HL 25: Poster Session: GaN - Optical Properties & Preparation and Characterization & Devices

Time: Monday 16:00–19:00 Location: Poster D

HL 25.1 Mon 16:00 Poster D

Feedback Control of a Quantum Dot Cavity-QED System — •Franz Schulze, Alexander Carmele, and Andreas Knorr — Institut für Theoretische Physik, Technische Unitversität Berlin, Germany

We investigate externally pumped quantum dots embedded in a nanocavity within an equation-of-motion-approach.[1] In the limit of many emitters and photons the standard cluster expansion scheme is a well-known factorization procedure to investigate quantum light emission.[2] A possible way of stabilizing this emission and its statistical properties is a time delayed self-feedback as it is described classically by the Lang-Kobayashi model.[3] Here, we discuss the transition from the classical [4] to the quantum mechanical model and present first steps toward a fully quantized feedback description.

[1] M. Richter *et al.*, Phys. Rev. Lett. **103**, 087407 (2009)
[2] C. Gies *et al.*, Phys. Rev. A **75**, 013803 (2007)
[3] R. Lang and K. Kobayashi, IEEE J. Quantum Electron. **16**, 347 (1980)
[4] C. Otto *et al.*, Phys. Status Solidi B **247**, 829 (2010)

HL 25.2 Mon 16:00 Poster D

Time Resolved Generallized Ellipsometry — •Christian Heinrichs, Chris Sturm, Helena Franke, Steve Linke, Tammo Böntgen, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

For the investigation of optical switching processes, change of the polarization in perovskite-based heterostructure, and its realization in devices, the change of the dielectric function (DF) as a function of time in dependence on the excitation is important up to the ps time scale. Ellipsometry is a suitable and sensitive tool for the determination of the DF. Up to now, no commercial ellipsometers are available which allow to perform time resolved measurements in this time regime. Therefore, we present a custom made ellipsometer setup which allows such measurements and devote special emphasis to the calibration routine, the data acquisition techniques, and the accuracy of the obtained data.

Our setup contains a linear polarizer and a compensator for both, the preparation of the polarization state of light and its analysis after reflection from a sample. Thereby we can measure the Stokes vector and determine the complete Mueller matrix. The signal is detected by a streak camera system which allows a time-resolution down to the ps range. The setup also allows PL measurements without changing the detection area on the sample at nearly the same time as the ellipsometry measurements. This allows a correlation of the time dependence of the luminescence processes and the corresponding contribution of the electronic components in the DF.

HL 25.3 Mon 16:00 Poster D

Spectral signatures of excitonic BEC in Cu_2O — •Rico Schwartz[1], Siegfried Sobkowiak[1], Dirk Semkat[1], Thomas Koch[2], Holger Fehske[2], and Heinrich Stolz[1] — [1]Institut für Physik, Universität Rostock, D-18051 Rostock, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, D-17489 Greifswald, Germany

When looking for an excitonic BEC one of the most important points to be clarified is the kind of spectral signatures of such a BEC. We present recent theoretical investigations for a weakly luminescing BEC of trapped excitons in Cu_2O. For exciton numbers below the critical density the spectrally resolved integrated intensity behaves Bose-like with a linear dependence on the exciton number. Above the critical number the spectrum consists of a Bose-like distribution (luminescence from thermalized excitons outside the condensate), two gaussian peaks with energetic position symmetrically around the chemical potential (contribution of the Bogoliubov quasiparticles in the condensate), and a third gaussian peak at the chemical potential (the weakly luminecing condensate). The dependence of the total integrated intensity shows a kink at the critical exciton number and has a different slope below and above this point. This results from the different luminescence efficiencies of excitons in a condensate and in thermal states. We also present recent experiments which confirm the theoretical predictions.

HL 25.4 Mon 16:00 Poster D

Resonance Raman and Selection Rules in Cuprous Oxide — •Ovidiu Dorin Gordan, Salvan Georgeta, Schäfer Philipp, Fronk Michael, and Dietrich R.T. Zahn — Semiconductor Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

Long known as a red pigment, cuprous oxide (Cu_2O) is one of the principal oxides of copper which crystallizes in a cubic structure. Even though Raman studies of Cu_2O in resonance conditions were reported in several papers, the relative intensities and the origin of the spectral features is still under debate. In this work natural, one side polished (100), (110), and (111) terminated Cu_2O single crystals purchased from SurfaceNet GmbH are investigated using a micro-Raman configuration. The selection rules in resonance conditions are revisited using parallel and cross polarization configurations for two different excitation energies, 2.41 eV and 3.82 eV, which probe in resonance with different excitonic transitions.

