HL 31: III-V-Compounds: Nitrides

Time: Tuesday 10:15–13:30 Location: POT 51

HL 31.1 Tue 10:15 POT 51

Direct measurement of the band gap and Fermi level position at InN(1120) — •Philipp Ebert[1], Sarah Schaafhausen[1], Andrea Lenz[2], Aizhan Sabitova[1], Lena Ivanova[2], Mario Dähne[2], Yu-Liang Hong[3], Shangjr Gwo[3], and Holger Eisele[2] — [1]Institut für Festkörperfoschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin — [3]Department of Physics, National Tsing-Hua University, Hsinchu 30013, Taiwan

A non-polar stoichiometric InN(1120) surface freshly cleaved inside UHV was investigated by scanning tunneling microscopy and spectroscopy. Due to the absence of intrinsic surface states in the band gap, scanning tunneling spectroscopy yields directly the fundamental bulk band gap EG=0.7 +/- 0.1 eV. The Fermi energy is pinned 0.3 eV below the conduction band minimum due to cleavage induced defect states. Thus, intrinsic electron accumulation can be excluded for this surface. Electron accumulation is rather an extrinsic effect due to surface contamination or material decomposition, but not an intrinsic material property of InN.

HL 31.2 Tue 10:30 POT 51

Growth and characterization of InN by RF MBE — •Andreas Kraus, Ernst Ronald Buss, Heiko Bremers, Uwe Rossow, and Andreas Hangleiter — Technische Universität Braunschweig, Institute of Applied Physics, Mendelssohnstraße 2, 38106 Braunschweig

InN layers were grown on GaN templates by radio frequency molecular beam epitaxy. After a low temperature nucleation layer InN was grown at different substrate temperatures and indium and nitrogen fluxes. With the intention to improve the quality of these thin films the In flux was pulsed by opening and closing the In shutter periodically. A set of samples was grown in this way by varying the In flux, the substrate temperature and the shutter frequency. The growth was monitored in-situ by reflection high energy electron diffraction and by optical reflectometry. The latter shows intensity oscillations following the shutter sequence allowing us to study the growth kinetics of InN on GaN templates.

Comparing both growth methods, the samples grown with a pulsed In flux exhibit improved structural quality in terms of XRD rocking widths and surface roughnesses measured by atomic force microscopy. Furthermore the samples exhibit no significant strain indicating that they are fully relaxed even at thicknesses of approximately 15 nm.

HL 31.3 Tue 10:45 POT 51

Optical gain in GaNAsP heterostructures pseudomorphically grown on silicon — Nektarios Koukourakis[1], Dominic Funke[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Sven Liebich[2], Christina Bückers[2], Steffen Zinnkann[2], Martin Zimprich[2], Kerstin Volz[2], •Stefan W. Koch[2], Wolfgang Stolz[2], and Bernardette Kunert[3] — [1]Photonics and Terahertztechnology, Ruhr-Universität Bochum, Bochum, Germany — [2]Material Science Center and Faculty of Physics, Philipps-University Marburg, Marburg, Germany — [3]NAsP III/V GmbH, Marburg, Germany

The realization of an electrically pumped semiconductor laser based on silicon remains a huge challenge due to the indirect nature of its band structure. However, a success in this effort would allow for combining the advantage of optical data processing with the well-established silicon processing technology, leading to optoelectronic integrated circuits (OEICs) with drastically improved performance. One promising approach is to grow the novel dilute nitride material Ga(NAsP) lattice matched on silicon. Ga(NAsP) has a direct band gap and has already led to optically and electrically pumped lasers on GaP, that have a lattice constant similar to that of silicon. Here, we analyse the modal gain of the Ga(NAsP) direct band gap material system grown on (001) Si-substrates. We compare the performance of several sample compositions and demonstrate high modal gain values at room temperature, comparable to common high quality laser materials.

