HL 25: Poster: Nitrides

Time: Monday 15:00–19:00 Location: P2-OG2

HL 25.1 Mon 15:00 P2-OG2

In-situ metal deposition for low contact resistance on n-type ZnSe — •Johanna Janssen[1], Torsten Rieger[1], Arne Hollmann[2], Lars Schreiber[2], and Alexander Pawlis[1] — [1]Peter Grünberg Institute 9 and JARA-FIT, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany

As promising for quantum computing, electron spin qubits realized in electrostatically-defined quantum dots (QDs) were studied in GaAs and Si systems. Our goal is to define QDs in the 2D electron gas of ZnSe/(ZnMg)Se quantum wells, as ZnSe combines the advantages of both systems, a direct band gap and nuclear spin-free host lattice. An important parameter is the n-doping profile of ZnSe. We use ex-situ implantation of Fluorine donors to provide quantitative and spatial control of the doping concentration. However, the main challenge is to fabricate ohmic contacts on n-ZnSe. Low contact resistance and a linear current/voltage characteristic even at low temperatures (100 mK) are crucial for charge-based read-out of the QDs. In the context of studies on ZnSe for optoelectronics, the contact metals Al, Mg and In have shown to be suitable candidates for contact fabrication.

Here, we report our studies on the transport characteristics through as-grown ZnSe layers for different doping concentrations, contact metals, and processing techniques such as surface etching or thermal activation. Additional to the mostly performed ex-situ metallization processes, we deposited the metal in-situ to avoid surface oxidation, thus reducing the contact resistance.

HL 25.2 Mon 15:00 P2-OG2

Optoelectronic coupling between colloidal quantum dots and quantum wells — •Mikko Wilhelm, Maria Steiger, Ruichan Lyu, Wolfgang Parak, and Wolfram Heimbrodt — Philipps-Universität Marburg

The interaction between colloidal CdS/ZnS core-shell quantum dots on a semiconductor substrate with buried quantum well is studied. The MBE grown quantum well structures consist of a 5nm thick ZnSe quantum well with a (Zn,Mn)Se barrier of different Mn concentrations. Quantum dots of different sizes have been deposited via spin coating on the surface of the quantum well structure. In order to investigate the energy transfer between the excitons in the quantum dots and the excitons in the quantum wells, cw- and time resolved luminescence measurements as well as photoluminescence excitation measurements have been performed at low temperatures (10K) and external magnetic fields up to 7 Tesla. To reveal the transfer properties the results of the hybrid system will be compared to the separated systems and discussed in detail.

HL 25.3 Mon 15:00 P2-OG2

Optical and magnetic studies of MBE-grown ferromagnetic CrSe and CrS layers in zincblende structure — •Johannes Röder[1], Richard T Moug[2], Kevin A Prior[2], Dana Vieweg[3], Hans-Albrecht Krug von Nidda[3], Alois Loidl[3], and Wolfram Heinbrodt[1] — [1]Department of Physics and Material Science Center, Philipps University, Marburg, Germany — [2]Institute of Photonics and Quantum Sciences, SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh , United Kingdom — [3]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

Theoretical calculations predicted Chromium chalcogenides in the zinc blende (ZB) structure to be promising candidates for half-metallic spin-aligner at room temperature. Unfortunately, the thermodynamically stable phase of CrSe and CrS is the hexagonal NiAs-structure. Different approaches have been tested to stabilize the ZB state. Most promising were CrSe layers grown on GaAs substrates with either ZnSe or ZnSe/MgS as buffer layers and CrS-layers embedded between ZnMgS layers. All samples have been grown by MBE. We investigated the ferromagnetic properties and magnetic phase transitions and the respective optical properties of these films by temperature dependent SQUID and time resolved photoluminescence measurements. Ferromagnetic phase transitions have been found. The highest yet observed Curie temperature was at 255 K. Optical measurements revealed excitonic transitions of ZnSe, CrSe as well as the type-II CrSe-ZnSe interlayer transition.

