HL 51: GaN: preparation and characterization

Time: Friday 11:00–13:30 Location: H13

HL 51.1 Fri 11:00 H13

GaN-based devices on 150 mm Si(001) substrate grown by MOVPE — •F. Schulze[1], A. Dadgar[1,2], A. Krtschil[1], O. Kisel[1], T. Hempel[1], J. Bläsing[1], C. Hums[1], A. Diez[1], L. Reissmann[1], J. Christen[1], and A. Krost[1,2] — [1]Otto-v.-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg — [2]AZZURRO Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg

The Si(001) orientation offers an obvious approach for the monolithic integration of GaN-based electronics and optoelectronics with standard silicon technology, because this substrate orientation is used in mainstream CMOS technology. However, the main challenges are the different lattice symmetries and crystallographic orientations of GaN and Si(001). We present structural and optical investigations on GaN layers on Si(001) grown by metalorganic vapour phase epitaxy (MOVPE). A key parameter to obtain high quality GaN layers on Si(001) is most likely the control of the surface reconstruction of the substrate, which can be influenced by changing the surface energy. The use of 4° off-oriented substrates prefers one type of dimer rows, and thus, the growth of c-axis oriented GaN on Si(001) with one defined in-plane alignment is possible. The crystallographic quality is investigated by x-ray diffraction measurements, Electron Back Scatter Diffraction, FE-SEM imaging, and AFM. By growing an approximately 2.8 μm thick, crack-free GaN buffer, the achieved crystallographic quality allows for fabricating GaN-based LEDs and FET devices on Si(001). Furthermore, we will present some first blue LED samples of the upscaling process up to 150 mm Si(001) substrates.

HL 51.2 Fri 11:15 H13

Nachweis der spontanen Polarisation in GaN mittels UHV-Kathodolumineszenz — •Martina Finke, Daniel Fuhrmann, Uwe Rossow und Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, 38106 Braunschweig

Die optischen Eigenschaften von GaN werden stark von den piezoelektrischen und spontanen Feldern beeinflusst, wobei das spontane Feld normalerweise von Oberflächenladungen abgeschirmt wird. Ein Entfernen dieser Ladungen führt dann zu einer Blauverschiebung und Intensitätszunahme der Emission, da der Quantum Confined Stark Effekt durch das Gegenfeld abgeschwächt wird. Kathodolumineszenzmessungen an Proben mit verschiedenen Oberflächenbehandlungen wurden im Ultrahochvakuum durchgeführt. Dabei wurde die Änderung der Energie und Intensität der Lumineszenz abhängig von der Strahlzeit des Elektronenstrahls aufgenommen. Unbehandelte Proben, angeätzte Proben und ausgeheizte Proben wurden bei Raumemperatur und bei 100 Kelvin untersucht. Diese Experimente zeigen, dass eine Änderung der Oberflächenbelegung durch Elektronenbestrahlung oder Ätzen zu einer Aktivierung des spontanen Feldes und damit zu einer Blauverschiebung und Intensitätszunahme der Emission führt. Mit Hilfe von speziellen Proben, bei denen die Tiefe des Quantum Wells variiert wurde, konnte der Aufbau des spontanen Feldes in den Proben nachgewiesen werden. Gleichzeitig wurde auch eine abschirmende Wirkung der von dem Elektronenstrahl erzeugten freien Ladungsträgern auf das spontane Feld beobachtet. Durch den Vergleich mit Photolumineszenzmessungen im UHV sollen diese Effekte überprüft werden.

HL 51.3 Fri 11:30 H13

Vertically increasing well thickness and In content in GaInN MQWs due to V-shaped pits — •Heiko Bremers, Lars Hoffmann, Daniel Fuhrmann, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institut für Angewandte Physik, Mendelssohnstr. 2, 38106 Braunschweig

So far the origin of the high efficiencies of light emission in the GaInN based quantum wells (QW's) is still under debate. It is commonly believed that the suppression of non-radiative recombination processes is due to fluctuations of In concentration, which could lead to a localization of carriers. Recently another approach has been proposed which shows that V-shaped pits with reduced well thicknesses on the facets might be responsible for the suppression of non-radiative recombination. In this work we investigate the influence of V-shaped pits on the growth of GaInN-GaN MQW's by TEM and x-ray diffraction measurements. We have grown different MQW's by a low-pressure MOVPE and studied the influence of the number of QW's as well as of the depth of V-shaped pits. During the growth of the samples a material transport takes place from the pits to the c-plane. We show that the thickness of the GaInN QW's and of the GaN barriers is increased due to material transport. With increasing number of quantum wells the diameter of the pits increases, which leads to a superlinear increase of these thicknesses. We present a model which describes the change in thickness due to material transport. Additional photoluminescence measurements performed on our samples exhibit a redshift as well as a broadening with increasing number of quantum wells.

