HL 40: Focus Session: Role of polarization fields in nitride devices I

Devices based on GaN and related compounds have conquered the fields of transistors, laser and illumination because of their unique materials properties. Polarization fields in particular have strong impact on device characteristics such as current transport in transistors and emission wavelengths in light emitters. This session is devoted to highlight the role of polarization fields in general and with regard to different device performances. Leading experts on theory, materials growth and characterization, and device fabrication will discuss phenomena arising from the physics of polarization fields in nitrides.

Organization: André Strittmatter (OvGU Magdeburg) and Michael Jetter (IHFG, U Stuttgart)

Time: Wednesday 9:30–11:15 Location: ER 164

Invited Talk HL 40.1 Wed 9:30 ER 164

Boon and bane of polarization induced effects in group III-nitride based heterostructures — •Oliver Ambacher — Fraunhofer Institute for Applied Solid State Physics, Freiburg, Germany

Gradients of spontaneous and piezoelectric polarization at surfaces and interfaces of group III-nitride based heterostructures having hexagonal crystal structure can cause huge sheet charges. These fixed sheet charges dominate the band edge as well as the concentration profiles of free carriers. Boon of polarization induced effects are high mobility two dimensional carrier gases with large sheet concentration appearing without intentional doping and opening up new concepts for high power as well as for high frequency transistors. Boon and bane is the sensitivity of polarization induced carrier profiles towards any change of surface potential which might be caused by charged defects, ions or polar molecules. This effect makes it very difficult to achieve suitable surface passivation and long term stable group III-nitride based electronics but opens up an interesting field of very charge sensitive devices suitable for pH-sensors or the detection dangerous polar molecules in gases and liquids. Based on an explanation of non-linear spontaneous and piezoelectric polarization in ternary group III-nitride hexagonal crystals ($c - Al_xM_{1-x}N$, M:= Ga, In, Sc) the state of the art as well as novel electronic and sensor devices will be presented

HL 40.2 Wed 10:00 ER 164

Composition of lattice-matched AlInN at the early stage of growth — •Philipp Horenburg[1], Uwe Rossow[1], Ernst Ronald Buss[1], Heiko Bremers[1], Daniel Henzler[2], Felix Schwarzhuber[2], Josef Zweck[2], and Andreas Hangleiter[1] — [1]Institute of Applied Physics, TU Braunschweig, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, Germany

With a nominal indium content of about 18%, $Al_{1-x}In_xN$ is a-lattice matched to GaN. As compared to $Al_{1-x}Ga_xN$, lattice-matched $Al_{1-x}In_xN$ has a higher contrast in refractive index to GaN. These advantageous properties make AlInN a promising material for Bragg-reflectors and cladding layers in optical devices. However, the epitaxy of lattice matched AlInN is a complex task due to the very different ideal growth conditions of AlN and InN. In this contribution, we will show that the effective In content of thin AlInN layers depends on their thickness. A series of tenfold superlattice structures with varying thickness of the AlInN layers and GaN interlayers of approximately 1 nm was grown by low-pressure MOVPE. Assuming a ternary AlInN layer, our observations suggest the formation of an indium depleted phase at the initial stage of growth. On the other hand, TEM-EDX measurements on AlInN single layers hint at parasitic gallium incorporation in the first few nanometers in AlInN growth, which can be misinterpreted assuming ternary layers. Parasitic Ga in the AlInN would also lead to an overestimation of the Al content assuming ternary AlInN layers in simulation of XRD-profiles.

HL 40.3 Wed 10:15 ER 164

Structural and optical properties of MOVPE grown InGaN/AlInGaN MQWs — •Silvio Neugebauer, Jürgen Bläsing, Armin Dadgar, and André Strittmatter — Institute of Experimental Physics, Otto-von- Guericke-University Magdeburg, Germany

Conventional InGaN/GaN light emitting diodes designed for the green spectral range lack in efficiency due to spontaneous and piezoelectric polarization fields. These fields have negative impact on the LED performance by reducing the recombination probability and wavelength stability of the active medium which is known as the quantum-confined Stark effect. Better device performance could be possibly achieved by using AlInGaN barriers instead of conventional GaN barriers. For a particular InGaN composition it is possible to eliminate the difference in total polarization across the QW/barrier interface by choosing a proper AlInGaN composition. In this context InGaN/AlInGaN MQWs have been grown by MOVPE. Within a set of samples the composition of the barriers have been varied from pure GaN to fully polarization-matched AlInGaN with respect to the InGaN. For better compositional and structural control, these AlInGaN barriers have been grown using the pulsed flow regime. In PL experiments we observe a blueshift of the MQW emission with increasing nominal polarization matching of the barriers. This is consistent with reduced electric fields across the quantum well region. Unfortunately, the whole MQW stack gets additionally strained due to the high indium content of the AlInGaN barrier leading to lattice relaxation as revealed by XRD.

HL 40.4 Wed 10:30 ER 164

Optical polarization of AlGaN quantum well LEDs with emission wavelength near 245 nm — •Martin Guttmann[1], Christoph Reich[1], Frank Mehnke[1], Christian Kuhn[1], Tim Wernicke[1], Jens Rass[1,2], Mickael Lapeyrade[2], Sven Einfeldt[2], Arne Knauer[2], Viola Kueller[2], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Institute of Solid State Physics, Technische Universität Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

For $Al_xGa_{1-x}N$ quantum wells (QWs) the order of the valence bands at the center of the Brillouin zone depends on the aluminum content and the strain state, and hence the optical polarization of the in-plane emission. We measured the optical polarization of AlGaN quantum well light emitting diodes (LEDs) with emission wavelength between 235 nm and 265 nm, corresponding to an aluminum content between 80% and 60% in the QWs. We observed a dominant TE emission for the compressively strained AlGaN multiple quantum wells in the entire wavelength range. The degree of polarization, i.e. $(I_{TE} - I_{TM})/(I_{TE} + I_{TM})$, decreases from 0.85 at 265 nm to 0.5 at 239 nm. From the TE/TM spectra and the temperature dependent polarization we were able to determine the energy difference between the two topmost valence bands to be e.g. 30 meV for 243 nm LEDs. The deviation from the expected splitting energy of -150 meV for unstrained $Al_{0.7}Ga_{0.3}N$ QWs can be explained by the large compressive strain in the QWs.

Invited Talk HL 40.5 Wed 10:45 ER 164

Overview of theoretical aspects of semi-polar and non-polar nitride surfaces — •John Northrup — Palo Alto Research Center (PARC), Palo Alto, California, USA

I will provide an overview of theoretical arguments employed to assess the effect of surface orientation on impurity incorporation in GaN. I will present an argument based on energetics explaining why indium incorporation on semipolar surfaces such as (11-22) is expected to be greater than on the m-plane surface. I will also discuss the structure of Mg-induced pyramidal inversion domains that form in heavily Mg-doped GaN. Unraveling the formation mechanism of these defects is a challenge for theory.