HL 25.4 Mon 15:00 P2-OG2

Characterization of epitaxial graphene nanoribbons (GNR) — •Jantje Schommartz[1,2], Talieh Ghiasi[2], Alexey Kaverzin[2], Johannes Aprojanz[1], Christoph Tegenkamp[1], and Bart J. van Wees[2] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Deutschland — [2]Physics of Nanodevices, University of Groningen, Netherlands

Epitaxially grown graphene nanoribbons (GNR) self-assembled on pre-structured SiC nanofacets are recently shown to be single channel ballistic conductor even at room temperature on a length scale greater than ten micrometers [1]. The reported long mean free path, as well as the presence of topologically protected edge states, makes the GNR a subject of intense interest at present. In contrast to GNR, patterned lithographically by etching graphene, epitaxially grown GNR on SiC mesas shows well-defined edge states. In this study, Conductive Atomic Force Microscopy (CAFM) and PeakForce TUNA (PF-TUNA) probe techniques are applied to study the current profile and height profile of both sidewall and natural-step GNR. Compared with the CAFM measurements where the sample and tip are in contact, in the PF-TUNA measurements the sample is oscillating and the tip-sample position is controlled via monitoring the maximum force on the tip which eliminates the lateral forces on the sample. Detection of the electrical current only on the sidewalls and natural steps of the SiC mesa pattern confirms the selective growth of freestanding GNR on SiC nanofacets.

[1] Baringhaus et al., Nature 506, 349 (2014)

HL 25.5 Mon 15:00 P2-OG2

***Ab initio* metal-insulator transition in doped silicon** — Edoardo G. Carnio[1], Nicholas D. M. Hine[1], and •Rudolf A. Römer[1,2] — [1]Department of Physics, The University of Warwick, Coventry CV4 7AL, UK — [2]Centre for Scientific Computing, The University of Warwick, Coventry CV4 7AL, UK

The Anderson metal-insulator transition (MIT) has long been studied, but there is still no agreement on its critical exponent when comparing experiments and theory. In this work, we employ *ab initio* methods to study the MIT that occurs in sulfur-doped silicon (Si:S) when the concentration of the dopants is increased. We use linear-scaling DFT, as implemented in the ONETEP code, to study model Si:S systems at realistic concentrations (i.e. a few impurities, in a large simulation cell). We then use the resulting *ab initio* Hamiltonian to build an effective tight-binding Hamiltonian for larger systems close to the critical concentration of the MIT. We finally use multifractal finite-size scaling to characterise the MIT in Si:S, including the *ab-initio*-determined possible interactions between the donated electrons.

HL 25.6 Mon 15:00 P2-OG2

In-situ monitoring of opto-coupler degradation during high energy proton irradiation — •Heinz-Christoph Neitzert[1], Carmine Pellegrino[1], Giovanni Landi[1], Sophie Seidel[2], Jürgen Bundesmann[2], and Andrea Denker[2] — [1]Dept. of Industrial Engineering (DIIn), Salerno University, Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Protons for Therapy, Hahn-Meitner Platz 1, 14109 Berlin, Germany

The degradation under a high energy proton beam of a series of industrial opto-couplers, consisting of GaAs based LEDs and Silicon phototransistors, has been tested by monitoring ex-situ typical parameters, like current-transfer-ratio, receiver photo-current and -voltage, transistor gain and LED current-voltage characteristics. The devices have been irradiated with a 68 MeV proton beam with different fluences between 10^{11} p+/cm^2 and 10^{13} p+/cm^2. These are typical conditions that are relevant for space missions. In order to distinguish between GaAs emitter degradation and Silicon receiver degradation, the photocurrents of both emitter and receiver diodes have been monitored in-situ during the irradiation. In this way we could verify that the emitter degradation saturates for intermediate irradiation levels of 10^{12} p+/cm^2, while the receiver degradation is continuous and for 10^{13} p+/cm^2 a photocurrent decrease of about 5 orders of magnitude has been found. A beneficial effect of the irradiation in terms of switching speed has been observed, which may be interesting for low-level irradiated devices.

