HL 96.1 Fri 9:30 H15

Dependence of band gap bowing of epitaxial In$_x$Ga$_{1-x}$N on composition, strain and ordering phenomena by first-principles calculations — •Yung Cui, Sangheon Lee, Gerard Leyson, Christoph Freyboldt, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Max-Planck-Str. 1, 40627 Düsseldorf

The band gap of In$_x$Ga$_{1-x}$N alloys does not only depend on the In composition, but also on the strain state and the ordering of In atoms. We performed a theoretical study to disentangle the different effects. Atomic force microscopy showed the band gaps of In$_x$Ga$_{1-x}$N alloys show parabolic behavior in compressive regions and linear dependence in the tensile regions. We further find a universal bowing behavior in In$_x$Ga$_{1-x}$N alloys for the whole In content range under constant relative strain. Inhomogeneous In distributions lead to a narrower band gap, but are energetically unfavorable. Based on the calculated results, an interpolating form for the band gap as a function of ordering, biaxial strain and chemical content for In$_x$Ga$_{1-x}$N alloys is suggested. Our results provide guidance to determine the band gaps of In$_x$Ga$_{1-x}$N alloys under real experimental conditions.

HL 96.2 Fri 9:45 H15

Ordering phenomena in In$_x$Ga$_{1-x}$N grown epitaxially on GaN(0001) — •Sangheon Lee, Christoph Freyboldt, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Str. 1, 40627 Düsseldorf

The spatial distribution of In in In$_x$Ga$_{1-x}$N epitaxial layers atters much attention, as In compositional fluctuations are often invoked to explain the realization of the high-efficiency blue light-emitting diodes (x ≥ 0.15) despite the large number of threading dislocations. However, the mechanisms determining the spatial distribution of In in the fully grown In$_x$Ga$_{1-x}$N epitaxial layers are not well understood. We therefore developed an effective crystal growth modeling technique that combines a semi-grand-canonical Monte Carlo simulation with an ab initio parameterized empirical force field. We elucidate local strain effects on the spatial distribution of In in coherent In$_x$Ga$_{1-x}$N grown epitaxially on GaN(0001), with particular attention to the effect of the surface. In particular, we observe a strong tendency towards ordering in In$_x$Ga$_{1-x}$N of x < 0.33, resulting in a stack of √3 × √3 patterned InGaN monolayers. The effect of temperature on the ordering and thermodynamics is discussed, revealing that the ordering phenomena persists at real growth temperatures. The ordering phenomena are identified as a key factor that determines characteristic In compositional fluctuations in In$_x$Ga$_{1-x}$N epitaxial layers with varying total indium contents.

HL 96.3 Fri 10:00 H15

Island nucleation during double pulsed growth of InN with RF-MBE — •Andreas Kraus, Uwe Rossow, Heiko Bremers, and Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

Although InN is predicted to have outstanding material properties the data obtained experimentally are more or less disappointing. In particular the carrier mobility is much lower than predicted. Since the growth of InN is very difficult, this discrepancy is most likely due to the low quality of the investigated material. Recently, the quality of MBE-grown InN has been improved by applying pulsed source fluxes. In our recent work we presented a double-pulsed growth method, where periodically the equivalent of less than one monolayer In is followed by a distinct time of nitridation. With this method a surface morphology made of huge and atomically flat grains (≈ 2 µm in diameter) was achieved.

To get a deeper understanding of this growth behavior a series of samples with various numbers of periods was grown. The growth was monitored in-situ by reflection high energy electron diffraction and by optical reflectometry. Ex-situ the samples were characterized by atomic force microscopy, scanning electron microscopy and high resolution X-ray diffraction.

At small period numbers only little islands with dendritic features at their boundaries are visible. These grains evolve to the huge ones that were observed previously. If the period number is large enough that the grains meet each other, they coalesce to a closed surface.

HL 96.4 Fri 10:15 H15

MBE growth and characterization of InN and Al$_x$Ga$_{1-x}$N with various x. — •Christopher Hein, Andreas Kraus, Heiko Bremers, Uwe Rossow, Kamran Forghani, Ferdinand Scholz, and Andreas Hangleiter — Institut für Angewandte Physik, TU-Braunschweig, Germany — Institut für Optoelektronik, Universität Ulm, Germany

Devices based on AlN have gained interest owing to their potential in optoelectronic devices, namely fast detectors, and as a starting material for GaN quantum dot growth. Our experiments include Riber 32P PA-MBE grown AlN layers and Al$_x$Ga$_{1-x}$N/GaN MQW’s. The samples were grown on MOVPE AlN and GaN templates. They were characterized in-situ using RHEED and an infrared reflectometry setup for thickness analysis. XRD measurements served as ex-situ determination of the structural quality and the composition of our MQW’s. The growth temperature behaviour of Al$_x$Ga$_{1-x}$N was investigated with a series of samples in the range of 700 to 850°C. The surface morphology was investigated using SEM and AFM. We found that for optimized Al fluxes in the nucleation layer, the epilayer surface morphology could be improved. Two growth modes have been investigated, the continuous mode which can easily lead to droplet formation and a metal pulsed method which further increases the possible Al/N flux ratio before droplet formation. We also discuss XRD analysis and UV-PL studies of our MQW samples.