HL 25.5 Mon 16:00 Poster D

Vibrational spectra of different phases of Cu_xO_y — •Christian Reindl, Thomas Sander, Daniel Reppin, Bruno K. Meyer, and Peter J. Klar — I. Physikalisches Institut, Justus Liebig University, Heinrich-Buff-Ring 16, 35392 Giessen

The vibrational spectra of different phases of copper oxide – CuO, Cu_2O and Cu_3O_4 – are investigated. The Raman spectra of the three phases differ in the number of Raman active modes and exhibit variations in the peak positions of the signals. To establish a relationship between growth condition and crystal phase obtained, a series of sputtered thin-film samples with varied oxygen concentrations was studied by Raman spectroscopy. The Raman spectra were recorded in backscattering geometry at room temperature using an 633 nm excitation laser. In addition, Raman spectra were obtained during in-situ tempering to study the stability of the various phases. Raman depth scans were performed to investigate changes of the copper oxide phase as a function of sample thickness.

HL 25.6 Mon 16:00 Poster D

Photoluminescence investigations of differently annealed and doped SrTiO3 single crystals in varying atmospheres — •Juliane Hanzig, Barbara Abendroth, Florian Hanzig, Hartmut Stöcker, and Dirk C. Meyer — TU Bergakademie Freiberg, Institut für Experimentelle Physik, Leipziger Straße 23, 09596 Freiberg

Strontium titanate is a well-known transition metal oxide for memory applications, which also exhibits interesting optical properties. Here, we utilized intrinsic and extrinsic doping of strontium titanate single crystals, e. g. oxygen vacancies, niobium and lanthanum. To introduce oxygen vacancies, $SrTiO_3$ single crystals were vacuum-annealed. The existence of free charge carriers was controlled by means of infrared (IR) spectroscopy. A model to extract the electron density will be figured out. The determination of defect levels in the band gap related to surface and bulk oxygen vacancies was performed by photoluminescence (PL) measurements. The interaction between surface defects and atmosphere is highlighted by using different temperatures and gases. We found a time dependence of the photoluminescence intensity, which was attributed to oxygen incorporation at the surface during laser exposure. In addition, surface sensitive investigation methods like elastic recoil detection analysis (ERDA) and X-ray photoelectron spectroscopy (XPS) were used to clarify surface absorption effects under different ambient conditions. Implications for the situation at metal-oxide contacts will be presented.

HL 25.7 Mon 16:00 Poster D

Energy transfer dynamics of the Mn $3d^5$ and Tb $4f^8$ luminescence in ZnS:Mn,Tb nanostructures — •Uwe Kaiser[1], Sebastian Gies[1], Limei Chen[1], Wolfram Heimbrodt[1], Sebastian Geburt[2], and Carsten Ronning[2] — [1]Dept. of Physics, Philipps-University Marburg — [2]Institute of Solid State Physics, Friedrich-Schiller University

The photoluminescence (PL) decay characteristics of ZnS nanostructures doped with different luminescence centers can be described by a

modified Förster model taking into account the concentration quenching as well as the dimensionality of the nanostructures. To check the general validity of this model, nanostructures of diverse morphology were doped with two different luminescence centers, namely Terbium and Manganese with concentrations of $4{\cdot}10^{-6}$% to 4% by ion implantation. The PL transients of the internal $Tb^{2+}(4f^8)$ and the $Mn^{2+}(3d^5)$ transitions were measured over four orders of magnitude.
For wires as well as for belts an enhancement of the effective dimensionality could be observed for increasing Mn concentration at 10K. Measurements at room temperature indicate, however, again a reduction of the effective dimensionality, due to the enhanced transfer probability inside the subsystem of the luminescence centers. Temperature treatment and ion irradiation were used to incorporate additional defects for a thorough investigation of the energy transfer influenced by nonradiative killer centers.