HL 31.4 Tue 11:00 POT 51

Surface polarity determination of polar and semi-polar InN — •Daria Skuridina[1], Duc Dinh[1], Michael Kneissl[1], Norbert Esser[1,2], and Patrick Vogt[1] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany. — [2]ISAS Berlin, Albert-Einstein-Str.9, 12489 Berlin, Germany

Over recent years InN has attracted much attention because of its possible applications in electronic devices. However, the growth of high quality InN films still remains a problem. Particularly, the understanding of the structure formation at InN surfaces and the dependency on the InN polarity are still insufficient. In our experiments we have performed X-ray photoelectron spectroscopy (XPS) measurements of the valence band structure of the polar and semi-polar (11-22) InN grown by MOVPE. From the analysis of the peak correlation in the valence band spectra we could determine the polarity of c-plane InN films with thicknesses even below 100 nm. Our measurements confirm that the polarity of the InN films depends strongly on the nitridation of the sapphire substrate before InN growth. Semi-polar (11-22) InN exhibits columnar surface structure along the c-direction at the angle of 58° with respect to the surface normal. The valence band spectra revealed an In polarity of these surfaces which indicates a [0001] growth direction of the columns on semi-polar InN surface.

HL 31.5 Tue 11:15 POT 51

Time-resolved photoluminescence in GaNAsP heterostructures grown on silicon — •Nektarios Koukourakis[1], Dominic Funke[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Sven Liebich[2], Steffen Zinnkann[2], Martin Zimprich[2], Kerstin Volz[2], Wolfgang Stolz[2], and Bernardette Kunert[3] — [1]Photonics and Terahertztechnology, Ruhr-Universität Bochum, Bochum, Germany — [2]Material Science Center and Faculty of Physics, Philipps-University Marburg, Marburg, Germany — [3]NAsP III/V GmbH, Marburg, Germany

The new direct band-gap dilute nitride material Ga(NAsP) is a very promising candidate for the realisation of optoelectronic integrated circuits (OEICs) as it can be grown lattice matched on silicon. Electrically pumped lasing of Ga(NAsP) on GaP has already been demonstrated, showing the high quality of the material. Samples grown on silicon have already shown high gain values, comparable to common high-quality laser materials. In this talk we present time-resolved photoluminescence studies of the Ga(NAsP) direct band gap material system grown on (001) Si-substrates. We compare the carrier dynamics of several samples that differ in growth parameters and material compositions to study the radiative and non-radiative recombination mechanisms.

HL 31.6 Tue 11:30 POT 51

Optical properties of quaternary AlInGaN alloys pseudomorphically grown on GaN — •Egidijus Sakalauskas[1], Benjamin Reuters[2], Lars R. Khoshroo[2], Holger Kalisch[2], Michael Heuken[2,3], Rolf H. Jansen[2], Andrei Vescan[2], Gerhard Gobsch[1], and Rüdiger Goldhahn[1,4] — [1]Institut für Physik, TU Ilmenau — [2]Institut für Theoretische Elektrotechnik, RWTH Aachen University — [3]AIXTRON AG — [4]Institut für Experimentelle Physik, OvGU Magdeburg

The optical properties of quaternary $Al_xIn_yGa_{1-x-y}N$ alloy system with $0.28<x<0.74$ and $0.04<y<0.15$ are presented. The (0001)-oriented AlInGaN films are pseudomorphically grown by metal-organic vapour phase epitaxy on thick GaN buffers with sapphire substrates. The ordinary dielectric function of AlInGaN samples was determined in the range 1-10 eV by synchrotron ellipsometry at room temperature (BESSY II). The sharp onset of the imaginary part of the dielectric function defines the direct absorption edge of the alloys. At higher photon energies, the pronounced peaks are observed in the dielectric function, which correspond to high-energy inter-band transitions attributed to the critical points of the band structure (Van Hove singularities), indicating a promising optical quality of the material. An analytical model, which permits to describe accurately the dielectric function (or optical constants) in the range 1-10 eV, is also presented. The band-gap and high-energy inter-band transition values are obtained by fitting the experimental dielectric function with the analytical model. The strain influence on the band gap is evaluated by using k·p formalism.

