HL 7: III-V semiconductors I

Time: Monday 11:00–13:00 Location: H17

HL 7.1 Mon 11:00 H17

Strain properties of AlN layers grown on different substrates — •Ronny Kirste[1], Ute Haboeck[1], Axel Hoffmann[1], Christian Thomsen[1], Barbara Bastek[2], Frank Bertram[2], Jürgen Christen[2], Armin Dadgar[2], and Alois Krost[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

We present results of micro-Raman investigations on AlN samples grown by MOCVD on silicon and sapphire substrates. Thermal and lattice mismatch lead to a strong tensile strain in case of growth on silicon. Thus, already thin layers tend to relax by cracking. In the vicinity of such cracks we observed a strong shift of the nonpolar E_2(high) line. This mode is suitable to probe the strain properties because it is not affected by free carriers or internal electric fields. Converting this shift we found strain gradients of about 1 GPa in 300 nm thick layers and less than 0.5 GPa in thicker films of 1 or 2 μm. Even, at the center of the cracks the AlN layers are not fully relaxed. We will discuss the reasons, therefore, in comparison to AlN samples grown on sapphire. AlN on sapphire is, contrarily to growth on silicon, almost relaxed or slightly and uniformly compressive strained. Apart from cracking good crystal quality is achieved in both cases.

HL 7.2 Mon 11:15 H17

Optical Spectroscopy of doped and undoped Aluminium Nitride Layers on Sapphire Substrates — •Günther M. Prinz[1], Martin Schirra[1], Martin Feneberg[1], Sarad B. Thapa[2], Matthias Bickermann[3], Boris Epelbaum[3], Ferdinand Scholz[2], Rolf Sauer[1], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, D-89069 Ulm — [3]Institut für Werkstoffwissenschaften 6, Universität Erlangen, D-91058

Doped and undoped aluminium nitride layers were grown by MOVPE on sapphire substrates. We investigate these layers by photoluminescence, cathodoluminescence, and reflectance spectroscopy, and determine the fundamental band gap energy and the crystal field splitting of aluminium nitride. The temperature dependence of the near-band edge luminescence is investigated from 10K to 300K.

Doped and undoped samples are differently strained. Strain is tensile as measured by red-shifts of the near-band edge luminescence. Tensile strain is also observed by Raman measurements which show a shift of the E2 mode to lower wave numbers. Based on these measurements we use appropriate deformation potentials to quantitatively calculate the strain in the aluminium nitride layers.

HL 7.3 Mon 11:30 H17

Spinoidal decomposition in GaN:Mn grown by MBE — •Dong-Du Mai, Tore Niermann, Martin Roever, Jan Zenneck, Henning Schuhmann, Amilcar Bedoya Pinto, Joerg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut and Virtual Institute for Spin Electronics (VISel), Georg-August Universität Göttingen, D-37077 Göttingen, Germany

GaN:Mn is grown by plasma assisted Molecular Beam Epitaxy (MBE) on $GaN/Al_2O_3(0001)$. Samples were grown at various substrate temperatures, from T_S=775°C down to T_S=575°C and at various metal-to-nitrogen fluxes. It was possible to define parameter regions in which wurtzite GaMnN grows without second phases. For growth at high T_S and close to stoichiometry GaN:Mn exhibits good crystallinity (TEM, XRD). However only a maximum of $\sim$ 1% incorporation of diluted Mn can be achieved. At lower T_S and nitrogen-rich growth regime higher manganese incorporation (up to $\sim$ 5%) is possible without second phase formation. However the crystal quality worsens. EDX maps measured both in cross-section and plane-view through a scanning TEM analysis reveal an inhomogeneous distribution of the Mn in the layers (spinoidal decomposition). SQUID measurements are discussed in correlation with the structural and compositional analysis.

