Electron beam induced current investigation of doped GaAsP nanowires for future III-V on Si nanostructured solar cells

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Recently semiconductor nanowires (NWs) have emerged as promising materials for solar cells. Thanks to the strain relaxation by the free lateral surface, III-V NWs can be grown on lattice-mismatched substrates without forming dislocations. This is particularly advantageous for III-V on Si tandem solar cells. In addition, NW arrays have very attractive optical properties such as a small optical reflectance and enhanced light diffusion, leading to an increased absorption in comparison to thin films. Today, NW solar cells have been demonstrated with a record efficiency of 15.3% for GaAs bottom-up NWs [1] and 17.8% for InP top-down NWs [2]. However, their efficiency remains below the typical values for planar devices. To understand the origin of this limitation and to boost the efficiency, it is necessary to characterize the electrical properties of NW-based solar cells down to the nanoscale level. This is a challenging task since the standard macroscopic characterization tools can only provide average parameters.

Electron Beam Induced Current (EBIC) microscopy has been widely used to characterize optoelectronic devices, and in particular solar cells, for more than thirty years. In 2D solar cells, EBIC was used to probe the electrical activity of the device with a high resolution, to extract material parameters and to detect failures induced by material defects. This technique offers a nanoscale resolution and therefore is ideally suited for nanostructured solar cell characterization.

In this contribution, we analyse the electrical properties of doped GaAsP NWs using EBIC microscopy. NWs were grown by Ga-catalyzed molecular beam epitaxy (MBE) at 610 °C using Be and Si dopants. GaAsP composition was adjusted to achieve a bandgap close to 1.7 eV, which is the optimal value for III-V on Si tandem device [3]. EBIC experiments are performed in a Hitachi SEM using Kleindiek micro-manipulators for single NW contacting. We first analyze the doping type for homogeneously doped GaAsP:Si and GaAsP:Be NWs using the induced current in the Schottky contact region as an electrical signature. EBIC signal polarity demonstrates that for the used growth conditions Si behaves as an n-dopant, whereas Be yields a p-doping. Next, an axial n-p junction (GaAsP:Si / GaAsP:Be) was grown and analyzed by EBIC as illustrated in Fig 1. The junction position can be localized from the SEM contrast. The n-p junction EBIC signal is clearly observed under a reverse bias. Axial EBIC profile allows to estimate the doping concentration, which is in the 5×10^{18} cm^{-3} range for the electrons and close to 3×10^{18} cm^{-3} for holes.

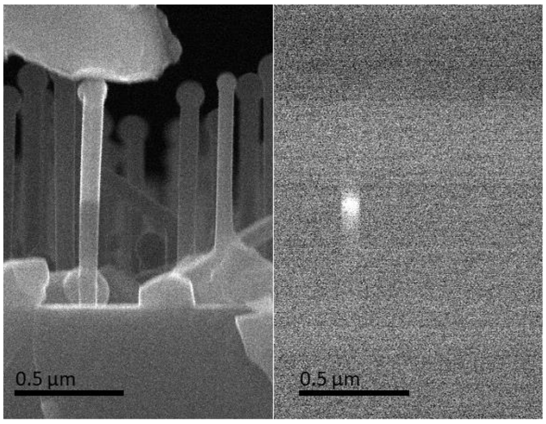

Fig.1: SEM image of a GaAsP NW containing an axial n-p junction contacted with a micromanipulator and the corresponding EBIC map.

[1] I. Aberg et al., IEEE J. Photovolt., 6, 185-190 (2016).

[2] D. V. Dam et al., ACS Nano, 10, 11414–11419 (2016).

[3] R. R. LaPierre, J. Appl. Phys., 110, 014310 (2011).