15 min. break

HL 31.7 Tue 12:00 POT 51

MOVPE von semipolarem AlGaN auf (10$\bar{1}$0) m-plane Saphir — •Frank Mehnke, Joachim Stellmach, Martin Frentrup, Gunnar Kusch, Tim Wernicke, Markus Pristovsek und Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

Die Bandlücke von AlGaN variiert von 3,4 eV – 6,2 eV und ermöglicht Leuchtdioden (LEDs) im ultravioletten Spektralbereich. In dieser Arbeit wurden semipolare (11$\bar{2}$2) AlGaN–Schichten untersucht, die ohne Nukleationschicht direkt auf (10$\bar{1}$0) m–plane Saphir mittels metallorganischer Gasphasenepitaxie (MOVPE) abgeschieden wurden. Beim Wachstum wurden die TMAl– und TMGa–Partialdrücke bei einer Suszeptortemperatur von 1100 °C unter H_2–Atmosphäre variiert. Die Schichten sind vorzugsweise (11$\bar{2}$2) orientiert. Die Halbwertsbreite des symmetrischen (11$\bar{2}$2) Reflexes entlang der $[1\bar{1}00]_{AlGaN}$ Richtung ist mit 2780 arcsec vergleichbar mit der von (11$\bar{2}$2) GaN Proben auf (10$\bar{1}$0) Saphir. Die Proben haben eine Oberflächenrauigkeit zwischen 15 nm und 2 nm. Der Al–Gehalt der glattesten Proben liegt bei 60 % und wurde aus Transmissionsuntersuchungen bestimmt. Unterhalb von 60 % Al–Gehalt wird die Morphologie von dreieckigen Strukturen bestimmt, deren Öffnungswinkel sich mit abnehmenden Al–Gehalt erhöht. Oberhalb von 70 % sind zusätzlich inselartige Strukturen zu erkennen. Die Absorbtionskante lag 0,05 eV (bei GaN) bis 0,35 eV (bei AlN) unterhalb der Bandkante von (0001) orientierten AlGaN–Schichten. Weitere Untersuchungen zur Eignung der semipolaren AlGaN–Schichten zur Realisierung von UV–LEDs sind in Vorbereitung.

HL 31.8 Tue 12:15 POT 51

Investigation of the influence from TMIn for the optical properties of MOCVD grown InN — •Stefan Mohn[1], Ronny Kirste[1], Gordon Callsen[1], Öcal Tuna[2], Michael Heuken[2], and Axel Hoffmann[1] — [1]TU Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Aixtron AG, Kaiserstr. 98, 52135 Herzogenrath, Germany

Indium Nitride is a member of the III-V semiconductors and has a band gap of approx 0.7 eV. It is a promising candidate for LED, solar cells and other optoelectronic applications. In this talk we report on photoluminescence studies of InN layers grown on sapphire/GaN substrate by metal organic chemical vapor deposition (MOCVD). Commonly used precursors for the growth are of InN Trimethyl Indium (TMIn) and ammonia (NH_3). It is common belief that the ratio between TMIn and NH_3, is the key parameter for the quality of a grown sample. In this contribution we can show that an increase of TMIn flow, while the ammonia flow was constant, leads to to a change of the optical properties. With increasing TMIn content the observed maximas of the photoluminescence measurements shifts to higher energies. At the same time the full width at half maximum (FWHM) is increasing. Therefore we assume a decreasing quality of the grown samples with increasing of the TMIn content. We also observed as decrease in the sample quality, when the TMIn and the ammonia flows are increased while the V/III-ratio remains constant. Theses results are confirmed by a bundle of experimental techniques such as Raman spectroscopy, AFM and XRD.

HL 31.9 Tue 12:30 POT 51

Growth of AlN on c-plane sapphire by pulsed MOVPE — •Hanno Kröncke, Stephan Figge, and Detlef Hommel — Institut für Festkörperphysik, Universität Bremen

Due to it's large bandgap and it's high thermal conductivity Aluminumnitride is of high interest for applications in high power electronics and optoelectronic device emitting in the ultra-violet region. Because Al shows a low surface diffusivity AlN is normally grown at high temperatures up to $1300\,°C$. An alternative approach is the pulsed or flow modulation MOVPE growth, where an alternating supply of the precursors increases the surface mobility of the atoms.

In this study Al-polar AlN layers with a thickness between 200 nm and 1 μm were directly grown on c-plane sapphire in a closed coupled showerhead MOVPE at temperatures between 1000 and $1250\,°C$. Beside the variation of the pulse length for precursors, different types of pre-growth treatments have been investigated. The crystal quality, expressed by surface morphology and dislocation density, was mainly characterized by HRXRD, SEM, AFM and also compared to continuously grown samples.