HL 25.8 Mon 16:00 Poster D

Investigation of Parametrizations for the Valence Band Structure of GaN — •Felix Schwarz, Steve Lenk, and Erich Runge — Institut für Physik und Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, 98693 Ilmenau, Germany

We calculate the dielectric function of hexagonal GaN including the A-, B-, and C-excitons using a multi-valence band formalism. The importance of excitons for the interpretation of reflectance spectroscopy of GaN was emphasized by several experimental groups, but only recently theoretical calculations were presented [1]. We obtain the dielectric function from a numerical solution of an initial-value problem [2] via an exponential split-operator method, taking into account the full 6x6 valence band structures of several parametrizations calculated by other groups. We present the complex dielectric function as well as the deduced reflectivity spectra of the excitons in GaN. After comparing the results to recent experimental spectra, we present an semi-empirically adapted parametrization for the valence band structure.

[1] A. T. Winzer, G. Gobsch, and R. Goldhahn, Phys. Rev. B **74**, 125207 (2006).

[2] S. Glutsch, *Excitons in Low−Dimensional Semiconductors*, Springer Heidelberg (2004).

HL 25.9 Mon 16:00 Poster D

Optical second harmonic spectroscopy of GaAs excitons in crossed electric and magnetic fields — •David Brunne[1], Marco Lafrentz[1], Victor Pavlov[2], Roman Pisarev[2], Dmitri Yakovlev[1], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Optical second harmonic generation is a powerful tool to investigate exciton resonances in semiconductors. Recent measurements on GaAs in an external magnetic field have revealed a rich spectrum of magneto-excitons related to carrier Landau levels with numbers up to eight[1]. In the present work we extend this research by additional application of an electric field, which modifies considerably the spectrum of magneto-excitons detected via second harmonic generation (SHG). Electric and magnetic fields are applied perpendicular to each other and to the (001) crystal axis of a GaAs sample. In the absence of these fields SHG intensity is zero as the nonlinear process is forbidden in the electric-dipole approximation. Polarization characteristics are analyzed. We discuss the rich spectrum of magneto-excitons which stems from the complex energy and spin structure of the valence band.
[1] V. V. Pavlov, A. M. Kalashnikova, R. V. Pisarev, I. Sänger, D. R. Yakovlev, and M. Bayer, Phys. Rev. Lett. **94**, 157404 (2005)

HL 25.10 Mon 16:00 Poster D

Long-range transport of indirect excitons by moving strain dots in a GaAs double quantum wells — •Snežana Lazić, Rudolf Hey, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

We report on the acoustic transport of spatially indirect (inter-well) excitons in a GaAs/AlGaAs double quantum well. The photo-excited excitons are trapped within an array of moving strain dots with a spatial periodicity of a few μm. These dynamic potential dots are formed by interfering two surface acoustic waves (SAWs) propagating along orthogonal non-piezoelectric crystallographic directions. The trapping mechanism relies on a dynamic type-I modulation of the band edges via the deformation potential interaction. The exciton lifetime is voltage-tunable via the top semi-transparent gate and is substantially longer than the SAW period. We show that such system offers a controllable way for artificially producing cold exciton gases for the investigation of quantum collective effects.

Using spectrally and spatially resolved low-temperature photoluminescence measurements, we have observed the formation of a luminescence ring around the laser illumination spot, which is discussed in terms of thermalization of long-living indirect excitons. Under acoustic excitation, we demonstrate the long-range transport (of the order of 100 μm) followed by recombination at the inter-well exciton transition energy. These experiments allow us to determine the distribution of indirect excitons as well as to probe the exciton-exciton interactions within the dot array.

HL 25.11 Mon 16:00 Poster D

Photoluminescence line shape features of carbon delta-doped GaAs heterostructures — Jürgen Schuster[1], •Tae Yang Kim[1], Edwin Batke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Physikalisches Institut der Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum, Germany

The PL line shape properties of quasi two-dimensional electron gas (2DEG) in setback delta doped GaAs heterostructure at liquid helium temperature are studied. We illuminated the sample with two different excitation energies, below and above the band gap of AlGaAs. The whole density of states of 2DEG can be directly visible due to the relaxation of k-selection rule. We observed clearly the ground and the first excited 2D subbands. A simple fit to the line shape including broadening demonstrated that there is an exponential low-energy tail associated with the ground subband. The fit precisely reveals the subband bottom energies, the quasi Fermi-energy, the electron temperature and the integrated strengths, enabling an accurate determination of the subband populations and the transition probability. A self-consistent calculation of subband properties including the potential contribution of the delta doping reproduces the subband separations and recombination intensities well. The dependence of excitation intensity, temperature and magnetic field strength on the PL line shape is studied.

