HL 46: Focus Session: AlGaN Materials for UV Emitters

Group III-nitride based ultraviolet light emitting diodes are gaining more and more attention, e.g. as replacement for bulky and inflexible mercury vapor lamps. However, their efficiencies are still far below that of blue and green LEDs. The key challenges are related to the AlGaN materials that are required to realize UV emitters. They can be attributed to fundamental material properties (i.e. band structure), the high defect densities caused by heteroepitaxy, and the difficulty in mixing very dissimilar materials like InN and AlN. It is the aim of this focus session to provide an overview of novel approaches to tackle these problems, ranging from bulk crystal growth of AlN to epitaxy of AlGa(In)N alloys, investigations of basic properties of AlGaN materials as well as performance characteristics of UV emitting (and detecting) devices. (Organizers: Markus Weyers, Ferdinand-Braun-Institut Berlin, Mathias Bickermann and Michael Kneissl, TU Berlin)

Time: Wednesday 9:30–12:45 Location: ER 164

Invited Talk HL 46.1 Wed 9:30 ER 164

AlN-based technology for electronics and optoelectronics — •Zlatko Sitar[1], Ramon Collazo[1], Raoul Schlesser[2], Spalding Craft[2], Baxter Moody[2], Seiji Mita[2], Jinqiao Xie[2], Anthony Rice[1], and James Tweedy[1] — [1]MSE, North Carolina State University, Raleigh, NC, USA. — [2]HexaTech, Inc., Morrisville, North Carolina, USA.

For the first time in history of III-nitrides, the availability of low defect density (<10E3 cm-2) native AlN substrates offers an opportunity for growth of AlGaN alloys and device layers that exhibit million-fold lower defect densities than the incumbent technologies and enable one to assess and control optical end electrical properties in absence of extended defects. Epi-ready AlN wafers are fabricated from AlN boules grown by physical vapor transport at temperatures between 2200 and 2300°C. Gradual crystal expansion is achieved through a scalable, iterative re-growth process in which the high crystal quality is maintained over many generations of boules. Low defect density AlN and AlGaN epitaxial films are grown upon these wafers that exhibit superior optical properties in terms of emission efficiency and line width and can be doped with an efficiency that is several orders of magnitude higher than possible in technologies using non-native substrates. UV LED structures and Schottky diodes were fabricated on these materials that exhibit low turn-on voltages and breakdown fields greater than 10 MV/cm. This presentation will review state-of-the-art of AlN-based technology and give examples of potential applications in future devices and contrast these with other wide bandgap technologies.

Topical Talk HL 46.2 Wed 10:00 ER 164

Towards Sub-300 nm AlGaN Laser Diodes on Bulk AlN Substrates — •Thomas Wunderer[1], Christopher Chua[1], John Northrup[1], Zhihong Yang[1], Noble Johnson[1], Michael Kneissl[1,4], Gregory Garrett[2], Hongen Shen[2], Michael Wraback[2], Baxter Moody[3], Spalding Craft[3], Raoul Schlesser[3], Rafael Dalmau[3], and Zlatko Sitar[3] — [1]Palo Alto Research Center Inc., Palo Alto, CA, USA — [2]US Army Research Laboratory, Adelphi, MD, USA — [3]HexaTech Inc., Morrisville, NC, USA — [4]Inst. of Solid State Physics, TU Berlin, Berlin, Germany

We report recent progress on the development towards sub-300 nm laser diodes. By using high-quality bulk AlN substrates we are able to achieve excellent crystalline quality of the epitaxially grown MOCVD laser hetero-structures. We successfully realized optically pumped AlGaN-based lasers in the wavelength regime between 237 and 291nm with threshold pump power densities below 130 kW/cm2. Results of structural and optical investigation methods will confirm the high material quality, which led to the high lasing performance. We will discuss the polarization properties of the lasers with different emission wavelengths and present concepts of how to address the electrical challenge of high bandgap laser diodes.

Topical Talk HL 46.3 Wed 10:30 ER 164

High-efficiency AlGaN-based light-emitting diodes for the UV-A wavelength range — •Richard Gutt[1], Thorsten Passow[1], Michael Kunzer[1], Wilfried Pletschen[1], Lutz Kirste[1], Kamran Forghani[2], Ferdinand Scholz[2], Klaus Köhler[1], and Joachim Wagner[1] — [1]Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Freiburg — [2]Institut für Optoelektronik, Universität Ulm

To date, AlGaN-based light emitting diodes (LEDs) emitting in the ultraviolet (UV) wavelength range exhibit much lower external quantum efficiencies (EQE) compared to their highly-developed GaN-based counterparts covering the visible spectral range. This can be ascribed to two major reasons. On the one hand, epitaxial growth of AlGaN on sapphire typically leads to a large density of threading dislocations, which are known to act as non-radiative recombination centers. On the other hand, the demand for shorter emission wavelengths inhibits the use of GaInN quantum wells (QWs), which show efficient light emission despite the quite high dislocation density in GaN-based LEDs.

