Kelvin probe force microscopy study of polarity and doping in III-Nitrides nanowires

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III-nitride nanowires (NWs) are of significant interest for optoelectronic and energy harvesting applications, which practically require tight growth control as their electronic and optical properties are polarity-dependent. Also a reliable method to characterize doping is a prerequisite. In this work, we demonstrate the capabilities of Kelvin probe force microscopy (KPFM) as a non-destructive technique for the determination of the polarity and assessment of doping in GaN NWs. This has been implemented on MBE grown GaN self-assembled NWs with mixed polarity and NWs with p-n junction dispersed on atomically flat highly oriented pyrolytic graphite (HOPG). For GaN NW assembly, this technique allows the assessment of the polarity of individual NWs from large images (tens of µm2), and provides the statistics on the polarity of the ensemble hardly measurable by other methods [1]. Our results show that the majority of NWs exhibiting N-polarity show CPD values much lower than that of Ga-polar NWs. These observations are quantitatively consistent with the same measurements on reference samples. For doping assessment in p-n junctions NWs, in p- and n-type single GaN NWs dispersed on HOPG, KPFM allowed spatial localization of the junction and surface built-in potential. KPFM measured in dark and under UV-illumination for photovoltage measurement show that the shift of the Fermi levels with respect to that of HOPG are the most important effects under above band-gap illumination, while changes in surface band bending are minor. The Fermi level shift was measured opposite for n-type and p-type NWs, explainable in terms of charge transfer at the metal-semiconductor junction in non-equilibrium.

References

[1] A. Minj et al. Nano Lett. 15, 6770-6776 (2015)