Doping inhomogeneity in GaN and $Al_xGa_{1-x}N$ nanowires

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UV Light emitting diodes (LEDs) are nowadays gaining particular attention due to their potential for replacing mercury lamps currently used for sterilization and water disinfection applications. Due to the bandgap tuning possibility, $Al_xGa_{1-x}N$ ternary alloy is the main candidate for such devices. Planar structure LEDs having a low internal efficacy due to a high density of extended defects and limited doping for high AlN molar fraction combined to a low light extraction efficacy, $Al_xGa_{1-x}N$ nanostructures such as nanowires (NWs) could be a realistic alternative with respect to their 2D counterparts due to their advantage of plastically relaxing the strain during growth, coupled with an improved solubility limit of Si dopants [1] and an eased light extraction coming from their particular morphology.

Material and doping homogeneity are nevertheless not easy to control in nanowires. Indeed, Atom Probe Tomography, Energy Dispersive X-ray and Raman spectroscopy performed on GaN pn junctions grown by PA-MBE have shown that both n-type and p-type dopants, namely Si and Mg, respectively, exhibit an inhomogeneous radial distribution, with dopant incorporation upper limits attaining 10^{21} atoms/cm^3 at the periphery, higher than in 2D layers[1][2]. The full control of electrical transport properties of NW-based devices implies taking into account these peculiarities of dopant physics in NWs. However, quantitative determination of doping levels by standard techniques such as Hall effect or SIMS measurements is inherently difficult. To overcome this limitation, Electron Beam Induced Current (EBIC) experiments have been performed providing information on the quality of materials and allowing to extract the electrical parameters of the junction, assessing wire to wire inhomogeneous p-n junction space charge region (SCR) distribution.

[1] Z. Fang, E. Robin et al, Nano Lett. 15 (10) (2015), 6794–6801
[2] A.M. Siladie, L. Amichi et al, Nanotechnology 29 (25) (2018)
[3] Z. Fang, F. Donatini et al, Nanotechnology 29 (2018)