HL 28: Focus Session: Breakthroughs in wide-bandgap semiconductor laser diodes II

Time: Wednesday 15:00–16:45 Location: POT 361

Invited Talk HL 28.1 Wed 15:00 POT 361

Fabrication of AlGaN-based UV-B laser diodes on lattice-relaxed high-quality AlGaN — •Motoaki Iwaya[1], Sho Iwayama[1,2], Tetsuya Takeuchi[1], Satoshi Kamiyama[1], and Hideto Miyake[2] — [1]Meijo Univ., Nagoya, Japan — [2]Mie Univ., Tsu, Japan

Recently, AlGaN-based ultraviolet (UV) light-emitting devices have been achieving remarkable performance. Highly efficient UV light-emitting diodes are finding applications in many fields, such as water and air sterilization. Meanwhile, room-temperature oscillation of laser diodes in the UV-C and UV-B region has also been realized in recent years by current injection. In this presentation, we show our realization of UV-B laser diode. To realize UV-B laser diodes, it is essential to fabricate them on lattice-relaxed AlGaN because the lattice mismatch between AlN and AlGaN active layers is at least 1.2%. We have obtained various methods for improving the quality of lattice-relaxed AlGaN, and would like to report on the methods and effects. As specific methods to fabricate lattice-relaxed high-quality AlGaN, we explain AlGaN fabricated by the spontaneous nucleation method and the AlN nanopillar method. We will also discuss the correlation between lattice defects such as dislocations, V-shaped pits, and hillocks and device properties. And we would like to present the characteristics of UV-B laser diodes fabricated on such AlGaN templates.

Invited Talk HL 28.2 Wed 15:30 POT 361

Breakthrough technologies to realize room-temperature continuous-wave deep-ultraviolet laser diodes — •Maki Kushimoto — Nagoya University, Nagoya, Japan

AlGaN-based UVC laser diodes operating at wavelengths are expected to be a low-cost, environmentally friendly, and highly efficient laser light source for a variety of applications. Although the pulsed operation of AlGaN-based laser diodes at UV-C wavelengths has been confirmed in the previous studies, continuous wave lasing without cooling was difficult because of the high operating voltage. In this study, we further reduced the threshold gain by improving the optical confinement and improved the threshold current density while lowering drive voltage by modification of device designs. The new design improved the optical confinement factor to the quantum wells from 4% to 6% , which has led to a significant reduction in threshold current density. Furthermore, A reduction in threshold voltage was achieved by reducing the lateral distance between the n- and p-electrodes by tapering the sides of the LD mesa. In the conventional structure, the presence of process-induced crystal defects forced a distance between the n and p electrodes, which was a major factor in increasing the operating voltage. This tapered mesa performs the role of suppressing crystal defects by controlling shear stress of mesa edge. As a result, room temperature CW lasing at a wavelength of 274 nm with a threshold current density of 4.2 kA/cm^2 and a voltage of 8.7 V was successfully achieved.

HL 28.3 Wed 16:00 POT 361

Spectral dynamics of lateral modes and filaments in InGaN broad-ridge laser diodes — •Lukas Uhlig[1], Dominic J. Kunzmann[1], Anna Kafar[2,3], Szymon Grzanka[2,3], Piotr Perlin[2,3], and Ulrich T. Schwarz[1] — [1]Chemnitz University of Technology, Chemnitz, Germany — [2]Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw, Poland — [3]Top-GaN Ltd., Warsaw, Poland.

Blue InGaN broad-ridge laser diodes are versatile, efficient, and compact high power emitters, which are demanded for copper welding, white light generation, and other applications. Compared with standard narrow-ridge laser diodes, in case of the broad-ridge devices the ridge width is increased from around 2 μm to tens of micrometers, leading to lateral multi-mode operation or filamentation.

We investigate a series of devices with ridge widths from 2.4 μm to 20 μm and study their lateral-spectral-temporal behavior as well as high-resolution spectra. With increasing ridge width, we observe the transition from lateral single-mode to multi-mode operation and in the case of the 20 μm wide ridge, filamentation occurs. In the multimode regime, the dynamic onset behavior as well as the spectral-lateral mode distribution are governed by competition of lateral and longitudinal modes for gain. Filaments form in the case of strong nonlinear interaction between intensity, charge carrier density, temperature, and refractive index. Using high-resolution spectroscopy, we can clearly differentiate between different lateral modes, which occur in parallel and form multiple longitudinal mode combs.

HL 28.4 Wed 16:15 POT 361

Temperature dependent electroluminescence studies of the carrier transport in multi colour deep ultraviolet light emitting diodes — •Jakob Höpfner[1], Florian Kühl[1], Marcel Schilling[1], Anton Muhin[1], Gregor Hofmann[2], Friedhard Römer[2], Tim Wernicke[1], Bernd Witzigmann[2], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institute of Solid State Physics, Berlin, Germany — [2]Lehrstuhl für Optoelektronik, Department EEI, Friedrich-Alexander-Universität, Erlangen-Nürnberg, German

Earlier studies have shown that a drop in current injection efficiency (CIE) is partly responsible for the poor external quantum efficiencies (EQE) of AlGaN-based deep ultraviolet light emitting diodes (DUV-LEDs). In particular, the hole injection and the carrier distribution in the AlGaN multi quantum well (MQW) active region is not well understood. In order to get a better insight we have performed temperature dependent electroluminescence (EL) investigations of three-fold AlGaN MQW LEDs with two of the QWs emitting at 233 nm and one QW emitting at 250 nm. In addition, the position of the 250 nm QW with the MQW structure was varied. From temperature dependent EL measurements we observe a strong shift in the intensity distribution over wavelength and temperature. We were able to correlate this with a change in the hole injection into the different QWs suggesting an efficient hole transport over the barriers between the QWs at room temperature. These experimental results are also supported by devices simulations and enable us to further improve the LED heterostructure.

HL 28.5 Wed 16:30 POT 361

265 nm LEDs and laser heterostructures with p-type distributed polarization doping AlGaN layers — •Massimo Grigoletto[1,2], Sarina Graupeter[1], Verena Montag[1], Jakob Höpfner[1], Luca Sulmoni[1], Tim Wernicke[1], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institute of Solid State Physics, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Efficient hole injection in AlGaN-based LEDs and lasers emitting in the ultraviolet (UV) spectral range remains a great challenge. Distributed polarization doped (DPD) p-type AlGaN heterostructures have been developed to overcome this hurdle. By introducing a constant piezoelectric polarization charge along compositionally graded $Al_xGa_{1-x}N$ layers a high density of free hole carriers can be established even in the absence of Mg dopants. In this study we have investigated the influence of the DPD design on the structural properties and electrooptic characteristics of AlGaN-based LEDs and laser heterostructures emitting near 265 nm. For efficient hole injection p-type $Al_xGa_{1-x}N$ layers with different Al gradients and thickness have been incorporated and grown by metal organic vapor phase epitaxy. On-wafer measurements of UV-LEDs exhibit forward voltages of 6 V at a dc current of 20 mA and output power of 1 mW comparable to conventionally Mg-doped heterostructures. The LEDs could be operated at high current densities up to 12 kA/cm^2 in pulsed mode, which shows the DPD is a promising approach for achieving low resistance p-type AlGaN layers with high al mole fractions.