HL 25.12 Mon 16:00 Poster D

Near-field scanning optical microscopy of infrared emitting semiconductor nanostructures — •Alexander Senichev[1], Uri Givan[1], Oussama Moutanabbir[1], Vadim Talalaev[2], and Peter Werner[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle (Saale), Germany — [2]Centre for Innovation Competence SiLi-nano, Martin-Luther-University, Karl-Freiherr-von-Fritsch-Str. 3, 06120 Halle (Saale), Germany

The fabrication of low-dimensional semiconductor materials with controlled variation of structural parameters in nanometer scale is fascinating activity in solid-state research. These structures are interested for study the fundamental physical properties and possibilities of their application in advanced optoelectronic devices as well. Optical spectroscopy is one of the most powerful tools for investigation of electronic and optical properties of low-dimensional semiconductor nanostructures which are determined by quantum-mechanical confinement of electronic wave functions. Using near-field scanning optical microscopy (NSOM) allows one to study these properties of single nanostructures with sub-wavelength spatial resolution.

In this work we address abilities of our NSOM technique to perform space resolved experiments at low temperature. We will report on results of a near-field optical study of semiconductor nanostructures, e.g. single Si nanowires and InGaAs nanoclusters. The combination of NSOM data with TEM, SEM, and Raman spectroscopy opens the possibility to get complete information about properties of low-dimensional nanostructures.

HL 25.13 Mon 16:00 Poster D

Direct determination of piezoelectric coefficients for GaN by AFM — •Uwe Röder[1], Frank Lipski[2], Martin Feneberg[3], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institute of Quantum Matter / Semiconductor Physics Group, Ulm University — [2]Institute of Optoelectronics, Ulm University — [3]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

For the piezoelectric coefficients of GaN a broad range can be found in literature (d_{33} = 2...4 pm/V; d_{15} = 2.9...3.3 pm/V). Mostly, these parameters have been determined from polycrystalline thin layers. We present here data obtained on thick semi-insulating Fe doped GaN lay-

ers grown by HVPE. By applying AC voltages with varying amplitude and frequency to top and bottom contacts, and measuring the elongation of the thick GaN layer with an AFM tip in contact mode and lock-in technique to record the phase-correlated periodic change of the quadrature diode signal, we get a direct measure of the piezoelectric constant d_{33}. We obtain a value of $d_{33} = (2.2 \pm 0.3)$ pm/V. Similarly, d_{15} could be obtained by recording the shear displacement. Effects of mechanical sample resonances etc. have to be carefully avoided.

HL 25.14 Mon 16:00 Poster D

Low voltage spatially resolved cathodoluminescence measurements on nitride semiconductors — •Matthias Hocker[1], Ingo Tischer[1], Robert A.R. Leute[2], Ferdinand Scholz[2], and Klaus Thonke[1] — [1]Institut für Quantenmaterie, Gruppe Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

Cathodoluminescence (CL) measurements with very low acceleration voltages can drastically improve spatial resolution. For low electron energies of $550 - 2000$ eV and small working distances of $2 - 4$ mm in the scanning electron microscope, we achieve a spatial resolution down to the diffusion length of the generated excitons. We demonstrate the application of low voltage CL measurements to InGaN quantum wells, and compare the results to Monte Carlo simulations.

HL 25.15 Mon 16:00 Poster D

Untersuchung von InGaN-basierten Quantenpunktsystemen mittels STEM Z-Kontrast — •Alexander Würfel[1], Thorsten Mehrtens[1], Christian Tessarek[2], Timo Aschenbrenner[2], Detlef Hommel[2] und Andreas Rosenauer[1] — [1]AG Elektronenmikroskopie — [2]AG Halbleiterepitaxie, Institut für Festkörperphysik, Universität Bremen, Deutschland

InGaN-basierte (Laser-)Dioden emittieren im blauen bis grünen Spektralbereich. Die Verwendung von Quantenpunkten (QPe) in der aktiven Schicht verbessert die Effizienz und ermöglicht neue Anwendungen wie z.B. Einzelphotonemitter.