HL 25.7 Mon 15:00 P2-OG2

CW and Pulsed mode Characterization of LED — •Laveen P. Selvaraj, Thomas Hünnerkopf, Matthias Wachs, and Ulrich T. Schwarz — Chemnitz University of Technology, Experimental Sensor Science, Reichenhainer str. 70, 09126 Chemnitz, Germany

Lambertian source LEDs are most commonly used for lighting applications, with an angular intensity distribution following a cosine law with respect to the viewing angle of the emitting surface [1]. The current investigation deals with the characterization of standard Lambertian LED sources using Continuous Wave (CW) and Pulsed mode. In CW mode, a DC bias current was applied to measure the low current range with long source-on time (>0.2 s) with high sensitivity. For high currents, the pulsed mode was used at a low duty cycle to limit heat generation. The total flux emitted was calculated by integrating the peak intensity with Lambert's cosine law. The emission rate in normal direction was determined by a photodiode. We use this setup to measure the standard current-voltage (IV) and current-optical output power (IP) characteristics as reference for other measurements. Nonthermal efficiency droop of LEDs at high currents densities, which is caused by non-radiative recombinations, is observed as well as thermal droop [2]. The effect of heat generation on the IP and IV characteristics can be observed by varying the duty cycle of the pulsed mode at high currents. References: [1] A. Ryer, Light Measurement Handbook. International Light Inc., Technical Publications Department, 1997. [2] E. F. Schubert, Light emitting diodes. Cambridge University Press, 2003.

HL 25.8 Mon 15:00 P2-OG2

Ohmic V-based contacts on n-Al0:8Ga0:2N for deep UV LEDs — •Luca Sulmoni[1], Martin Guttmann[1], Johannes Enslin[1], Christian Kuhn[1], Frank Mehnke[1], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

Minimizing the contact resistance on both *p*- and *n*-layers in deep ultraviolet (UV) light emitting diodes (LEDs) is essential for improving the efficiency of these devices suffering from the high operating voltages and resistive heating. Ohmic contacts to n-$Al_xGa_{1-x}N$ are challenging especially for high AlN mole fractions mainly due to the low electron affinity. Standard metal schemes such as Ti/Al/Ti/Au can form ohmic *n*-contacts only up to about 40% AlN mole fraction. In this study, we investigated the influence of vanadium as first-layer metal in a four-metal electrode V/Al/Ni/Au.

We evaluated the contact characteristics under various annealing conditions. The V/Al/Ni/Au contacts on n-$Al_{0.8}Ga_{0.2}N$ annealed at 800°C under N_2 atmosphere exhibit ohmic characteristics with contact resistivities as low as $8{\cdot}10^{-5}$ Ωcm^2 at a current density of 0.1 kA/cm^2. In contrast, Ti/Al/Ti/Au contacts form rectifying Schottky barriers of about 6 V. We finally demonstrate the fabrication of UVC LEDs emitting at 265 nm using both electrodes. A significant reduction of the operating voltage compared to the standard Ti/Al/Ti/Au electrodes was observed with V_{op} 11 V instead of 21 V at a current of 50 mA.

HL 25.9 Mon 15:00 P2-OG2

Influence of p-AlGaN superlattice and quantum barrier composition on electro-optical characteristics of UVC-LEDs — •Pascal Röder[1], Christian Kuhn[1], Sylvia Hagedorn[2], Arne Knauer[2], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institute of Solid State Physics — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

Ultraviolet light emitters can be used for the disinfection of water, sterilizing surfaces, and detecting gases such as NO_x and SO_2. However, the external quantum efficiency (EQE) of AlGaN-based LEDs in the UVC wavelength range (200 nm to 280 nm) is still relatively low. In this paper, we investigate the effect of carrier confinement on the EQE of UVC-LEDs emitting near 270 nm.

Electron leakage into the p-side of UVC-LEDs is a major contributor to the low efficiency. In order to investigate the carrier confinement we varied the aluminum content of the quantum barriers and the Mg-doped AlGaN short period superlattice (p-SPSL). The results indicate an intricate interplay of the band offsets of all interfaces. This includes the confinement of electrons in the quantum wells and the electron leakage from the last barrier into p-SPSL.

By improving the carrier confinement UVC-LEDs emitting at 270 nm with an output power of 0.9 mW at 20 mA (EQE 0.95 %, measured on wafer) have been fabricated.