In this talk, we present different approaches towards the reduction of threading dislocations in AlGaN with an Al content of $\sim 20\,\%$. Moreover, a significant enhancement in light emission by using GaN QWs with very low In content is demonstrated. We also address the challenges in achieving a high carrier injection and light extraction efficiency. Combining all these measures, we demonstrated LEDs emitting at wavelengths around 350 nm with an EQE exceeding 7 %, which is among the highest values reported for AlGaN-based LEDs.

Coffee Break (15 min)

Topical Talk HL 46.4 Wed 11:15 ER 164

Growth and properties of bulk AlN crystals — •Boris Epelbaum — CrystAl-N GmbH, Dr.-Mack-Straße 77, D - 90762 Fürth

Single-crystalline aluminum nitride is a very promising substrate material for nitride-based optoelectronic devices performing in deep UV spectral range. The feasibility of bulk AlN growth using high-temperature Physical Vapor Transport (PVT) method has been convincingly confirmed during last years, but important crystal quality issues still remain. In this presentation we will show our most recent achievements in growth of bulk AlN crystals and discuss some quality issues:

(i) Specific defects in bulk AlN such as macropipes and localized misoriented domains and their evolution during growth process, (ii) Crystal faceting and boule enlargement within a single growth process. The influence of temperature gradient on growth interface and faceting effects on enlargement and structural quality of crystal rim. (iii) Variations of UV transmission in different crystal areas

Finally high structural quality crack-free bulk AlN crystals up to 40 mm in diameter grown using various polar and semi-polar orientations will be demonstrated.

Topical Talk HL 46.5 Wed 11:45 ER 164

Studies about defect reduction in AlGaN hetero structures — •Ferdinand Scholz[1], Kamran Forghani[1], Haoyuan Qi[1], Mohammadreza Gharavipour[1], Martin Klein[1], Oliver Klein[2], Ute Kaiser[2], Benjamin Neuschl[3], Klaus Thonke[3], Richard Gutt[4], and Thorsten Passow[4] — [1]Institut für Optoelektronik, Universität Ulm, 89081 Ulm — [2]Zentrale Einrichtung Elektronenmikroskopie, Universität Ulm, 89081 Ulm — [3]Institut für Quantenmaterie, Universität Ulm, 89081 Ulm — [4]Fraunhofer-Institut für Angewandte Festkörperphysik, 79108 Freiburg

Owing to its large and tunable band gap, $Al_xGa_{1-x}N$ is the key semiconductor for the development of UV light emitting devices. Currently, many groups study the realization of such LEDs emitting at wavelengths below 350nm. Obviously, the radiative efficiency decreases with decreasing wave length, which is most probably caused by the increasing defect density in such materials with increasing Al content x. We have investigated how the defect density in AlGaN structures with x 20 - 50% can be reduced by optimizing the respective MOVPE process. One possibility is the integration of in-situ deposited SiN interlayers which should act as dislocation blocking layers. This concept works excellently in GaN, but with only limited success in AlGaN. By transmission electron microscopy studies, we analyzed the functionality of SiN in AlGaN in more detail. UV LEDs grown on optimized AlGaN layers showed very high light output powers proving the success of our defect density reducing methods.

Topical Talk HL 46.6 Wed 12:15 ER 164

Dielectric properties and band structure evolution in AlGaN alloys — •Christoph Cobet — Center of Surface and Nanoanalytics, Johannes Kepler University , Linz, Austria

During the past 10 years the optoelectronic properties of group-III-nitrides have been investigated in a wide spectral range. These efforts were driven on one hand by the demand on reference data for novel optoelectronic devices and for proving band structure calculations and on the other hand by the continuous improvement of the crystal quality of epitaxial films. Step by step it was possible to elucidate many fundamental electronic properties and to increase the general understanding of the constituting electronic background. Recently remaining uncertainties concerned for example the fundamental question whether cubic AlN has an indirect band gap and the identification of related band structure peculiarities. Moreover, the impact of the exciton formation and the exact band ordering at the Γ- and other high symmetry points in the Brillouin-zone are discussed under consideration of strain effects. It will be shown on the basis of complete AlGaN series, how these kinds of questions were addressed by measuring the entire dielectric function from the visible to the far UV.