Calibrated measurements of dopant concentration 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 (N_a) is crucial for screening defective NWs and analyze their effects on solar cell performance. To this end, high-resolution measurements are performed using electrical scanning probe microscopy techniques with reference N_a values for traceable measurements on NWs.

Scanning microwave microscopy (SMM) is a powerful technique for measuring impedances at the nanoscale with sub-50-nm spatial resolution. A conductive tip is in contact with the sample surface 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 N_a measurements, SMM was calibrated using a reference sample based on p-doped GaAs multilayers with different doping levels N_a ranging from $6{\cdot}10^{16}/cm^3$ to $1{\cdot}10^{19}/cm^3$, measured by secondary-ion mass spectrometry.

The SMM calibration on doped GaAs multilayer samples show a good agreement for N_a values with a combined uncertainty of 10%. We have also found a deviation of 20% for N_a values on another similar GaAs multilayer sample, which corresponds to two standard deviations. The SMM calibration allowed us to extract the doping levels of p-doped GaAs NWs, with preliminary N_a values of $(5.0 \pm 1.2){\cdot}10^{18}/cm^3$ and $(4.6 \pm 1.1){\cdot}10^{18}/cm^3$, 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.

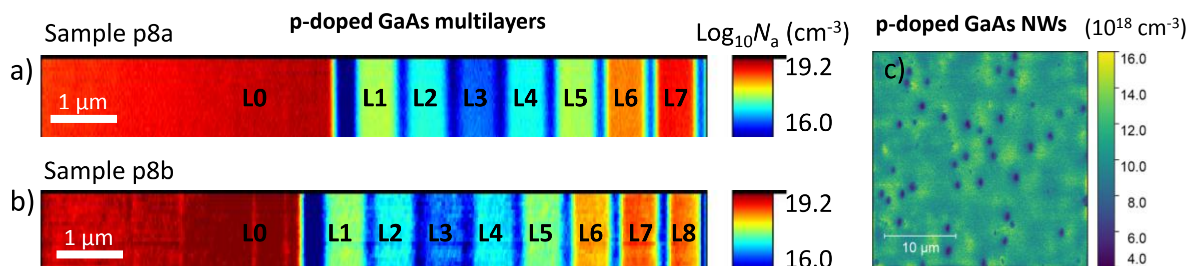

Figure 1. Dopant concentration map on similar p-doped GaAs multilayers (a,b) and p-doped GaAs NWs (c).

References:

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