HL 51.4 Fri 11:45 H13

Luminescence properties of high quality non-polar a-plane GaN epilayers — •Martin Noltemeyer, Barbara Bastek, Lars Reissmann, Frank Bertram, Alexander Franke, Jürgen Christen, Matthias Wieneke, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

A set of high quality a-plane GaN layers is grown on r-plane sapphire-substrates by MOVPE and characterized by temperature (T) dependent photoluminescence (PL) and cathodoluminescence (CL). The T=4K PL spectra consist of several emission peaks: Near the band edge, a donor bound (D^0, X) at 3.495 eV as well as an acceptor bound exciton (A^0, X) at 3.482 eV can be resolved. Their spectral position corresponds to a compressive strain of 0.9 GPa. An emission at 3.30 eV originating from donor-acceptor-pair recombination (DAP) and accompanied by several LO-phonon replicas. A blue-shift of 34 meV is observed with increasing excitation density and with increasing temperature a high energy peak, i.e. the free-to-bound (e, A^0) emerges. The dominating defect emission at 3.42 eV is attributed to excitons localized at stacking faults (SF) forming a wurtzite/cubic/wurtzite GaN quantum well. Temperature (T) dependent PL studies show a thermal quenching of the SF perfectly following an Arrhenius behavior with three activation energies (25 meV, 4 meV, and 40 meV). The SF peak energy shows an S-shaped T-dependence corresponding to a localization energy of 25 meV. Spatially resolved CL spectroscopy shows a homogeneous intensity distribution of the SF luminescence.

HL 51.5 Fri 12:00 H13

Nonlinear elastic effects in group III-nitrides — •Michal Petrov, Liverios Lymperakis, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Max-Planck-Strasse 1, 402 37, Düsseldorf, Germany

The zero-dimensional nature of Quantum Dots (QD) allows the design of novel high performance optoelectronic devices. In group III-nitrides, due to the large lattice mismatch and the stiffness of the material, the quantum dots embedded in the semiconductor matrix are highly strained and the inclusion of nonlinear elastic effects is crucial. However so far experimental and/or theoretical data on the composition and pressure dependence of the elastic constants of AlGaN alloys are lacking. Therefore, we computed the composition and pressure dependence of the bandgaps and the elastic constants of the AlGaN alloys employing planewave pseudopotential calculations within the density functional theory. The calculation of the second and third order elastic constants was performed within the framework of anisotropic hyperelasticity [1]. To model ternary random alloys within a supercell formalism (which intrinsically contains periodic boundary conditions), we considered a number of different ordered configurations based on the concept of Special Quasirandom Structures (SQS). The thus calculated nonlinear coefficients are used as input for a multi-scale scheme based on Finite Elements and k.p theory calculations and allows an accurate description of the binding states and optical Coulomb matrix elements in materials QDs.

[1] P. Dluzewski, Journal of Elasticity **60**, 119 (2000).

HL 51.6 Fri 12:15 H13

Optical Properties of Si- and Mg-Doped GaN Nanorods — •Florian Furtmayr, Martin Vielemeyer, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

Quasi one-dimensional semiconductor single crystals are a key component for future applications in nano-electronics and nano-optics. Using a catalyst free growth technique, GaN-nanorods were fabricated by plasma assisted molecular beam epitaxy on Si(111) substrates. Both

Si- and Mg-doping over a wide concentration range was realized and the influence of doping on the growth kinetics has been investigated. In addition, the optical properties were studied by photoluminescence spectroscopy in the temperature range 4K to 100K. Emission from free and donor bound excitons are the dominant effects for undoped samples, whereas the contribution of donor-acceptor recombination increases for increasing doping concentrations. The relation between luminescence characteristics, nanorod geometry, degree of coalescence, and doping concentration is analyzed.

HL 51.7 Fri 12:30 H13

Band gap and Van-Hove singularities of cubic InN — •Pascal Schley[1], Rüdiger Goldhahn[1], Christian Napierala[1], Gerhard Gobsch[1], Jörg Schörmann[2], Donat J. As[2], Klaus Lischka[2], Frank Fuchs[3], and Friedhelm Bechstedt[3] — [1]Institut für Physik, TU Ilmenau — [2]Department Physics, Universität Paderborn — [3]Institut für Festkörpertheorie und -optik, FSU Jena

InN has attracted much interest recently due to the band gap revision for the hexagonal compound from the long-time accepted value of 1.89 eV down to only 0.68 eV. Theoretical calculations predict an even lower gap for the cubic (c-) counterpart. We succeeded in growing single crystalline c-InN films on 3C-SiC substrate with a c-GaN buffer layer by MBE. Ellipsometry was applied in order to determine the dielectric function (DF) of c-InN from the near infrared into the VUV spectral region (data above 4 eV refer to the use of synchrotron radiation at BESSY II). The spectra show pronounced features in the high-energy part which arise from the Van-Hove singularities in the band structure. High-resolution transition energy determination is achieved by fitting the third derivatives of the DF. The values as well as the shape of the DF are in excellent agreement with the results of DFT-LDA calculations for which electron-hole interaction was taken into account. The position of the absorption edge depends clearly on the electron density of the films. Taking into account carrier-induced band gap renormalization and the Burstein-Moss shift we estimate the zero-density band gap of c-InN with 0.62 eV which is by 60 meV lower than for hexagonal InN.