Es werden InGaN/GaN-Strukturen untersucht, die mittels MOVPE unter Verwendung komplexer Temperaturprofile gewachsen wurden. Die spinodale und binodale Entmischung wird als treibende Kraft für die QP-Bildung vorgeschlagen. Unüberwachsene Proben zeigen große In-reiche Inseln auf der Oberfläche, die sich beim Überwachsen auflösen. Zusätzlich bildet sich eine Meanderstruktur (ca. 20% In), aus der beim Überwachsen die QPe hervorgehen.

Die aufgenommenen hochauflösenden HAADF-STEM-Bilder werden quantitativ ausgewertet. Dazu wird die von der Kernladungszahl Z abhängende Intensität mit simulierten Bildern verglichen, um die In-Konzentration zu bestimmen.

Die QPe sind als Fluktuationen mit höherer In-Konzentration sichtbar und aus ihrer Ausdehnung lässt sich die Konzentration im QP abschätzen. Zusätzlich ist bei einigen Proben eine zweite InGaN Schicht zu erkennen, die beim Überwachsen mit GaN entstanden ist.

HL 25.16 Mon 16:00 Poster D

Photoluminescence of cubic AlGaN layers — •Florian Hörich[1], Sarah Osterburg[1], María Fátima Romero[1], Martin Feneberg[1], Thorsten Schupp[2], Christian Mietze[2], Donat J. As[2], and Rüdiger Goldhahn[1] — [1]Otto-von-Guericke University Magdeburg, Germany — [2]Universität Paderborn, Department Physik, Paderborn, Germany

Thin cubic AlGaN layers grown by melcular beam epitaxy were investigated by photoluminescence (PL) at variable temperatures. Excitation was provided by λ=193nm ArF*-excimer laser pulses. We study localization properties of the ternary alloy over the whole composition range by analyzing PL peak position, full width at half maximum, and intensity. Model calculations are presented and compared to the experimental data yielding parameters like the characteristic localization energy. The evolution from direct (GaN) to indirect (AlN) semiconductor is explored.

HL 25.17 Mon 16:00 Poster D

Ultraviolet photoluminescence spectroscopy of homo- and heteroepitaxially grown AlN — •Christoph Reich[1], Viola Küller[2], Arne Knauer[2], Martin Feneberg[3], Jessica Schlegel[1], Markus Weyers[2], Rüdiger Goldhahn[3], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [3]Otto-von-Guericke-Universität, Abteilung Materialphysik, Universitätsplatz 2, 39106 Magdeburg, Germany

For high power deep UV LEDs, high quality AlN templates are required. However, heteroepitaxial growth of AlN on sapphire substrates leads to high threading dislocation densities (TDD) of $10^{10}\,\mathrm{cm}^{-2}$, which significantly deteriorate the internal quantum efficiency of LEDs. The optical properties of homoepitaxially grown AlN layers on bulk AlN and heteroepitaxially grown AlN layers on patterned and unpatterned AlN/sapphire templates have been investigated by low temperature photoluminescence spectroscopy (PL), temperature dependent PL and excitation density dependent PL. High quality AlN layers are grown homoepitaxially on bulk AlN substrates (TDD $< 10^{8}\mathrm{cm}^{-2}$) or epitaxial lateral overgrowth (ELO) of patterned AlN/sapphire templates (TDD $< 10^{9}\mathrm{cm}^{-2}$) by metalorganic vapour phase epitaxy (MOVPE). The recombination of free excitons and several donor bound excitons has been observed. Exciton emission energies, exciton linewidths and the temperature dependence PL for different substrate materials will be compared.