At regular T_S PL measurements near the band edge show strong bound and free excitonic luminescence (3 meV FWHM). Also a characteristic intra-3d luminescence for substitutional Mn at 1.42 eV (ZPL) could be detected. The latter is quenched at increasing Mn incorporation and its intensity correlates with the near band edge PL.

HL 7.4 Mon 11:45 H17

In-N anti-correlation in InGaAsN alloys: the delicate interplay between adatom thermodynamics and kinetics — •Hazem Abu-Farsakh[1,2] and Jörg Neugebauer[1,2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [2]Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

Quaternary InGaAsN alloys have sparked a lot of interest in making infrared laser diodes for optical data transmission. Recent growth experiments showed a complex behavior for this quaternary system, such as In-N anti-correlation and a tendency to 3D growth with increasing growth temperature. The underlying mechanisms, however, could not be identified so far. We have therefore performed an extensive theoretical study to identify and quantify the fundamental growth mechanisms. Specifically, we computed the incorporation/solubility of N at GaAs and InGaAs surfaces employing density functional theory within the PAW approach. Based on theses results, we (i) derive the thermodynamics phase diagram for N incorporation into the experimentally relevant surface reconstructions, and (ii) identify the kinetic processes for N incorporation at different surface and subsurface sites. Based on these results we have been able to interpret recent experiments and to identify suitable growth conditions.

HL 7.5 Mon 12:00 H17

MOCVD Prozessentwicklung und Charakterisierung von AlIn/GaN-HEMT-Strukturen — Steffen Weller[1], Christoph Giesen[1], Lars Rahimzadeh-Khoshroo[2], Michael Fieger[2], Martin Eichelkamp[2], Holger Kalisch[2], Andrei Vescan[2], Rolf Jansen[2] und •Michael Heuken[1,2] — [1]AIXTRON AG, Kackertstr. 15-17, 52072 Aachen — [2]Institut für Theoretische Elektrotechnik, RWTH Aachen, Kopernikusstr. 16, 52074 Aachen

Im Rahmen der vorliegenden Arbeit wurden MOCVD-Prozesse für die Herstellung von AlInN/GaN-Heterostrukturen für HEMTs (High Electron Mobility Transistors) entwickelt. Zunächst wurden Basisprozesse für die Abscheidung von AlInN auf Saphir untersucht. Es wurde der jeweilige Einfluss der wichtigsten Prozessparameter auf die strukturellen, morphologischen und elektrischen Schichteigenschaften untersucht. Anschließend wurde die komplette AlInN/GaN-Heterostruktur hinsichtlich ihrer elektrischen Eigenschaften optimiert. Der Schwerpunkt der Optimierung lag auf dem In-Gehalt in der AlInN-Barriere und den Wachstumsparametern an der AlInN-GaN-Grenzfläche. Es hat sich gezeigt, dass sich eine ca. 1 nm dicke AlN Zwischenschicht positiv auf die elektrischen Eigenschaften der Heterostruktur auswirkt. An optimierten Strukturen wurden $n_S = 2,3 \cdot 10^{13}$ cm^{-2} und μ = 700 cm^2/Vs gemessen. Neben der detaillierten Darstellung der Wachstumsexperimente und der Schichtcharakterisierung werden auch die Eigenschaften von ersten fertig prozessierten AlInN/GaN-HEMTs diskutiert werden.

HL 7.6 Mon 12:15 H17

MOVPE Wachstum und Charakterisierung von AlInN Schichten auf Si(111) — •C. Hums, A. Gadanecz, A. Dadgar, J. Bläsing, T. Hempel, A. Krtschil, A. Dietz, J. Christen und A. Krost — Otto-von-Guericke-Universität Magdeburg, FNW/IEP/AHE, Universitätsplatz 2, 39106 Magdeburg

