Cross-sectional cathodoluminescence and EBIC characterization of (Al,Ga)N/GaN nanowire light emitting diodes

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Understanding of the fundamental optical and electrical properties of GaN-based LED nanowire structures is essential for the development of the novel light emitting nano-devices. We present the nano-scale correlation of morphological, electrical and optical properties of GaN/(Al,Ga)N nanowire (NW) light emitting diodes (LEDs) as observed by a combination of spatially and spectrally resolved cathodoluminescence (CL) spectroscopy and imaging, electron beam induced current (EBIC) technique and scanning electron microscopy (SEM). To complement the results, also photo- and electro- luminescence (PL and EL) were studied.

LED structures based on GaN/(Al,Ga)N nanowires with 3 GaN quantum wells (QWs) in the p-n junction and (Al,Ga)N barriers were grown on in-situ nitridated Si(111) substrates without any catalyst by plasma-assisted molecular-beam epitaxy.

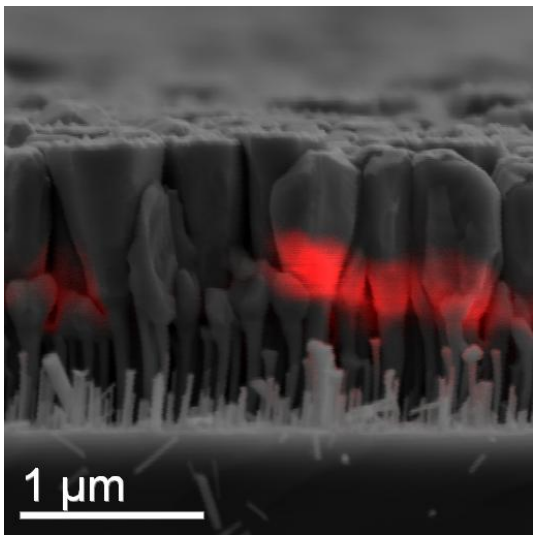

Fig. 1. Superimposed EBIC signal (red) and SEM image (grey) of the LED NWs. The strong EBIC signal reveals position of the p-n junction.

Luminescent properties of the NWs were studied in a cross-sectional configuration by CL and PL at temperature of 5 K. The CL spectra revealed four main strong emission bands. Two – at 3.65 and 3.83 eV are related to $Al_{0.06}Ga_{0.94}N$ and $Al_{0.12}Ga_{0.88}N$ barriers. The GaN DX luminescence is observed at 3.47 eV. The fourth band – at 3.29 eV could be related to donor-acceptor pairs but its energy coincides also with QW emission as revealed by EL spectroscopy.

The EBIC technique enabled spatially resolved electrical current mapping of the active region in NW LEDs with a nanoscale resolution. In particular, electrical activity of the p–n junction was studied. Strong EBIC signal in the QWs region of the NW, indicating position of the p-n junction was observed (Fig. 1).

The observed inhomogeneities of the EBIC signal and differences in CL spectral features can be correlated with differences in NWs morphology. In particular, as revealed by SEM studies, there are two kinds of the NWs morphology (in the same growth process), most probably related to N and Ga growth polarities. These two had different influence on electrical and optical signals: the reduced EBIC signal in the active region of the structures in one case is accompanied by increase of CL intensity. The differences and their possible origins are discussed.

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