HL 25.10 Mon 15:00 P2-OG2

Simulation of the temporal behavior of LEDs during fast modulation — •Dominic Kunzmann and Ulrich T. Schwarz — Chemnitz University of Technology, Experimental Sensor Science, Reichenhainer Str. 70, 09126 Chemnitz

In blue and green light emitting diodes (LEDs) based on InGaN quantum wells, the strain induced piezoelectric field and the field due to the built-in potential of the p-n junction causes a tilt of the band profile. The consequence is a red-shift of the emission (quantum confined Stark effect, QCSE) and reduction of the wave function overlap and consequently of the radiative recombination rate. Because the field of the p-n junction depends on the bias voltage, the radiative recombination rate can be modulated by the bias. In particular, a faster recombination is observed for zero or reverse bias [1]. This results to a rapid increase in light intensity at the trailing edge of a driving pulse. Here we simulate the temporal behavior of the light emission during modulation with a rectangular driving current. We are interested in the time averaged internal quantum efficiency (IQE). We observe an increase of the IQE for a standard set of LED parameters. The maximum gain of several percent points was observed for driving frequencies of 0.2 GHz to 1 GHz for the chosen parameters.

References: [1] U. T. Schwarz et al., Interplay of built-in potential and piezoelectric field on carrier recombination in green light emitting InGaN quantum wells, Appl. Phys. Lett. 91, 123503 (2007).

HL 25.11 Mon 15:00 P2-OG2

Continuous wave(CW) and Pulsed Characterization of LED — •Laveen Prabhu Selvaraj — Chemnitz University of Technology, 09107 Chemnitz, Germany, Experimental Sensor Science

Lambertian source LED is most commonly used for which states that radiation depends on the viewing angle of the emitting surface [1]. The current investigation deals with the characterization of standard Lambertian sources using CW and pulsed mode. CW mode was used to observe the small changes in low currents by sourcing continuously without switching it off (>0.2 s). To avoid heat generation on high current, source was switched on in regular intervals of time which is between 1 microsecs to 0.25 secs. The DC bias current was applied in two different modes for the characterization of the LED source. The continuous wave mode was used to sweep the LED on low current from 0 to 15 mA. On high currents more than 15 mA, the pulsed mode was used. The total flux emitted can be calculated by integrating the peak intensity with cosine law. The current from the photodiode placed normal to the emitter was used to calculate the peak intensity. The droop in efficiency of LEDs on high currents are caused by non-radiative recombinations [2]. These recombinations result in the heat generation in the LED. The heat generation cause electrical and optical power drop in the LED system. This effect of heat generation can be observed by varying the duty cycle of the Pulsed mode on high currents. References: [1]A. Ryer, Light Measurement Handbook. Newburyport: International Light Inc., Technical Publications Department, 1997. [2]E. F. Schubert, Light emitting diodes.Cambridge University Press, 2003.

HL 25.12 Mon 15:00 P2-OG2

Investigation of crystal properties of epitaxially grown BAlN layers with boron content in the lower percentage range — •Jan-Patrick Scholz[1], Sebastian Bauer[1], Oliver Rettig[2], Yueliang Li[3], Haoyuan Qi[3], Johannes Biskupek[3], Ute Kaiser[3], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University, 89081 Ulm, Germany — [2]Institute of Optoelectronics, Ulm University, 89081 Ulm, Germany — [3]Central Facility of Electron Microscopy, Ulm University, 89081 Ulm, Germany

AlGaN based UV-LEDs development is currently in progress. These LEDs still suffer from low external quantum efficiencies. One of the major problems is the high amount of threading dislocations, which emerge mostly due to the lattice mismatch of AlGaN layers on AlN.

Wurtzite BN is expected to have a smaller lattice constant than AlN, what helps to compensate the increase of the lattice constant when adding gallium to AlN.

First samples of AlBN layers on AlN substrate show a big change in surface morphology and luminescence properties: Typically columnar growth is found, and the surface roughness increases. We show cross section TEM micrographs to reveal details about the growth mode. According to SIMS, ~5% boron are incorporated in the AlBN layers.

