HL 33 GaN: Preparation and characterization

Time: Wednesday 14:30–17:15 Room: BEY 154

HL 33.1 Wed 14:30 BEY 154

Analysis of AlN/Diamond Heterojunctions by Photoelectron Spectroscopy — •Olaf Weidemann, Bernhard Laumer, Thomas Wassner, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, 85748 Garching

N-type doping of diamond still is a major problem which hinders the realization of bipolar devices like p-n-diodes. In contrast, Si-doping of AlN has been shown to result in technologically relevant n-type conductivity. The combination of both materials in a light emitting AlN/diamond hetero diode has recently been demonstrated. For a detailed understanding of carrier transport and light emission at the AlN/diamond interface, knowledge of the respective band alignment and interface structure is necessary. We have analyzed the AlN/diamond interface by X-ray and UV-photoelectron spectroscopy carried out during the sequential growth on H-terminated and O-terminated single crystalline diamond substrates. The influence of the nucleation process on the electron affinity of the diamond substrate has been analyzed and the growth mode of the AlN-film as well as the conduction band profile at the heterojunction has been determined. Complementary analysis by atomic force microscopy and electronic transport measurements has been carried out.

HL 33.2 Wed 14:45 BEY 154

Critical points of the band structure of AlN/GaN superlattices investigated by spectroscopic ellipsometry and modulation spectroscopy — •C. Buchheim[1], R. Goldhahn[1], A. T. Winzer[1], C. Cobet[2], M. Rakel[2], N. Esser[2], U. Rossow[3], D. Fuhrmann[3], and A. Hangleiter[3] — [1]Institute of Physics, Technical University Ilmenau, PF 100565, 98684 Ilmenau, Germany — [2]Institute of Analytical Sciences, Department Berlin-Adlershof, Albert-Einstein-Str. 9, 12489 Berlin, Germany — [3]Institute of Applied Physics, Technical University Braunschweig, Mendelssohnstr. 2, 38106 Braunschweig, Germany

AlN/GaN superlattices (SL) are suitable for the design of distributed Bragg reflectors and optical devices based on intersubband transitions. Applications are light emitters in the near to mid infrared region, quantum well infrared photodetectors and quantum cascade laser structures. For the design of such heterostructures and their evaluation the detailed knowledge of their optical properties over an extended energy range is essential. Three AlN/GaN SLs with different barrier and well thicknesses were investigated by modulation spectroscopy and photoluminescence to determine their ground state transition. A shift of the transition energies in dependence of the barrier and well width is found. The results are compared to quantum mechanical calculations at the Brillouin zone centre. In addition the dielectric function is determined by spectroscopic ellipsometry from the infrared to the vacuum ultraviolet spectral range (0.75 - 9.8 eV). Quantum confinement effects are observed not only for the band gap, but also for the higher energetic critical points of the band structure as can be seen from the comparison to AlGaN alloys.

HL 33.3 Wed 15:00 BEY 154

GaN-based devices on Si(001) grown by MOVPE — •F. Schulze, J. Bläsing, A. Dadgar, T. Hempel, A. Diez, A. Krtschil, J. Christen, and A. Krost — Institut für Experimentelle Physik, Otto-v.-Guericke-Universität Magdeburg, PF 4120, 39104 Magdeburg

The Si(001) substrate orientation offers an obvious approach for the integration of GaN-based devices with the standard silicon technology, because this orientation is used in silicon mainstream technology. However, the main challenges are the different lattice symmetries and crystallographic orientations of GaN and Si(001). We will present structural and optical investigations on GaN layers on Si(001) grown by metalorganic vapour phase epitaxy (MOVPE). In our approach a high temperature AlN-seed layer and 4° off-oriented substrates allow to grow c-axis oriented GaN on Si(001) with one well defined in-plane alignment. Thus, a smooth and fully closed single-crystalline GaN layer on Si(001) is obtained. The crystallographic structure is investigated by X-ray diffraction measurements. The achieved FWHM of the GaN(0002) rocking curve is 0.26° and the in-plane twist is 0.82°, determined by a GaN(10-10) ω-scan. The surface morphology was analyzed by FE-REM imaging and AFM, and the optical properties by photo- and cathodoluminescence. By growing an approx. 2.3 μm crack-free buffer layer GaN-based LEDs and FET devices on Si(001) were made and will be presented.

HL 33.4 Wed 15:15 BEY 154

Nanostructering of GaN-based semiconductors with focused ion beam — •Timo Aschenbrenner, Jens Dennemarck, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, Semiconductor Epitaxy, University of Bremen, 28359 Bremen, Germany

Nowadays quantum dots and photonic crystals take an important role for light emitting devices. The manufacturing of such nanostructures on GaN-based semiconductors is difficult because on the one hand the commonly used method of wet etching is not applicable. And on the other hand the needed structure size is below the limit of photolithography.

