with these point defects play a decisive role in non-radiative carrier recombination and consequently low internal quantum efficiency (IQE) of DUV-LEDs. Therefore, the understanding of the generation of point defects during the growth of high Al containing AlGaN layers is crucial for the development of efficient DUV-LEDs. In this study the influence of the AlGaN MQW growth temperature on the point defect density in 235 nm DUV-LEDs is investigated. DUV-LEDs were grown by MOVPE with MQW growth temperatures between 850 °C and 1100 °C. Temperature dependent PL measurements show that the point defect incorporation might be controlled with the MOVPE growth temperature. Electroluminescence measurements showed an increase in optical output power from 5 μW up to 300 μW at 20 mA for 235 nm DUV-LEDs for increasing MQW growth temperatures from 850°C up to 1020 °C.

HL 10.8 Mon 17:00 H34

Temperature dependent electroluminescence spectroscopy on AlGaN-based 235nm far-UVC LEDs with different active region growth temperature — •Paula Vierck, Jakob Höpfner, Martin Guttmann, Marcel Schilling, Luca Sulmoni, Anton Muhin, Tim Wernicke, and Michael Kneissl — Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany

Light emitting diodes (LEDs) emitting in the far ultraviolet-C (far-UVC) spectral range are promising for applications such as sensing and monitoring of gases, and skin safe disinfection. To improve their external quantum efficiency (EQE), it is crucial to understand the influence of growth parameters on their performance. In this paper, AlGaN-based LEDs emitting around 235 nm were investigated, while their active region growth temperature (T_{growth}) was varied between 900 °C and 1100 °C. Temperature dependent light output power-current-voltage characteristics (LIV) and spectra were measured on-wafer for temperatures between 100 K and 340 K. An increasing EQE was observed for increasing T_{growth} up to 1060 °C with a maximum value of 0.25 % at room temperature. This increase in EQE is attributed to a reduced point defect incorporation at higher active region growth temperatures. This finding is supported by a shift of the EQE vs. temperature maximum from a sample stage temperature of 220 K for an active region growth temperature of 900 °C to 260 K for an active region growth temperature of 1060 °C indicating an increased radiative recombination efficiency as a consequence of reduced point defect incorporation.

HL 10.9 Mon 17:15 H34

UVC-LEDs grown on HTA-AlN templates with low dislocation densities and high Si doping for strain management — •Sarina Graupeter[1], Michael Gail[1], Giulia Cardinali[1], Massimo Grigoletto[1,2], Sylvia Hagedorn[2], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH),Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

High temperature annealing (HTA) of AlN layers reduces the threading dislocation densitiy of such layers on sapphire substrates below $10^9$$cm^{-2}$ enabling UVC-LEDs with improved efficiencies. However, the HTA AlN-layers are under high compressive strain after cooling down, which leads to strain relaxation and defect formation during further LED heterostructure growth. Growing Si-doped AlN layers on HTA-AlN can reduce the strain. In this work we investigate the influence of such an AlN:Si-interlayer on the growth of UVC-LEDs emitting at 265nm on HTA AlN/sapphire templates, with different thicknesses and offcut angles. XRD measurements show a reduction of the compressive strain from 0.5% to 0.1% depending on layer thickness. Optical characterization with Photoluminescence and Cathodoluminescence shows, that depending on the layer thickness, defect formation in the form of Ga-rich plateus occurs. Electroluminescence measurements of full UVC-LED structures shows emission powers around 0.75mW at 20mA for the templates with 350nm layer thickness, which is comparable to LEDs grown on more expensive standard templates.

HL 10.10 Mon 17:30 H34

Distributed polarization doping for 265 nm UVC LEDs — •Massimo Grigoletto[1,2], Sarina Graupeter[1], Anton Muhin[1], Fedir Bilchenko[1], Eviathar Ziffer[1], Norman Susilo[1], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, 12489 Berlin, Germany

Distributed polarization doping (DPD) for optoelectronic devices with high aluminium mole fractions in AlGaN alloys is a promising concept for achieving high hole densities and simultaneously minimize the light absorption on the p-side.

A continuous grading downward from an higher to a lower aluminium mole fraction in the alloy composition of the AlGaN layer, leads to a steady piezoelectric polarization change creating a negative net charge that is compensated by free holes. In this way, dopant-free without thermal activation is possible, which can exhibit orders of magnitude higher hole densities than comparable magnesium impurity doped AlGaN layers.

