Electron tomography for revealing nanowire surface features

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The development of semiconductor nanostructures depend on reliable analysis at the atomic level, most often provided by transmission electron microscopy (TEM). When applying tomography using the TEM, electron tomography (ET), more easily interpreted 3D data of the semiconductor can be produced. These reconstructions overcome the lack of depth in regular micrographs and has the capability to map density, composition, and even atomic positions[1]. 3D analysis of the semiconductor nanostructures is useful for evaluating the increasingly complex morphology that extends in all directions. Semiconductors, especially compound III-V semiconductors, exhibit substantially different surface chemistry that greatly depend on the direction of the surface[2] and through the use of ET, surface features can be related to specific directions and hopefully better explain the mechanism of growth.

Here we demonstrate the use of electron tomography to analyze the surface structure of Au-seeded Sn-doped zincblende GaAs nanowires in relation to the crystallography. The wires were grown by Aerotaxy[3], an aerosol based technique. For certain Sn-precursor concentrations, droplets are formed on the surface of the nanowires, in a systematic arrangement. The droplets are determined to be of Ga and the reason for formation and their positioning is hence an important factor in order to understand how transport of Ga affects the growth. We used scanning TEM (STEM), simultaneous iterative reconstruction technique (SIRT)[4] and a watershed segmentation of the reconstruction to form a tomogram showing the wire including the Ga droplets on the surface. In addition, we performed correlative high resolution TEM (HRTEM) to relate directions in the tomogram, and hence the positions of the droplets, to specific crystallographic directions on the nanowire. The surface features of interest on the wires, including the droplets and side facets, can be illustrated either by a 3D conventional tomogram representation or an azimuthal map (Figure 1), which is a topological illustration of the surface of the nanowire, projected onto 2-D. The topology is shown as a function of distance along the wire from the seed particle vs. the azimuthal angle (around the wire).

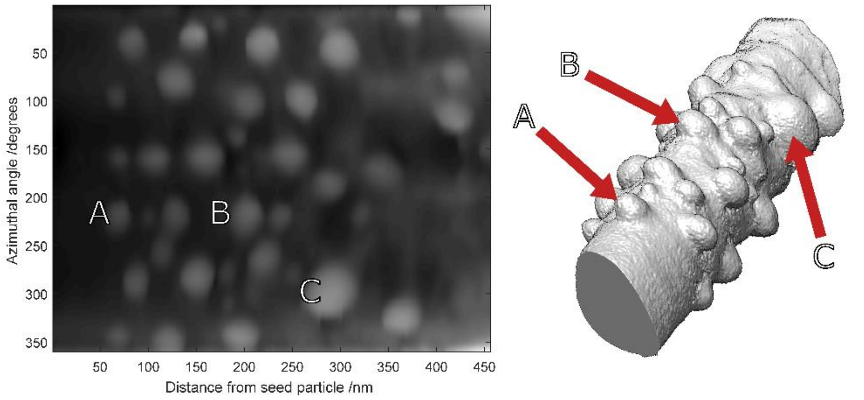

Figure 1: An azimuthal map of the nanowire topology (left) and the tomogram of the same wire (right). Three surface features (Ga droplets) are marked with A, B, and C both in the azimuthal map and in the tomogram.

The azimuthal maps show that the Ga droplets appear positioned close to specific azimuthal angles along the wire with an azimuth periodicity of 60 degrees, however, the symmetry at a given distance along the wire is threefold. This is explained by the crystal twinning of the zincblende wire and the Ga droplets showing a preference of {111}B facets, the same kind of facet and polarity as the growth direction. The data shows a clear trend of an increase in number density of droplets with an increased Sn-precursor concentration[5].

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[6] We gratefully acknowledge NanoLund at Lund University, *Knut and Alice Wallenberg Foundation (KAW), Energimyndigheten* and *EU Nano-Tandem* for financial support.