HL 25.13 Mon 15:00 P2-OG2

Photoluminescence Pumping Characteristics in Ga(N,As,P) /(B,Ga)(As,P) Heterostructures — •Florian Dobener[1], Robin C. Döring[1], Peter Ludewig[2], Wolfgang Stolz[1,2], and Sangam Chatterjee[3] — [1]Faculty of Physics and Materials Science Center, Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]NAsPIII/V GmbH, Am Knechtsacker 19, D-35041 Marburg, Germany — [3]Institute of Experimental Physics I, Justus-Liebig-University Giessen, D-35392 Gießen, Germany

The realization of monolithically integrated on-chip laser sources for optical data transmission remains one of the major goals of optoelectronic integration nowadays. The quaternary III-V material system Ga(N,As,P) promises to fulfil this task - as composition variations allow both, bandgap engineering and tuning of the lattice constant to the one of Si through the control of nitrogen and phosphorous incorporation, potentially covering the near-infrared regime as well as the telecom wavelength.

Here, we investigate a series of Ga(N,As,P) multiple quantum well samples grown by MOVPE. The well thickness is varied between 1.5 and 9.9 nm. The bandgaps of the quantum-well material and of the barriers are determined by means of wavelength-modulation spectroscopy. Furthermore, photoluminescence excitation experiments reveal which of the layer contributes to the optical emission process. Thereby, some restrictions to the excited carrier injection from the (B,Ga)(As,P) barrier to the Ga(N,As,P) quantum well layer are found depending on the quantum well thickness.

HL 25.14 Mon 15:00 P2-OG2

Conoscopic Investigation of Birefringence in GaN Samples — •Lukas Uhlig, Ines Trenkmann, Matthias Wachs, and Ulrich T. Schwarz — Chemnitz University of Technology, Experimental Sensor Science, Reichenhainer Str. 70, 09126 Chemnitz, Germany

The propagation of light through GaN layers is influenced by birefringence. That means the refractive indices of the ordinary and extraordinary rays are different and depend in the case of the extraordinary one on the angle between the extraordinary ray and the c-axis. Superposition of these both rays leads to a change of the state of polarization compared to the initial ray. This effect can be observed well using the introduced conoscopic experimental setup, where the sample is located between a polarizer and an analyzer, that is rotated by 90°. For uniaxial crystals, like GaN, with the c-axis orientate parallel to the optical axis the observed conoscopic images show concentric rings and a dark "maltese" cross in the middle, wich is called isogyre. We describe a method for the evaluation of the resulting conoscopic pattern and compare these with simulated images using refractive indices $\Delta n = n_e - n_o$ from various studies [1-3].

References: [1] S. Shokhovets, R. Goldhahn and W. Richter, J. Appl. Phys. 94, 307 (2003). [2] G. Yu, H. Ishikawa and M. Umeno, Jpn. J. Appl. Phys. 36, L1029 (1997). [3] S. Ghosh, P. Waltereit and K. H. Ploog, Appl. Phys. Lett. 80, 413 (2002).

HL 25.15 Mon 15:00 P2-OG2

Investigation of electrical conduction mechanisms in Si-doped GaN — •Stefan Kammer[1], Klaus Irmscher[2], Frank Mehnke[1], Tim Wernicke[1], Johannes Enslin[1], Norman Susilo[1], Martin Guttmann[1], Luca Sulmoni[1], Matthias Bickermann[2], and Michael Kneissl[1,3] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Leibniz-Institut für Kristallzüchtung, Max-Born-Str. 2, 12489 Berlin, Germany — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12480 Berlin, Germany

The electronic properties of Si-doped GaN grown by metal-organic vapor phase epitaxy with various doping concentrations were investigated by temperature dependent Hall-effect measurements. In contrast to the commonly described behavior of $n \propto \exp(-E_\mathrm{A}/k_\mathrm{B}T)$, the data show an increase of the Hall carrier density below 50 K. This implies the presence of multiple conduction mechanisms, requiring a more complex evaluation of the Hall carrier density. For this reason, a model considering carrier densities and mobilities from different conduction mechanisms has been applied in order to extract donor and acceptor concentrations as well as ionization energies from the Hall data. To determine the concentrations of Si and background impurities SIMS measurements have been performed. The influence of donor concentration and the effects of impurity conduction and interface charges on the temperature dependent charge carrier density will be discussed.