Therefore two different approaches to achieve nanostructures were performed: Electron beam lithography and the structuring with focused ion beams (FIB). Electron beam lithography with an acceleration voltage of 30 kV and a beam current of a few pA up to 1 nA were used to define a pattern in polymethylmethacrylate (PMMA) resist on GaN-substrates. After developing the mask was transfered to GaN by chemical assisted ion beam etching (CAIBE). The resolution is limited by the size of the polymer to above 100 nm.

A FIB can be used as a direct approach for nanostructuring. In this case the resolution is only limited by the minimum diameter of the ion-beam to hole-diameter of 30 nm. But this approach has the disadvantage, that ion damaged occurs. To reduce the damage different protection layers as titanium or nickel were used. The surfaces were investigated with AFM and SEM.

HL 33.5 Wed 15:30 BEY 154

MOVPE of Cr-doped GaN — •Yong Suk Cho[1], Nicoleta Kaluza[1], Uwe Breuer[2], Vitaliy Guzenko[1], Hilde Hardtdegen[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG-1), Center of Nanoelectronic Systems for Information Technology, Research Center Jülich, 52425 Jülich, Germany — [2]Central Department of Analytical Chemistry (ZCH), Surface Analysis, Research Center Jülich, 52425 Jülich, Germany

Recently, first studies on MBE grown Cr-doped GaN revealed ferromagnetism for dilute magnetic semiconductors. Here we report for the first time on the incorporation of Cr in GaN with metalorganic vapor phase epitaxy using different hardware setups and different flow conditions. Conventional Ga and N precursors were used and bis(cylcopentadienyl)chromium (Cp_2Cr) was employed as the Cr precursor. Undoped GaN epilayer were grown to serve as a template for Cr-doped GaN. The mole fraction of Cp_2Cr used for Cr-doped GaN was varied in gas phase from 5.67×10^{-9} mol/min to 1.02×10^{-7} mol/min, while the growth temperature and V/III ratio were kept constant. Secondary ion mass spectrometry provided that the different hardware setups as well as the flow conditions strongly affect the concentration of Cr in the layer by 18%. Also a linear dependence between mole fraction of Cp_2Cr in gas phase and incorporated Cr in solid phase was found. X-ray diffraction, photoluminescence and Raman spectroscopy studies were performed as well as superconducting quantum interference device measurements carried out to study the structural and magnetic properties of the layers. The results will be presented.

HL 33.6 Wed 15:45 BEY 154

MBE Growth of cubic InN — •Jörg Schörmann[1], Stefan Potthast[1], Mark Schnietz[1], Christian Napierala[2], Rüdiger Goldhahn[2], Donat Josef As[1], and Klaus Lischka[1] — [1]University of Paderborn, Department of Physics, Warburger Strasse 100, D-33095 Paderborn, Germany — [2]Institute of Physics, TU Ilmenau, PF 100565, D-98684 Ilmenau, Germany

Among III-nitride semiconductors, InN has the highest electron drift velocity, the smallest effective mass and the smallest direct band gap. Therefore it is expected to be one promising material for high frequency electronic devices such as field effect transistors (FET). Another application for InN are InN/GaN quantum well structures for intersubband transitions. Due to the large conduction band offset (about 1.4eV 60:40) this material system allows intersubband transitions in the range of 1-10μm. 140nm thick cubic InN films were grown on top of a c-GaN buffer layer (800nm) by rf-plasma assisted MBE at different growth temperatures. X-Ray diffraction investigations show that the c-InN layers consist of a predominant zinc blende structure with a fraction of the wurtzite phase on the (111) facets of the cubic layer. The full-width at half-maximum

of the c-InN (002) reflex is less than 50arcmin. Reflection measurements show an absorption edge at ∼1.5eV. The bandgap of our c-InN layers was obtained by photoluminescence and ellipsometry.

HL 33.7 Wed 16:00 BEY 154

Nitrogen-15 and Gallium-71 nuclear magnetic relaxation measurements in GaN — •Anthony Kent, Robin Morris, Helen Geen, C Thomas Foxon, and Sergei Novikov — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK.

We have grown by RF plasma-assisted molecular beam epitaxy (PA-MBE) zinc-blende crystal structure GaN using an isotopically pure nitrogen-15 source. We have measured the nuclear spin-lattice (T_1) and spin-spin (T_2) relaxation times using pulsed NMR at 20 MHz. For Gallium-71 we found T_1 was of order seconds at low temperature, and $1/T_1$ proportional to $T^{1/2}$ where T is the temperature. This is characteristic of semiconductors in which the spin-lattice relaxation is mediated by mobile electrons and allows us to estimate the free carrier concentration. The spin lattice relaxation time was found to be much longer for nitrogen-15, of order minutes, and the temperature dependence more characteristic of an insulator. This suggests that the free electron-nuclear coupling is weaker for nitrogen-15 compared with Gallium-71. We also show that illumination of the sample by band-gap UV light with circular polarization resulted in hyperpolarization of the Nitrogen-15 and an increase in the NMR signal amplitude.