HL 25.18 Mon 16:00 Poster D

Effect of growth parameters and annealing on the p-doping of GaN:Mg — •Gunnar Kusch, Martin Frentrup, Tim Kolbe, Tim Wernicke, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

One of the key challenges limiting the output power of group-III-nitride light emitting diodes (LEDs) and laser diodes is the p-doping of (Al)GaN with magnesium (Mg). During growth of GaN:Mg by metal-organic vapor phase epitaxy compensating defects are incorporated such as nitrogen vacancies, Mg-H-N complexes and inversion domains. The high activation energy is a further obstacle for effective p-doping with hole concentrations $> 1 \cdot 10^{18}\,cm^{-3}$. We have investigated Mg incorporation in GaN in the range of 10^{19} to $10^{20}\,cm^{-3}$ as well as ex-situ activation and the influence of activation on LEDs. Variation of the Mg/III ratio showed a strong influence on the hole concentration. The lower limit is given by the n-type background doping below a II/III ratio of $15 \cdot 10^{-3}$ and the upper limit by compensating defects above a II/III ratio of $25 \cdot 10^{-3}$. The resulting growth window for p-doping is in good agreement with calculations and literature. Other growth parameters, such as V/III ratio, growth rate and growth temperature show lesser influence. Annealing studies at different temperatures show a lower limit for full activation at 600 °C.

HL 25.19 Mon 16:00 Poster D

Optimization of the internal and external quantum efficiency of high In content GaInN LED structures — •Fedor Alexej Ketzer, Holger Jönen, Ailun Zhao, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

We investigate high indium content GaInN based light emitting diodes grown via low pressure MOVPE. The efficiency of such structures is rather small due to the high indium content. In order to improve the efficiency we study the growth of the p-doped GaN layer and rapid thermal annealing (RTA), needed to activate the p-dopants (Mg). Due to the high thermal load these processes influence the quantum well (QW) and therefore the internal quantum efficiency (IQE). These influences appear to raise with higher indium content.

For this purpose the IQE before and after RTA is compared with the external quantum effiency (EQE). Also conditions during RTA and growth of the layers following the QW were modified to examine changes in emission spectra and efficiency. The IQE was determined by temperature dependent photoluminescence and the EQE was determined by electroluminescence. With these results the growth conditions of the active region and their following layers can be optimized for high internal and external quantum efficiencies.

HL 25.20 Mon 16:00 Poster D

MBE growth and characterization of group III/N quantum dots on various templates — •Christopher Hein, Andreas Kraus, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

Devices based on quantum dots are expected to overcome some of the limitations of quantum well based structures opening the way to applications such as laser diodes and single photon sources. Our experiments include RF MBE (Riber 32) grown self-organized group III/N dots using Stranski-Krastanov (SK) growth mode under metal rich conditions. Various templates including AlN were used with sapphire

and SiC as substrates. Afterwards the dots were capped, allowing studies of the optical properties.

In situ RHEED reveals a dotty pattern indicating 3D island formation and therefore SK growth mode. AFM characterization of the samples hints at rough surface morphology with dot-like features. The structural properties were investigated with XRD. Concerning the AlN buffer layer XRD revealed an improvement for optimized growth conditions. The optical properties were investigated using a UV photoluminescence setup. We discuss PL studies of the samples as well as the optimization of dot formation via adjusted growth conditions.

HL 25.21 Mon 16:00 Poster D

Investigation of the incorporation of Mg as p-dopant in GaN grown by metal modulated epitaxy — •Thorsten Klein[1], Stephan Figge[1], Tomasz Krajewski[2], Marek Godlewski[2], and Detlef Hommel[1] — [1]Institute of Solid State Physics, University of Bremen, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

Group III-nitrides are of high interest for use in optoelectronic devices such as light emitting diodes or laser diodes. However, one of the main challenges remains the growth of highly p-doped GaN:Mg to achieve higher efficiencies of such devices. In our work we present an approach of low-temperature GaN-growth by metal modulated epitaxy (MME) which was reported in the literature to strongly increase the doping level up to $4\times10^{19}\,\mathrm{cm}^{-3}$. During MME the metal shutters (Ga, Mg) are periodically opened and closed while the N-shutter remains constantly open. This method is used to optimize the incorporation of Mg into the structure while preserving a smooth surface. The growth takes place under metal-rich conditions and is monitored in-situ by RHEED. The substrate temperature is 550 °C. AFM investigations reveal RMS values of 1.9 nm. The surface shows holes with a depth of about 30 nm, in between them RMS values of 0.7 nm indicate an atomically flat surface. Hall effect measurements were performed to determine the doping level. Charge carrier densities up to $1.6\times10^{19}\,\mathrm{cm}^{-3}$ are achieved, which remain almost constant over a temperature range between 50 - 400 K. Activation energies of 10 - 12 meV as well as mobilities around $30\,\mathrm{cm}^2/\mathrm{Vs}$ indicate electron conductivity.