HL 25.16 Mon 15:00 P2-OG2

Determination of threading dislocation density of AlN on sapphire substrates by X-ray diffraction — •Daniel Pacak[1], Johannes Enslin[1], Tim Wernicke[1], Sylvia Hagedorn[2], Arne Knauer[2], Carsten Hartmann[3], Heike Oppermann[3], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik — [3]Leibniz-Institut für Kristallzüchtung, Berlin

AlN on sapphire substrates with low threading dislocation density (TDD) is essential for the growth of efficient UV light emitting diodes. The TDDs of a series of AlN layers on sapphire with different dislocation densities, ranging from $1{\cdot}10^9\mathrm{cm}^{-2}$ to $2{\cdot}10^{10}\mathrm{cm}^{-2}$ were determined by X-ray diffraction (XRD) by measuring the FWHM of ω-scans for different reflections. For this, we first separated the broadening of the XRD peaks due to finite coherent length and wafer curvature from the broadening by tilt and twist. Then the tilt and twist contributions were determined by two different approaches. One method was based on obtaining the tilt value by measuring a reflection in asymmetric geometry and calculating the corresponding twist value. In a second approach the tilt and twist components were determined by extrapolating the FWHM against the χ-angle. From these tilt and twist values we calculated the TDDs for correlated and randomly distributed dislocations, based on the models of Chierchia et al. and Dunn & Kogh. Finally we compared the TDD obtained by XRD with the results from defect selective etching.

HL 25.17 Mon 15:00 P2-OG2

Light extraction in UVC LEDs grown on ELO AlN/sapphire templates — •Sarina Graupeter[1], Martin Guttmann[1], Frank Mehnke[1], Christian Kuhn[1], Tim Wernicke[1], Mickael Lapeyrade[2], Arne Knauer[2], Sven Einfeldt[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

Light emitting diodes (LEDs) in the UVC spectral range have various promising applications, e.g. gas sensing and water disinfection. However, the external quantum efficiency strongly decreases with decreasing emission wavelength. This can be partly explained by a reduced light extraction efficiency (LEE) due to an increasingly transverse magnetic polarized emission, with increasing Al content and total reflection at the AlN/sapphire interface. In this contribution, we investigate UVC LEDs using epitaxially laterally overgrown (ELO) AlN on patterned sapphire substrates, which can potentially increase the LEE due to photon redirection. The emission wavelength and the optical polarization has been varied by adjusting the aluminium content in the quantum wells, thus changing the optical polarization. Using ray tracing simulations and measurements of the far field pattern the emission has been studied in dependence of the optical polarization and the ELO geometry. Both, simulation and experiment, show that the influence of the optical polarization on the far field is negligible. However, the ELO geometry has significant influence on the far-field pattern enabling new pathways for the improvement of light extraction.

HL 25.18 Mon 15:00 P2-OG2

Investigation of AlGaN multiple quantum wells for deep ultraviolet emission using temperature and excitation power density dependent photoluminescence spectroscopy — Christoph Reich, •Baran Avinc, Johannes Enslin, Norman Susilo, Christian Kuhn, Tim Wernicke, and Michael Kneissl — Technische Universität Berlin, Institute of Solid State Physics

Light emitting diodes in the deep UV spectral region have various interesting applications, e.g. gas sensing or water disinfection. However, the output power and performance of devices emitting in the UVC (200 nm - 280 nm) spectral region are poor compared to devices emitting at longer wavelenghts. This low external quantum efficiency in the UVC spectral region can be explained by the challenging carrier injection and lower internal quantum efficiency as well as a reduced light extraction due to a switching of the optical polarization from TE (transverse electric) to TM (transverse magnetic) for decreasing emission wavelengths. Using temperature and excitation power density dependent photoluminescence spectroscopy, we investigated the influence of the AlGaN-based multiple quantum well (QW) active region design on the internal quantum efficiency, the quantum confined Stark effect, and the radiative recombination processes. In a systematic study, the QW width as well as the aluminum contents in the QWs and barriers have been varied. The measured photoluminescence results will be compared with simulations based on $\mathbf{k}\cdot\mathbf{p}$-perturbation

theory including a discussion of the influence of the QW design on the optical polarization.

