Electroluminescence and current-voltage measurements of single (In,Ga)N/GaN nanowire light-emitting diodes in the nanowire ensemble

David van Treeck*[1], Johannes Ledig[2], Gregor Scholz[2], Jonas Lähnemann[1], Mattia Musolino[1], Abbes Tahraoui[1], Oliver Brandt[1], Andreas Waag[2], Lutz Geelhaar[1], Henning Riechert[1]

[1]Paul-Drude-Institut für Festkörperelektronik , Hausvogteiplatz 5-7, 10117 Berlin, Germany

[2]Institut für Halbleitertechnik, TU Braunschweig, Hans-Sommer-Straße 66, 38106 Braunschweig, Germany

*Email: treeck@pdi-berlin.de

During the last years, light-emitting diodes (LEDs) based on (In,Ga)N/GaN nanowire (NW) ensembles have been increasingly investigated as an alternative to conventional planar LED structures. With NWs one can achieve high crystal quality on foreign, cost-efficient substrates, e.g. silicon, since dislocations do not propagate from the substrate interface throughout the entire NW but terminate at the side walls. Furthermore, the strain induced by the (In,Ga)N insertions can relax elastically to the side facets, which might lead to reduced piezoelectric fields and therefore to an enhanced emission efficiency. Considering the analysis of NW-LEDs, most studies found in literature focus mainly on the characterization of the NW ensemble. However, the properties of single NWs might differ due to ensemble fluctuations. Especially the electroluminescence (EL) and the current-voltage (I-V) behavior of the single NW LEDs in the ensemble are of large interest to gain a deeper insight into the current transport and the emission properties of such nanostructures. Our study presents an approach to measure the I-V behavior as well as the EL of one or a few, freestanding nanowire LEDs in a self-assembled NW ensemble. To this end, NWs are contacted with a nanoprobe installed in a scanning electron microscope (SEM) [see Fig.1(a)]. The setup also allows the acquisition of an optical signal from the sample. The EL spectra obtained for different measurement points usually contained several peaks at various wavelengths [see Fig.1(b)], which are either emissions of different single NWs or of different insertions within one NW. Comparing these EL spectra to the ensemble, it was found, that the EL emission of the ensemble is a superposition of the contributions of the single NW LEDs. Analyzing the I-V data [see Fig.1(b)] of various measurement points, the series resistances as well as the threshold voltages of the single NWs could be determined and estimations for the current densities in single NWs in the working NW ensemble could be made. In summary, our study contributes to a better understanding of the opto-electronic properties of (In,Ga)N/GaN NW LEDs.

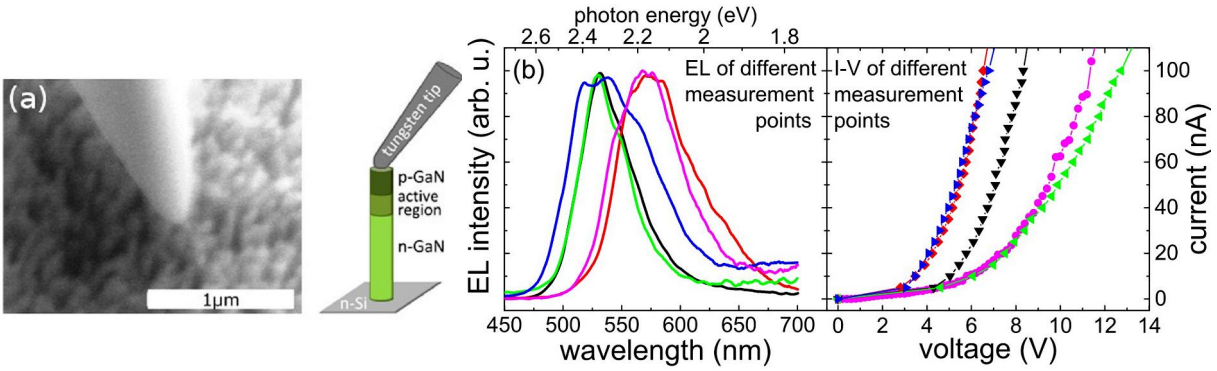

Fig.1: (a) Bird's eye view SEM image of a nanoprobe contacting one or a few NWs and schematic of the measurement principle. (b) EL spectra and respective I-V curves of different measurement points.