Das große Potential von AlInN / GaN Heterostrukturen für elektronische und opto-elektronische Bauelemente wurde durch das MOVPE Wachstum von hoch reflektierenden Bragg-Spiegeln und n-Kanal FETs bereits demonstriert. AlInN wächst bei einer Indiumkonzentration von $\approx$ 17 % gitterangepasst auf GaN. Auf Grund der pyroelektrischen Eigenschaften bei gitterangepasstem Wachstum auf GaN wurde von Dadgar et al. ein n-Kanal FET realisiert. Um eine nitridische Hochtemperatur-CMOS-Logik zu realisieren, ist zusätzlich ein p-Kanal FET notwendig. Dieser wird im selben Materialsystem ab einer Indium Konzentration von $\approx$ 34 % bei pseudomorphem Wachstum auf GaN durch die dann vorhandenen starken piezoelektrischen Felder prognostiziert. Mittels MOVPE wurden $Al_{1-x}In_xN$ Schichten mit Konzentrationen von $0.09 < x < 1$ gewachsen und mit FEREM und Röntgenbeugung charakterisiert. Es kann gezeigt werden, daß $Al_{1-x}In_xN$ bis zu $x < 0.5$ mischbar ist. Bei höheren Konzentrationen kommt es zur Phasenseparation, wobei sich eine stabile Phase mit

$x \approx 0.6$ ausbildet. Mit steigendem Indiumgehalt nimmt die Qualität der Morpholgie ab. Um pseudomorphe Schichten mit hohen Konzentrationen herstellen zu können, wurde detaillert der Zusammenhang zwischen Indiumgehalt, Schichtdicke und Verspannung untersucht.

HL 7.7 Mon 12:30 H17

Thermal stability and structural properties of AlInN grown on Si(111) by metalorganic vapor phase epitaxy — •Aniko Gadanecz, Jürgen Bläsing, Armin Dadgar, Christoph Hums, Thomas Hempel, and Alois Krost — Otto-von-Guericke Universität Magdeburg, FNW/IEP/AHE, Postfach 4120, 39016 Magdeburg

AlInN layers with In concentrations between 9..22 % and maximal thickness of 100 nm were grown by MOVPE on GaN/Si(111). Depending on the In concentration the layers are fully pseudomorphic or exhibit relaxed/pseudomorphic parts.

The thermal stability of such layers was investigated between 30 and 960 °C. It is significantly affected by the degree of relaxation: after different thermal treatment, the relaxed areas show decreasing quality, a loss of Indium and a pronounced phase separation. Additionally, with increasing lattice mismatch, a higher extension of relaxed regions under thermal treatment is observable.

Morphological characteristics, as the values of twist and lattice constants, In-sublimation and the degree of relaxation in the alloy were determined by high resolution X-ray diffraction and field emission scanning electron microscopy (FESEM).

HL 7.8 Mon 12:45 H17

Comparison of the electronic band formation and band structure of GaN_xAs_{1-x} and GaN_xP_{1-x} — •Martin Güngerich[1], Wolfram Heimbrodt[1], Gerhard Weiser[1], Bernardette Kunert[1], Kerstin Volz[1], Peter Jens Klar[2], and John Franz Geisz[3] — [1]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universität, Renthof 5, D-35032 Marburg, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [3]National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401, USA

Incorporation of an increasing amount of N into GaAs causes a strong red shift of the fundamental band gap (E_-) which is accompanied by the blue shift of a higher lying band of N impurity states (E_+). This repulsive behaviour is successfully parameterized by a phenomenological two-level band-anticrossing (BAC) model. In GaP:N the energetic ordering of host and impurity states is reversed compared to GaAs:N because the localized levels lie within the host band gap. We show that the simple BAC model fails to describe the evolution of the lowest conduction states in GaN_xP_{1-x}. Photocurrent and electromodulated reflection measurements of GaN_xP_{1-x} support a BAC-related blue shift of its E_+ band which in this material originates from the GaP-like lowest direct band gap. On the other hand, electromodulated absorption and pressure-dependent photoluminescence studies indicate that the wide energy distribution of the lower-lying N-related states leads to an anticrossing interaction involving many N levels.