HL 25.19 Mon 15:00 P2-OG2

Impact of a SiN surface layer on the core-shell growth of InGaN quantum wells around GaN microrods — •Christian Tessarek[1,2], Stefanie Rechberger[3], Christel Dieker[3], Martin Heilmann[2], Erdmann Spiecker[3], and Silke Christiansen[1,2,4] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH — [2]Max-Planck-Institut für die Physik des Lichts, Erlangen — [3]Friedrich-Alexander-Universität Erlangen-Nürnberg, Institut für Mikro- und Nanostrukturforschung & Center for Nanoanalysis and Electron Microscopy (CENEM) — [4]Physics Department, Freie Universität Berlin

GaN microrods were grown by metal-organic vapor phase epitaxy (MOVPE) using a self-catalyzed and Si-induced growth mode [1]. Spontaneous formation of SiN on the surface of microrods leads to enhanced vertical growth due to the antisurfactant and stabilization effect of SiN [2]. Core-shell growth of InGaN multiple quantum wells with GaN barriers is carried out on microrods with different growth times and thus different heights. Microrods with a short growth time are completely covered with an InGaN shell. For microrods with an extended height the InGaN shell only forms at the upper part leaving the lower part free of any deposition. Based on structural investigations including transmission electron microscopy a growth model will be proposed to explain this behaviour. Furthermore, optical properties of the different core-shell structures will be discussed.

[1] C. Tessarek et al., J. Appl. Phys. **114**, 144304 (2013).
[2] C. Tessarek et al., Cryst. Growth Des. **14**, 1486 (2014).

HL 25.20 Mon 15:00 P2-OG2

The effective potential energy drop as a control parameter for the sheet carrier density of two-dimensional electron gases in AlGaN/GaN heterostructures — •Dennis Mauch, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig, Germany

We introduce the effective potential energy drop in AlGaN/GaN heterostructures as a control parameter for the sheet carrier density of two-dimensional electron gases (2DEG). As a consequence of the non-centrosymmetry of the wurtzite structure in group-III nitrides and the large ionicity factor of the covalent metal-nitrogen bond, a large spontaneous polarization is oriented along the hexagonal c-axis. In addition, group-III nitrides are highly piezoelectric. Hence, in AlGaN/GaN heterostructures, where the AlGaN layer is grown pseudomorphically on top of GaN, strain leads to piezoelectric polarization in the AlGaN epitaxial layer. Under certain conditions, the induced electric fields, due to polarization discontinuity at the heterointerface, give rise to the formation of a 2DEG. We also investigated the influence of an additional AlN-interlayer at the AlGaN/GaN interface in order to reduce alloy disorder scattering and thus to reach higher 2DEG mobilities. The samples were grown in our commercial MOVPE system/reactor on c-oriented sapphire substrates. The electrical properties were obtained via Hall effect measurements at room temperature using the van der Pauw configuration, and the structural details via HR-XRD. Our aim is to optimize these structures to highest mobilities and small sheet carrier densities down to the quantum Hall regime.

HL 25.21 Mon 15:00 P2-OG2

Formation of I2-type basal-plane stacking faults in In0.25Ga0.75N multiple quantum wells grown on a (10-11) semipolar GaN template — •yueliang li[1], haoyuan qi[1], tobias meisch[2], matthias hocker[3], klaus thonke[3], ferdinand scholz[2], and ute kaiser[1] — [1]Central Facility of Electron Microscopy, Electron Microscopy Group of Materials Science, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Institute of Optoelectronics, Ulm University, Albert-Einstein-Allee 45, 89081 Ulm, Germany — [3]Institute of Quantum Matter, Ulm University, Albert-Einstein-Allee 45, 89081 Ulm, Germany

InGaN/GaN heterostructures grown on semipolar GaN templates have received considerable attention over the past years for the fabrication of LEDs operating in the green spectral range. However, the quantum efficiency is still substantially lower than that of their blue counterparts due to the defects such as dislocations and stacking faults, which appear during the growing process.