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Nonpolar a-plane GaN grown on r-plane sapphire by metal-organic vapor-phase epitaxy — •Matthias Wieneke, Armin Dadgar, Jürgen Bläsing, Andre Krtschil, Thomas Hempel, and Alois Krost — Otto-von-Guericke-University Magdeburg, FNW/IEP, Postbox 4120, 39016 Magdeburg

Conventional GaN based devices grow along the [0001] c-direction. In the c-orientation, the internal spontaneous and the strain-induced piezoelectric polarization generate electric fields at heterointerfaces. These electric fields cause spatial separation of electrons and holes in quantum wells reducing the oscillator strength and red shifting the luminescence. Growing nonpolar wurtzite III-N films, as a-plane GaN for example, are a possibility to avoid polarization effects. (11-20) a-plane GaN films were grown on (1-102) r-plane sapphire by metal-organic vapor-phase epitaxy (MOVPE). By varying growth-parameters as, e.g., V-III ratio, temperature and reactor pressure several sets of samples were grown and the influence to the micro structural properties and surface morphology were studied. The grown films were investigated by high resolution X-ray diffraction (XRD), scanning electron microscopy (SEM) and atomic force microscopy (AFM). It was found that the structural properties of the films and their dependence of some growth-parameters were anisotropic in the in-plane m- and c-direction. Therefore the strain properties of a-plane GaN layers are not biaxial.

HL 51.9 Fri 13:00 H13

MOVPE growth and characterization of Cr-doped GaN — •Yong Suk Cho[1], Nicoleta Kaluza[1], Hilde Hardtdegen[1], Thomas Schaepers[1], Vitaliy Guzenko[1], Klaus Schmalbuch[2], Bernd Beschoten[2], Uwe Breuer[3], Astrid Besmehn[3], Hans-Peter Bochem[1], and Hans Lueth[1] — [1]Institute of Bio- and Nanosystems (IBN-1), Center of Nanoelectronic Systems for Information Technology (CNI), Virtual Institute of Spin Electronics (VISel), Research Center Juelich, 52425 Juelich, Germany — [2]II. Physikalisches Institute and Virtual Institute of Spin Electronics (VISel), RWTH Aachen, 52056 Aachen, Germany — [3]Central Division of Analytical Chemistry (ZCH), Research Center Juelich, 52425 Juelich, Germany

We grew Cr-doped GaN by metal organic vapor phase epitaxy on undoped GaN epilayers. Conventional Ga and N precursors were used and bis(cylcopentadienyl)chromium (Cp_2Cr) was employd as the Cr precursor. We investigated the effects of growth temperature, carrier gas and Cr/Ga source ratio on the Cr incorporation efficiency and on the morphological and magnetic properties of the layers. The concentration of Cr is linearly dependent on source partial pressure. The growth temperature mainly determines morphology and Cr incorporation efficiency in the layer. A certain amount of H_2 in carrier gas helps to make a coalesced surface. Our Cr-doped GaN grown by MOVPE shows remanent magnetization even above room tempeature.

HL 51.10 Fri 13:15 H13

Piezoelectric Fields in Semipolar GaInN/GaN Quantum Wells — •Martin Feneberg[1], Frank Lipski[1], Klaus Thonke[1], Rolf Sauer[1], Thomas Wunderer[2], Peter Brückner[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

Piezoelectric fields lower the efficiency of GaInN/GaN quantum well devices via the Quantum Confined Stark Effect (QCSE). To circumvent the problems introduced by the QCSE, growth on nonpolar or semipolar crystal planes can be used. We investigate the piezoelectric field strength on {1-101} semipolar facets of selectively grown GaN stripes by voltage-dependent photoluminescence. We find a reduced piezoelectric field of about -0.1 MV/cm on the semipolar facet compared to about -1.85 MV/cm on a structure grown on the polar {0001} plane for GaInN layers with 15% and 10% indium content, respectively[1]. The indium composition dependence of the piezoelectric field is evaluated and the results are compared to theoretical values of the piezoelectric tensor elements reported in the literature.

[1] Feneberg et al., Appl. Phys. Lett. 89, 242112 (2006).