Type of presentation: Oral

IT-5-O-2167 Electro-optical characterization of single InGaN/GaN core-shell LEDs inside an SEM

Ledig J.[1], Scholz G.[1], Popp M.[1], Steib F.[1], Fahl A.[1], Wang X.[1], Hartmann J.[1], Mandl M.[1,2], Schimpke T.[1,2], Strassburg M.[2], Wehmann H. H.[1], Waag A.[1]

[1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig, Germany, [2]OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg, Germany

Email of the presenting author: j.ledig@tu-bs.de

Three dimensional light emitting diodes (LEDs) with a shell geometry around a columnar GaN core are supposed to have substantial advantages over conventional planar LEDs. The active area along the sidewalls of the GaN pillars can considerably be increased by high aspect ratios - leading to a lower current density inside the InGaN multi quantum well (MQW) at the same operation current per substrate area. Due to the 3-dimensional (3D) shape, the electrical and optical characterization of such device structures is a substantial problem because most of the conventional characterization techniques (e.g. Hall effect, capacitance/voltage) cannot be used with 3D geometries.
A nano-manipulator setup inside a scanning electron microscope (SEM) has been used in combination with a cathodoluminescence (CL) system to characterize the electro-optical properties by directly contacting single facets of the 3D structure. The investigated core-shell LEDs are grown by selective area metal organic vapor phase epitaxy on templates consisting of a patterned SiOx mask layer on an n-type GaN layer on 2” sapphire wafers. The light extraction of optical emission from a small region is related to the structure shape, this is estimated using ray tracing simulation and observed by spatially resolved and angle resolved microscope images inside the CL system.
Electron beam induced current (EBIC) images obtained on 3D structures contacted inside the SEM via the substrate and a probe tip clearly prove that a conjunct p-type shell is wrapped around the entire n-type column with an aspect ratio of about 5 forming a depletion region. By comparing spatially resolved CL and EBIC, the rate of charge carrier generation, trapping and separation in different regions of the structure are discussed.
We will present results of electroluminescence (EL) of MQW as well as defect related emission from single core-shell LED structures obtained at different injection currents. A wavelength shift of the MQW emission by 60 nm is observed along the structure height for both excitation methods (CL and EL), indicating a gradient of the indium incorporation caused by changing local growth conditions. The spectra are corrected with respect to the spectral sensitivity of the optical system - including the collection optics, monochromator and the CCD parallel detector.
In addition, metal contacts have been fabricated in order to get a defined contact area. By evaluating the contact area and the EL spectra we gain an insight to the internal efficiency of a single structure versus current density and the average spatially resolved extraction properties.

Acknowledgement: We thank Dr. Uwe Jahn for support regarding optical characterization. The financial support of the European commission (SMASH and GECCO) as well as the endorsement of the NTH and the JOMC are acknowledged.

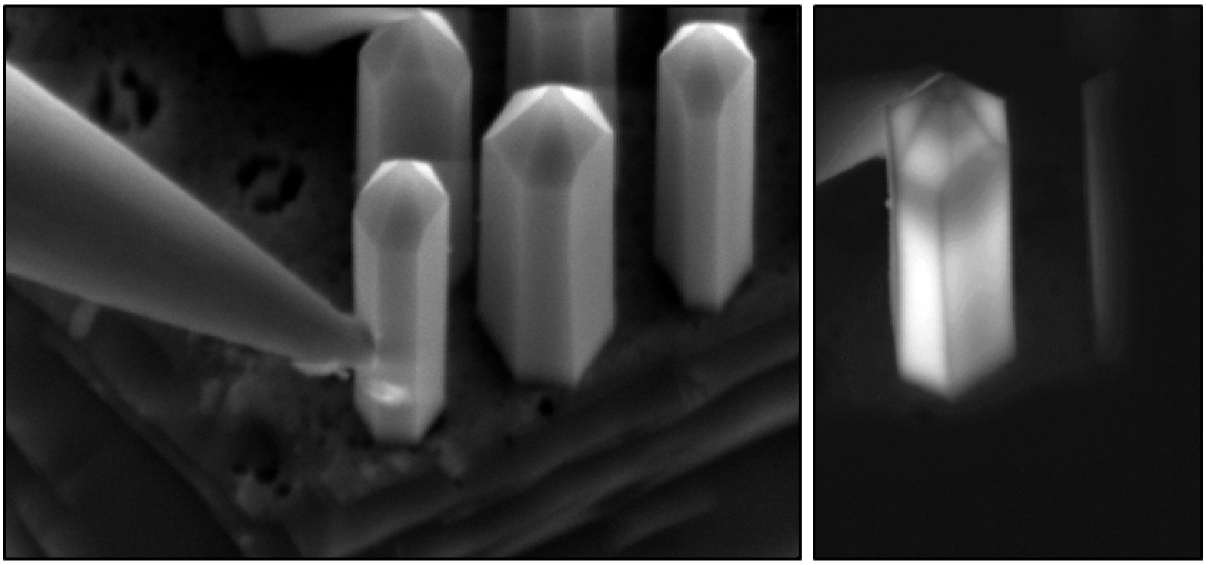

Fig. 1: SE image of a core-shell LED structure on the cleaved growth template contacted by a probe tip on the sidewall at a height of 2.6 µm at an FOV =11.4 µm, EHT = 15 kV, tilt = 30°. EBIC image (right) at a reverse bias of VR = 7 V obtained by contacting a core-shell LED with a probe tip, the core is contacted via the n-type GaN buffer layer.

Fig. 2: Photograph of the CL-SEM chamber showing the arrangement of the parabolic mirror (1) for light collection, the micromanipulator (2) and sample (3) tilted by 30°. The sample is a contacted inside the focal point of the optical collection system by a tungsten probe tip attached to the micromanipulator.

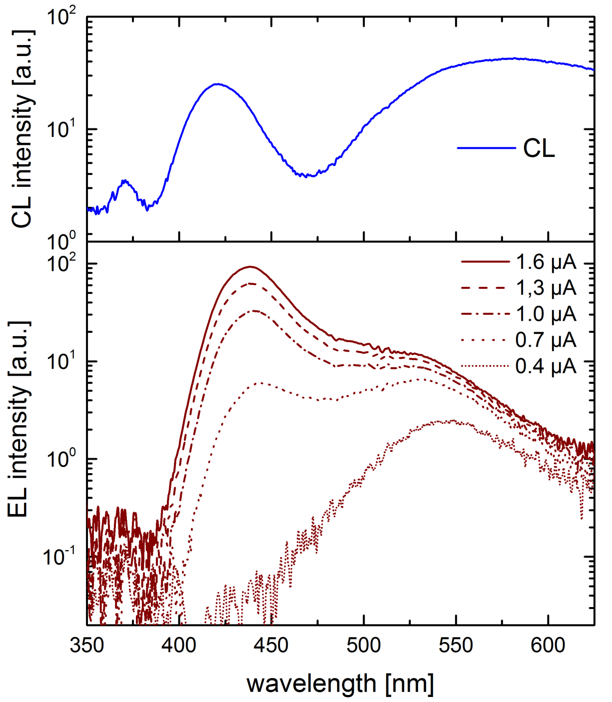

Fig. 3: EL spectra of the core-shell LED shown above obtained by different injection currents through a tip contact placed on the sidewall at a height of 4.4 µm and CL spectrum (upper curve) obtained by electron probe excitation at the same height. The spectra are captured with a spectral FWHM of about 7.5 nm using a CCD parallel detector.