Titre: Calibrated measurements of dopant concentrations on vertical nanowires by scanning microwave microscopy

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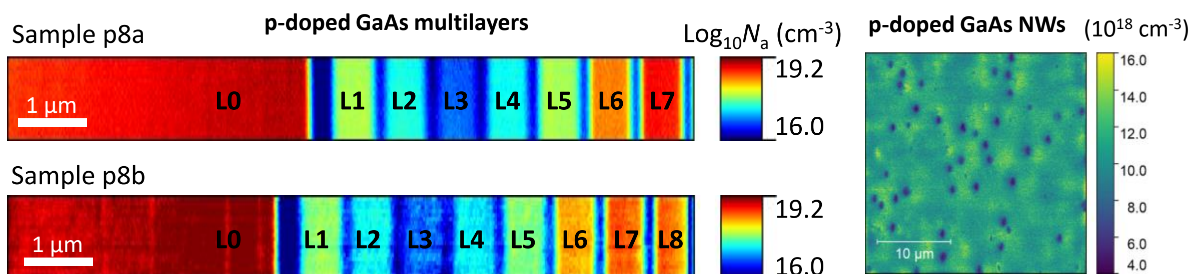
Abstract

Arrays of vertically aligned semiconducting GaAs nanowires (NWs) with radial and axial p-n junctions constitute the core element for novel photovoltaic cells for enhanced efficiency [1]. Nevertheless, the accurate characterization of their junctions' dopant concentrations is crucial for screening defective NWs and analyze their effects on the overall performance of the cell. The metrology of dopant concentrations for these NWs imposes two main conditions as follows. First, high-resolution measurements are key to characterize every single NW, which can only be addressed using electrical scanning probe microscopy techniques such as the scanning microwave microscopy (SMM). Second, reference values of dopant concentrations are essential for traceable measurements on NWs.

SMM is a powerful technique for measuring impedances at the nanoscale with a spatial resolution lower than 50 nm. In SMM, a conductive tip is in contact with the surface of the sample of interest and connected to a RF source in the GHz range. Measuring the impedance of doped semiconductor with a native oxide layer enables the determination of its dopants concentration levels [2]. To perform quantitative dopant concentration measurements, SMM has been calibrated using a reference sample based on p-doped GaAs multilayers with different doping levels N_a ranging from $5 \cdot 10^{16}/cm^3$ to $2 \cdot 10^{19}/cm^3$. The N_a values have been precisely measured by secondary-ion mass spectrometry (SIMS). The uncertainties on SIMS measurements have been largely investigated in the literature providing concentration values within an overall 10 % relative uncertainty and concentration ratios with a typical uncertainty of 1%.

In SMM calibration on doped GaAs multilayer samples, a good agreement was found both for the absolute N_a values and for relative dopant concentration ratios within the combined standard uncertainties ranging from 10% to 35% in function of the doping concentration values. However, this has some limitations, *i.e.* the reference sample and the sample of interest should have the same doping type and present native oxide layers of same thickness to within 1 nm (and subsequently on the top surface of the p-doped GaAs NWs). The SMM calibration allowed us to extract the doping levels of these NWs, with N_a values of $(5.8 \pm 1.2) \cdot 10^{18}$ cm-3 and $(4.8 \pm 0.8) \cdot 10^{18}$ cm^{-3}, which are in the same order of magnitude as the estimated values of about $3.3 \cdot 10^{18}$ cm^{-3} and $1.8 \cdot 10^{18}$ cm^{-3}, respectively.



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References

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