HL 25.22 Mon 16:00 Poster D

Implantation studies on silicon doped group-III nitride semiconductors — Ronnie Simon[1], •Reiner Vianden[1], and Klaus Köhler[2] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn — [2]Fraunhofer Institut für angewandte Festkörperphysik, Freiburg

Silicon doped GaN layers grown by low-pressure metal-organic vapor-phase epitaxy with Si concentrations ranging from $2*10^{17}$ atoms/cm^3 to $9.2*10^{18}$ atoms/cm^3 were investigated by means of the perturbed angulat correlation (PAC) technique applied to implanted ^{111}In(Cd). An undoped GaN film is used as a reference. The Si-atoms replace Ga-atoms in the lattice and silicon, being a group-IV element, acts as a donor on the Ga-site and contributes one extra electron to the conduction band. Hall effect measurements confirmed that the free charge carrier density is essentially increased and of the order of the silicon concentration. PAC investigations of the annealing behavior after implantation of the ^{111}In probes shows that best recovery is achieved after annealing at 1200 K and that high silicon concentrations make GaN films more stable at high temperatures. Further, it was found that the temperature dependence of the electric field gradient is reduced by increasing Si concentrations.

HL 25.23 Mon 16:00 Poster D

External oxidation of GaN studied by Perturbed Angular Correlations — •Michael Steffens[1], Reiner Vianden[1], and Alberto Pasquevich[2] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Universität of Bonn, Bonn, Germany — [2]Departamento de Física, Facultad de Ciencias Exactas, UNLP, La Plata, Argentina

A sample of 7 μm GaN was heated in air at 1273 K in steps of 5 min for a total of 80 min. During this treatment, external oxidation of the sample occured. After each oxidation step, perturbed angular correlation measurements were performed at room temperature. The growth of the oxide will be discussed.

β-Ga_2O_3 can be used for transparent conductors or electronic devices. Thin films were already achieved with external oxidation, but the feasibility of these films for UV-photo diode production is largely reduced, possibly because of surface defects like oxygen vacancies [1].

The perturbed angular correlation (PAC) is an important tool to study point defects or lattice deformations in semiconductors. It is based on the hyperfine interaction between the intermediate state of a probe nucleus undergoing a γ-γ-cascade and an electric field gradient (EFG) generated by the electronic conditions in the sample. The strong dependence of the EFG to its origin makes PAC ideal for studies on the nanoscale.

[1] Weng et al., IEEE Sensors Journal, 11, 999 (2011)

HL 25.24 Mon 16:00 Poster D

Electrochemical characterization of Si- and Mg- doped GaN nanowire electrodes — •Jens Wallys[1], Florian Furtmayr[1,2], Jörg Teubert[1], Wladimir Schäfer[1], Jörg Schörmann[1], and Martin Eickhoff[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Walter Schottky Institut, Technische Universität München

Recent progress in the field of GaN nanowire (NW) growth, in particular the possibility to realize both p- and n-type doping, suggest their use as novel electrodes for chemical and biological sensors or in the field of photo catalysis. However, the knowledge about their electrochemical properties and the influence of doping is still very limited.

We investigated ensembles of undoped, Si-doped and Mg-doped GaN NWs with different doping concentrations and average diameters grown on Si (111) substrates by plasma assisted molecular beam epitaxy. The samples were analyzed using bias dependent electrochemical impedance spectroscopy measurements under physiological electrolyte conditions. By fitting the results to an equivalent circuit model the electronic properties of GaN NW ensembles could be extracted. According to these results a classification of the NWs into conducting and depleted ones is suggested and verified by cyclic voltamogramms in the presence of a redox couple and correlated to scanning electron microscope images.