In this work, I2-type basal stacking faults were observed in In0.25Ga0.75N multiple quantum wells grown on a (10-11) GaN template by HRTEM. The structure and formation mechanism of the I2-type stacking faults were investigated. The relationship between the In content in the InGaN layer and the density of the I2-type stacking faults is discussed.

HL 25.22 Mon 15:00 P2-OG2

Epitaxial growth and characterization of thin AlBGaN layers with low boron content — •Natja Steiger[1], Jan-Patrick Scholz[1], Sebastian Bauer[1], Oliver Rettig[2], Tomáš Hubáček[2], Haoyuan Qi[3], Yueliang Li[3], Johannes Biskupek[3], Ute Kaiser[3], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institut of Quantum Matter/ Semiconductor Physics Group, Ulm University, 89081 Ulm, Germany — [2]Institute of Optoelectronics, Ulm University, 89081 Ulm, Germany — [3]Central Facility of Electron Microscopy, Ulm University, 89081 Ulm, Germany

The development and design of efficient LEDs for the ultraviolet regime is of great interest, aiming at applications like water purification and sterilization. Using AlGaN as material for such an ultraviolet solid-state light source, the desired emitted wavelength can be chosen by variation of relative Al/Ga content. We try to incorporate boron into this material to reduce the lattice mismatch between the optically active AlBGaN layer and AlN barrier layer of the QWs. Lattice matching leads to a reduction of QCSE caused by strain.

Our AlBGaN thin layers are grown by MOVPE on AlN templates with sapphire as substrate at growth temperatures up to 1400°C. To examine the crystal structure and quality X-ray diffraction, scanning- and transmission electron microscopy and atomic force microscopy are performed. By exciting the samples with an ArF-laser, photoluminescence spectroscopy is used for further characterization of the samples.

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Angular dependence of the Raman scattering intensity of optical phonons in wz-GaN — •Simon Brehm, Christian Röder, Cameliu Himcinschi, and Jens Kortus — TU Bergakademie Freiberg, Institute of Theoretical Physics, Leipziger Str. 23, D-09599 Freiberg, Germany

Gallium nitride (GaN) as one of the most promising wide-bandgap semiconductors has been studied intensively over the two last decades due to its numerous opto- and microelectronic applications. In this work, the angular dependence of the Raman scattering intensity of optical phonon modes was investigated in backscattering geometry using an a-plane oriented GaN thin film. For this purpose, two experimental approaches were realized as the observed Raman scattering intensity is connected with the scattering geometry by the so-called Raman tensor elements. At first the GaN sample was turned in-plane with respect to the laboratory coordinate system while the polarization directions of exciting and scattered light remained the same. Secondly, sample and position of the analyzer were fixed with respect to the laboratory coordinate system and the polarization direction of the incident laser beam was rotated. Using relative Raman scattering cross sections [1] the experimental results were found to be in an excellent agreement with theoretical simulations.

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[1] Irmer et al. J. Appl. Phys. **116** (2014) 245702

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Optical biosensing with InGaN/GaN quantum wells — •Benedikt Hörbrand[1], Sabyasachi Chakrabortty[2], Martin Schneidereit[3], Dominik Heinz[3], Sebastian Bauer[1], Florian Huber[1], Tanja Weil[2], Ferdinand Scholz[3], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University, 89081 Ulm, Germany — [2]Institute of Organic Chemistry III, Ulm University, 89081 Ulm, Germany — [3]Institute of Optoelectronics, Ulm University, 89081 Ulm, Germany

Sensing biomolecules is essential in the fields of medicine, pharmacy and biotechnology. Normally it goes along with previous preparation steps like labelling of the molecules. To avoid these complex preparation processes we are aiming at a detection of such molecules using pre-treated semiconductor surfaces. The optical emission of surface-near polar InGaN/GaN quantum well layers reacts on the attachment of biomolecules to the surface.

The surface-near band bending is changed by the deposition of biomolecules like ferritin, which are adsorbed on a functionalized layer on the surface. As a result the emitted wavelength and intensity of the emission changes, depending on the biomolecule.