In this study we investigate the influence of the DPD graded layer design on the electro optical properties and material properties of 265 nm AlGaN-based LEDs by varying the thickness and aluminium gradient. The LED heterostructures with and without the different DPD-layers are grown by metal organic vapor phase epitaxy and analyzed by electroluminescence measurements, transmission spectroscopy, high resolution X-ray diffraction, atomic force microscopy, capacitance voltage spectroscopy and determination of sheet and contact resistance.

HL 10.11 Mon 17:45 H34

Temperature dependent photoluminescence spectroscopy of self-assembled InGaN superlattices embedded in GaN Nanowires — •Rudolfo Hötzel[1], Manuel Alonso Orts[1], Tim Grieb[2], Jörg Schörmann[1], Stephan Figge[1], and Martin Eickhoff[1] — [1]University of Bremen, Institute of Solid State Physics, 28359 Bremen, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

In this work, the structure and optical properties of single InGaN/GaN Nanowires grown by plasma assisted molecular beam epitaxy have been analyzed by micro photoluminescence (PL), scanning transmisssion electron microscopy (STEM) and energy dispersive X-rayspectroscopy (EDX). These nanowires consist of an indium rich core that contains a self assembled InGaN superlattice within a GaN shell. In order to understand the origin of their optical properties, PL was combined with STEM analysis to idendify single nanowire structures. Temeperature-dependent as well as polarized PL were conducted on isolated nanowires and revealed an emission consisting of broader bands at room temperature and multiple narrow peak superpositions at low temperatures. The overall emission ranges from 1,8 eV to up to 2,9 eV. One contributing factor to their emission is the indium distribution within the superlattice, which was determined by EDX. A polarization dependence of the PL signal with respect to the growth direction was observed at 4K and room temperature and ascribed to the indium rich core (parallel contributions) and self assembled superlattice (perpendicular contributions).

HL 10.12 Mon 18:00 H34

Luminescence Characteristics of GaInN/GaN Multi Quantum Wells with Ga and N Polarity — •Samar Hagag, Malte Schrader, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut f. Angewandte,TU Braunschweig,Germany

The optical properties of Ga- and N-polar GaInN/GaN Multi Quantum Wells (MQW) grown on sapphire and bulk N-polar GaN substrates, respectively, using metal-organic chemical vapor deposition were investigated using photoluminescence (PL) and time-resolved photoluminescence (TRPL) spectroscopy. The low temperature PL spectrum of N-polar GaInN/GaN MQW showed a reduced PL intensity and broad emission peak compared to their Ga-polar counterparts and shorter PL decay times of N-polar GaInN/GaN MQW were observed in low temperature TRPL measurements. Using non-resonant excitation, N-polar GaN PL spectra at low temperature have shown the presence of luminescence lines associated with structural defects of the type I1 basal-plane stacking faults. The low PL intensity and short PL decay time at low temperature of N-polar GaInN/GaN MQW indicate the existence of non-radiative recombination at low temperature likely caused by partial dislocations associated with the stacking faults. For the fabrication of pyramidal nanostructures serving as nanooptical light emitters, wet etching of N-polar GaInN/GaN MQW in KOH solution has been used. The etched N-polar samples have shown an improved luminescence and the absence of stacking fault-related luminescence lines. Optimization of the growth procedure for N-polar GaInN/GaN MQW is required in order to reduce structural defects.

HL 10.13 Mon 18:15 H34

Pump-probe studies with varying excitation wavelengths applied for GaInN/GaN single quantum wells — •Malte Schrader, Rodrigo De Vasconcellos Lourenco, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik & Laboratory for Emerging Nanometrology, Technische Universität Braunschweig, Germany

The goal of this study is to characterize the ultra-fast carrier dynamics in c-plane GaInN/GaN single quantum wells (SQWs). To make transmission experiments possible the samples were grown on double-side polished sapphire by MOVPE. Furthermore we use time-resolved photoluminescence (TRPL) to measure the radiative and non-radiative carrier lifetimes of the samples from 5 K up to 300 K. By using a transmission-mode degenerate pump-probe technique at 300 K the generated state occupation in the SQW can be observed directly. Different excitation wavelengths produced using an optical parametric amplifier provided pulses of nominal 35 fs duration.

We observe carrier lifetimes at room temperature in the low ns range by TRPL, which are strongly impacted by nonradiative processes. Pump-probe at 300 K gives a fast characteristic relaxation time in the low ps range and a slower component associated with the decay observed in TRPL. This indicates that a fast initial non-equilibrium relaxation is followed by a component representing recombination of a quasi-equilibrium carrier ensemble. A surprising observation is the relatively slow relaxation time of a few ps, which one would rather expect to be in the femtosecond range.