HL 25.25 Mon 16:00 Poster D

Investigation of efficiency of blue and green GaN based LEDs — •Ailun Zhao, Uwe Rossow, and Andreas Hangleiter — Institut für Angewandte Physik TU Braunschweig

GaN based light-emitting diodes (LEDs) have been attracting much attentions due to their promising and wide application in display and lighting during the past decades. In spite of significant improvements in their performance, there still remain many technical challenges impeding further applications of LEDs, an important one of which is the efficiency droop. The efficiency droop includes two aspects: one is the efficiency decreasing with increasing injection current and another is the decrease with longer wavelength. We grow blue and green LEDs strutures on sapphire substrate along c-direction by MOVPE. As we are mainly interested in effects related to the internal efficiency, simple on-wafer processing is used, providing small but fairly well-known extraction efficiency. The samples were characterized by electroluminescence. We investigated the series resistance, external quantum efficiency (EQE), efficiency droop and peak emission wavelength of our samples. We observe that, generally, LEDs showing strong efficiency droop also show a strong injection blue shift. We discuss the implications on the possible droop mechanism.

HL 25.26 Mon 16:00 Poster D

Current-injection and carrier confinement in InAlGaN ultraviolet light emitting diodes — •M.-A. Rothe, T. Kolbe, J. Stellmach, F. Mehnke, T Wernicke, P. Vogt, and M. Kneissl — Institute of Solid State Physics, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Ultraviolet (UV) light emitting diodes (LEDs) have attracted great interest in recent years because of their potential applications in phototherapy and sensing. However the external quantum efficiency (EQE) of these LEDs is only in low percentage range. One of the key challenges to improve the EQE is the carrier injection in to the active region. Therefore, an optimisation of the electron blocking layer (EBL) is very important to prevent an electron leakage into the p-layers of the LED with a simultaneous unhindered hole injection. In this work we have investigated 320 nm LEDs with different $Al_xGa_{1-x}N$:Mg EBLs. The devices were grown by metalorganic vapour phase epitaxy on (0001) sapphire substrates. A combination of electroluminescence measurements and simulations of the LED heterostructure were performed to investigate the carrier injection in the active region of the LEDs. We will compare LEDs with AlGaN EBLs with an aluminum content between 37 % and 48 % and show that the highest EQE is obtained for LEDs with an $Al_{0.44}Ga_{0.56}N$ EBL. This is in a good agreement with our simulation results. The temperature effect on the performance of LEDs with different EBLs is investigated by tempera-

ture dependent electroluminescence measurements which shows a clear influence of the temperature on the electron leakage current of the UV LEDs.

HL 25.27 Mon 16:00 Poster D

Performance Enhancement of InAlN/AlN GaN-HEMTs by using In-Situ SiN Passivation for High Temperature Applications — •Alexander Alexewicz[1], Paul Marko[1], Mohammed Alomari[2], Hannes Behmenburg[3,4], Christoph Giesen[3], Michael Heuken[3,4], Dionyz Pogany[1], Erhard Kohn[2], and Gottfried Strasser[1] — [1]TU Wien — [2]Universität Ulm — [3]AIXTRON SE, Herzogenrath — [4]RWTH Aachen

We present InAlGaN/AlN GaN high electron mobility transistors (HEMTs) with an optimized MOCVD-grown (metal organic chemical vapor deposition) SiN passivation, compared to the standard PECVD (plasma enhanced CVD)-SiN. Passivating the devices effectively reduces electronically active surface states, which can deteriorate the device performance drastically. In this work, GaN HEMTs are processed on SiC substrate with MOCVD-SiN passivation layers of different thicknesses (5 nm, 30 nm, no passivation). SiN is grown in the same run (in-situ) as the InAlGaN/AlN/GaN heterostructure, before the actual processing of the device, what enhances the interface quality by avoiding surface contamination before deposition of the passivation. The non-passivated devices show a maximum drain current of 0.8 A/mm in DC and 0.5 A/mm in pulsed mode at a gate voltage of 3 V. The 5 nm and 30 nm passivated devices exhibit an improvement of these values by 25 % and 50 % in DC, and 80 % and 140 % in pulsed mode, as well as a strongly reduced electron trapping related current collapse. Due to the better interface quality, this kind of passivation has great potential for high temperature device applications.