In general the crystal quality is very sensitive to the growth-start and common concepts, known from the growth of GaN, like low temperature nitridation and buffer layers, lead to very rough surface and high mosaicity. With optimized parameter we achieved RMS surface roughness is below 1 nm and dislocation densities, determined by XRD, in the order of $1\cdot10^7$ cm^{-2} (screw type) and $3\cdot10^{10}$ cm^{-2} (edge type).

HL 31.10 Tue 12:45 POT 51

Carbon doped InAlAs/InGaAs/InAs heterostructures — •Marika Hirmer[1], Dominique Bougeard[1], Dieter Schuh[1], and Werner Wegscheider[2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg, Germany — [2]Laboratorium für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland

InAlAs/InGaAs heterostructures with a high In content are promising candidates for spintronic applications such as spin-valve mesoscopic devices due to their large Landé g-factor (around 15 in InAs) and the large Rashba effect.

Here, we present results on carbon doped InGaAs/InAlAs heterostructures with embedded InAs channel. We got a two-dimensional hole gas with a hole density of $p = 1.06 * 10^{12}$ cm^{-2} and a hole mobility of $7.26 * 10^3$ cm^2/Vs. Magnetotransport measurements on L-shaped Hall bars along [011], [01-1], [010] and [001] crystal directions exhibit well-developed Shubnikov-de-Haas oscillations and quantum Hall plateaus, indicating the high quality of the material. In the field range from minus 6T to 6T the longitudinal resistance is superimposed with a negative parabolic magnetoresistance background. The minimum of the longitudinal resistance at $B = 0$T decreases with increasing temperature, and hence, is a sign for weak antilocalization.

HL 31.11 Tue 13:00 POT 51

Point defects in AlN — •Jan E. Stehr[1], Detlev M. Hofmann[1], Bruno K. Meyer[1], and Matthias Bickermann[2] — [1]1st Physics Institute, Justus-Liebig-University Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany — [2]Department of Materials Science 6, University of Erlangen, Martensstraße 7, 91058 Erlangen, Germany

Aluminum nitride (AlN) bulk crystals are due to their high thermal conductivity and the low lattice mismatch a promising substrate material for group III-element-nitrides, e.g. AlGaN. AlN has a band gap of 6.2 eV, but shows a sub-band-absorption, which is a problem for many applications. Therefore it is necessary to understand which defects are responsible for the absorption bands in the crystals. We investigated AlN bulk crystals with UV-VIS spectroscopy and Electron Paramagnetic Resonance spectroscopy (EPR). In the EPR measurements we observe a donor signal with g=1.994 and an acceptor signal with g=2.006. UV-VIS measurements show an optical absorption band at 580 nm. By Photo-EPR we can correlate the absorption band with the EPR signals, which show up after illumination of the sample with light wavelengths shorter than 580 nm. Defect models will be discussed at the conference.

HL 31.12 Tue 13:15 POT 51

Electrical characterization of ion implanted AlN on sapphire — •Niels Henrik Borth, Ulrich Vetter, Tristan Koppe, Marc Brötzmann, Hans-Gregor Gehrke, Kun Zhang, and Hans Hofsäss — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

AlN with its large bandgap of 6.2 eV is a promising candidate for application in high power high frequency devices, UV detectors and UV light emitters. Despite the fact that there are a large number of publications concerning the optical activation of dopants in AlN, no attempt was made to achieve electrical activation after ion implantation. In this study we report on the electrical behaviour of ion implanted AlN on sapphire. Silicon, magnesium and fluorine were implanted with several energies forming a boxlike profile. The samples were annealed in a RTP furnace. SIMS measurements were used to investigate the implantation profile before and after the annealing process. Before evaporating contacts the surface was etched by RIE using a Cl_2/BCl_3 plasma. The peak concentrations ranged from 0.05 at% up to 1 at%. Results of the electrical measurements as a function of doping concentration are presented. Additionally sputter and RIE experiments were performed for different fluences and times, respectively. AFM measurements illustrate a smoothening of the surface.