HL 33.8 Wed 16:15 BEY 154

Electrical properties of cubic $Al_xGa_{1-x}N$/GaN heterostructures — •Stefan Potthast[1], Jörg Schörmann[1], Donat Josef As[1], Klaus Lischka[1], Hiroyuki Nagasawa[2], and Masayuki Abe[2] — [1]University of Paderborn, Department of Physics, Warburger Str. 100, 33095 Paderborn, Germany — [2]HOYA Advanced Semiconductor Technologies Co., Ltd, 1-17-16 Tanashioda, Sagamihara, Kanagawa 229-1125, Japan

The absence of spontaneous and piezoelectric fields in cubic group-III nitride semiconductors enables the realization of a two-dimensional electron gas (2DEG), whose concentration is independent on the thickness and the Al-content of the barrier material and is adjusted only by the Si-doping of the AlGaN barrier. In this contribution we report on the growth of cubic $Al_xGa_{1-x}N$/GaN heterostructures by rf-plasma assisted molecular beam epitaxy on 3C-SiC substrates with an Al-mole fraction between 0.2 and 0.5. Temperature dependent Hall-Effect measurements and CV measurements between 300K and 5K were performed to estimate the electrical properties of the 2-dimensional electron gas, showing a sheet carrier density of $1.6 \cdot 10^{12} cm^{-2}$. The carrier density was quantitatively verified by a self consistent solution of the Schrödinger and Poisson equation. Detailed analysis of the electron mobility showed that interface roughness scattering is the dominating scattering process in our structures.

HL 33.9 Wed 16:30 BEY 154

Detailed analysis of the dielectric function for wurtzite In- and N-face InN — •P. Schley[1], R. Goldhahn[1], A.T. Winzer[1], G. Gobsch[1], M. Rakel[2], C. Cobet[2], N. Esser[2], H. Lu[3], W.J. Schaff[3], M. Kurouchi[4], and Y. Nanishi[4] — [1]Institut f. Physik, TU Ilmenau — [2]ISAS Berlin — [3]Cornell University Ithaca — [4]Ritsumeikan University

A detailed analysis of the dielectric function (DF) for wurtzite In- and N-face InN is presented for the first time. The experimental data cover the energy range from 0.74 up to 9.5 eV (data above 4 eV refer to the use of synchrotron radiation at the Berlin storage ring BESSY II) and were obtained by ellipsometric studies from temperatures of 440 K down to 160 K. Before the measurements, the surface quality was improved by annealing the samples for 10 minutes at 400 °C. By fitting the third derivatives of the DF's a high resolution determination of the transition energies of the high energy critical points of the band structure is achieved. All critical points shift to higher energies if the temperature is decreased. At $T = 160$ K up to seven transitions are analyzed. For both polarities the obtained transition energies show an excellent agreement within 20 meV. The experimental results are compared with recent theoretical calculations.

HL 33.10 Wed 16:45 BEY 154

Structural studies of GaN:Mn films — •Tore Niermann, Martin Kocan, Martin Röver, Jörg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We studied the effect of Mn incorporation on the microstructure of GaN films by high resolution electron microscopy and energy dispersive X-ray analysis. The GaN films were grown by molecular beam epitaxy under various conditions. It is found, that Mn can be dissolved up to nearly 5% metal content. In these films the Mn incorporation results in a columnar growth of the GaN, i.e. in a degradation of the film quality. Further properties of the incorporated Mn were studied. Higher Mn amounts result in the formation of precipitates which are identified as $GaMn_3N$ by chemical analysis and diffraction techniques. The Mn concentration in the remaining GaN matrix is below the detection limit of EDX, i.e. about 0.5 at%.

HL 33.11 Wed 17:00 BEY 154

Optical investigations of the lateral homogeneity of InGaN MQW heterostructures on 2 inch wafers — •Christoph Hums[1], Armin Dadgar[1,2], Jürgen Bläsing[1], and Alois Krost[1] — [1]Otto-von-Guericke Universität Magdeburg, Fakultät für Naturwissenschaften, Institut für Experimentelle Physik, Universitätplatz 2, 39106 Magdeburg — [2]AZZURRO Semiconductor AG, Universitätplatz 2, 39106 Magdeburg

The growth of ternary In-containing alloys is a very temperature sensitive process since small variations in temperature lead to large variations in the In-content and to a small part in the growth rate. A main source for temperature inhomogeneities of the wafer surface in MOVPE growth is the bowing of the wafer induced by strain and the vertical temperature gradient . The optical properties of the sample are effected strongly by Indium content, InGaN-QW layer thickness and overall layer thickness of the structure and have been investigated with spatially resolved photoluminescence. As sample basis we used entire 2 inch wafers from a production type and a research reactor. The peak energy, e.g., shows a standard deviation of ˜15meV at a center energy of 2.783eV. Fabry-Perot oscillations are well visible at yellow luminescence energies. These thickness interferences have an influence on the luminescence intensity and peak energies of the InGaN related luminescence. To determine the influence of the interferences the overall layer thickness has been measured spatially resolved and compared with the PL properties. We discuss the possible impact of wafer bowing on temperature and In inhomogeneities.