HL 96.5 Fri 10:30 H15

InGaN quantum wells grown on 2° semipolar GaN — •Tobias Mersch, Sabine Schönhör, Junjun Wang, Klaus Thonke, and Ferdinand Scholz — 1Institut für Optoelektronik, Universität Ulm, 89081 Ulm — 2Institut für Quantenmaterie, Arbeitsgruppe Halbleiterphysik, Universität Ulm, 89081 Ulm

We have grown high quality (10-11) GaN and (11-22) GaN on (11-3) and (10-12) patterned sapphire respectively. The patterning of the substrate was done by reactive ion etching to produce periodic trenches about 1.5 µm deep and 1.5 µm wide, revealing a c-plane-like facet on one side. All other facets are subsequently covered with SiO2 to inhibit epitaxial growth. In the following MOVPE process, GaN nucleates on this unmasked side facet, grows out of the trench and forms a coalesced semipolar surface. By decreasing the trench depth to 400 nm, we could reduce the RMS of the surface roughness by about a factor of two. First experiments on depositing InGaN quantum wells on the homogeneous GaN surface show much lower indium incorporation on the (11-22) plane as compared to the conventional c-plane. However, by a substantial increase of the indium flux, the QW emission could be shifted to 520 nm. Using comparable growth conditions, QW’s on (10-11) GaN show an emission wavelength of 482 nm and a much higher intensity.

Coffee break

HL 96.6 Fri 11:00 H15


In photoluminescence spectra of wurtzite AlN, several broad exciton emission bands can be observed. Recently, one of them could be identified as being related to substitutional silicon on aluminum site [1]. In this study, we present a correlation of secondary ion mass spectrometry and photoluminescence at liquid helium temperature of a variety of AlN single crystals. From our analysis we tentatively assign a bound exciton line as being related to substitutional oxygen on nitrogen site. For this defect, DX center formation is expected, which is discussed in light of our experimental findings.


HL 96.7 Fri 11:15 H15

Activation of a new europium center in Europium-implanted GaN by both Mg and Si codoping — •Javanta Kumar Mishra,

Location: H15

Time: Friday 9:30–12:15

Friday

HL 96: GaN: Growth and doping

Friday 9:30–12:15
Rare earth ions implanted into GaN are promising for optoelectronic applications. They show luminescence in the visible range while the luminescence from this material system is sharper as well as independent of temperature due to intra 4f transition of rare earth ions. To improve the emission efficiency we implanted Europium in GaN codoped with Mg at dose range from 10^13 cm^-2 to 10^14 cm^-2 with an energy of 100 keV. The red emission from codoping. The typical Eu enhanced by Mg codoping. It further enhances by both Mg and Si Mg at dose range from to D0→F2 of europium was remarkably enhanced by Mg codoping. It further enhances both by Mg and Si doping. The typical Eu luminescence in GaN at 2.000 eV (620 nm) is not found to be dominant. A new peak which is already present in europium-implanted Mg-doped GaN at 2.0047 eV (618.9 nm) is enhanced about ten times. This peak is found to be more than three times more intense than the typical 620 nm line of Mg-doped GaN:Eu. A new site dominates in the spectrum especially in the D0→F2 transition range which is different from the sites present in undoped GaN:Eu. The excitation process of europium ions is proposed to take place through a donor-acceptor pair related energy transfer mechanism.

We investigate n-doping of AlGaN films with thicknesses of about 400 nm were grown on an undoped Al_{0.2}Ga_{0.8} buffer. With both dopant sources, it was possible to achieve electron concentrations of nearly 10^{20} cm^{-3} as determined by Hall-effect measurements. However, when doping was applied, an increase in tensile stress was observed by means of in-situ curvature measurements. This effect becomes more pronounced at higher dopant fluxes and higher dislocation densities of the buffer. For Si-doping this effect is similar to GaN, where Si-doping is known to lead to dislocation climb. On the contrary, it can be shown that for Ge-doping the tensile stress is caused by a change in alloy composition as determined by X-ray diffraction. With higher Ge-fluxes, the Al-concentration of the film increases, consequently the Ge-doped film grows tensely strained on the buffer. Interestingly, the influence on the composition also depends on the dislocation density.

Influence of Si- and Ge-doping on the properties of AlGaN layers — Christian Berger, Hartmut Witte, Armin Dadgar, Jürgen Bläsing, Peter Viet, Annette Diez, and Alois Kroth — Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Magdeburg

We investigate n-doping of Al_{0.2}Ga_{0.8} layers using silane and germane as dopants. For this purpose doped AlGaN films with thicknesses of about 400 nm were grown on an undoped Al_{0.2}Ga_{0.8} buffer. With both dopant sources, it was possible to achieve electron concentrations of nearly 10^{20} cm^{-3} as determined by Hall-effect measurements. However, when doping was applied, an increase in tensile stress was observed by means of in-situ curvature measurements. This effect becomes more pronounced at higher dopant fluxes and higher dislocation densities of the buffer. For Si-doping this effect is similar to GaN, where Si-doping is known to lead to dislocation climb. On the contrary, it can be shown that for Ge-doping the tensile stress is caused by a change in alloy composition as determined by X-ray diffraction. With higher Ge-fluxes, the Al-concentration of the film increases, consequently the Ge-doped film grows tensely strained on the buffer. Interestingly, the influence on the composition also depends on the dislocation density.