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IT-10-O-2765 A method for quantitative analysis and improvement of 3D electrostatic nanopotentials reconstructed by electron holographic tomography

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Electron holographic tomography (EHT), i.e. using off-axis electron holography (EH) as imaging mode for electron tomography (ET) in the transmission electron microscope (TEM), facilitates the 3D mapping of materials on the nanometer scale [1,2]. The phase shift of the electron wave that can be reconstructed by EH contains the projected electrostatic scalar potential and, for magnetic samples, the projected magnetic vector potential of the specimen [3]. Therefore, tomographic reconstruction of phase tilt series results in 3D maps of the electric potential (magnetic case is not considered here).

At nanometer resolution (1-10nm), the major contribution to tomograms reconstructed by EHT is the mean inner potential (MIP). Its value depends on the atomic species, the atomic packing in the unit cell, but also on the distribution of the valence electrons. Thus, the MIP represents a finger print of chemical composition and can be used to detect for example core-shell structures (e.g. AlGaAs-GaAs [2]) or gradients of composition in nanowires (NWs). Recently, the three-dimensional nanosponge structure of Si embedded in SiO_2 has been revealed with EHT [4]. Furthermore, functional potentials, such as the built-in potentials across p-n junctions in semiconductors can be measured [1,2]. In this context, also surface and sub-surface effects, e.g. Fermi-level pinning [5], have been studied, quantitatively.

In order to extract quantitative information from the 3D reconstructions, it is indispensable to know their fidelity. Here, we show a procedure to proof the reliability of the tomograms by comparing their re-projections with the original ones (Fig. 1a)). By applying this procedure on an Ag, ZnO and Si NW and evaluating the potential averaged over the entire specimen, we determine the MIP values from the projection data (Fig. 1b)).

Moreover, the 3D reconstruction can be remarkably improved by normalizing it with the tomogram reconstructed from the projected thickness. The latter is obtained after step 3 in the procedure shown in Fig. 1a). Because its reconstruction is done from the same tilt range, the resulting tomogram contains very similar missing wedge artifacts as the original one. Therefore, such artifacts can be corrected to a great amount using this approach (compare in Fig. 2: a,b with c,d).

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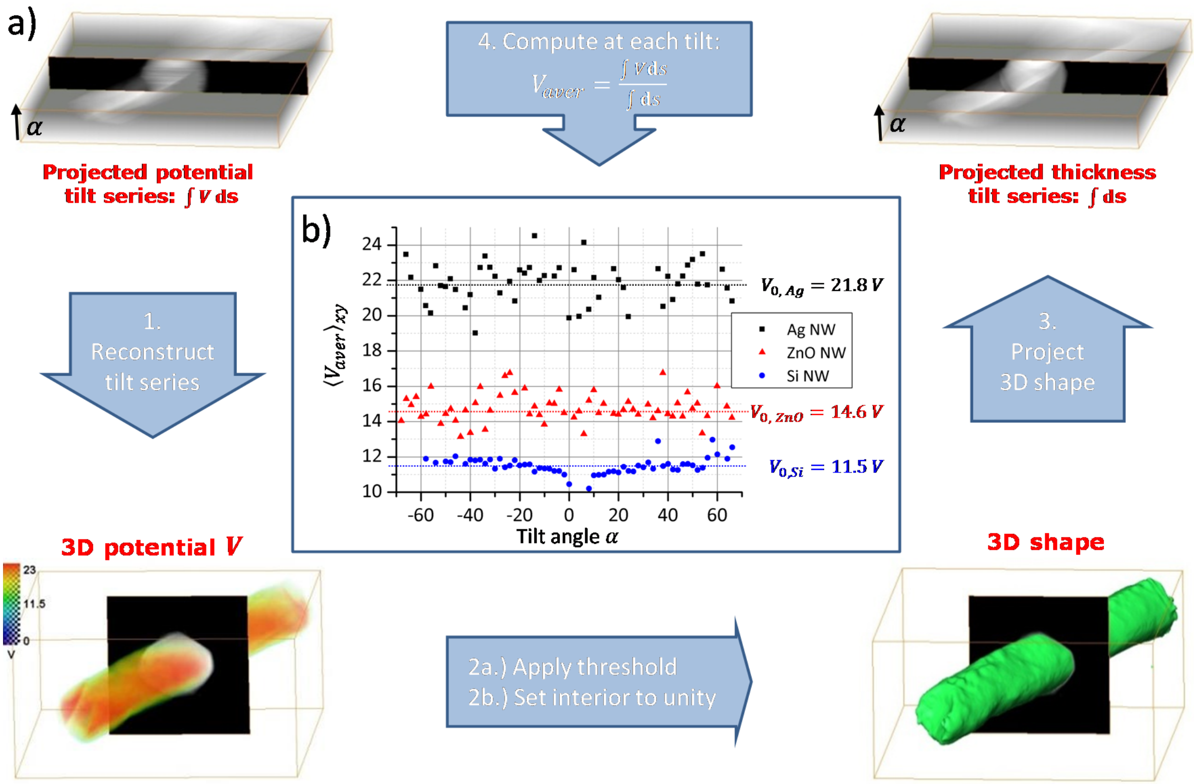

Fig. 1: a) Procedure to determine from the projected potential tilt series the averaged potential tilt series on the example of an Ag nanowire. b) Potential averaged over the entire specimen vs. projection angle a. The mean of these values corresponds to the mean inner potential V_0.

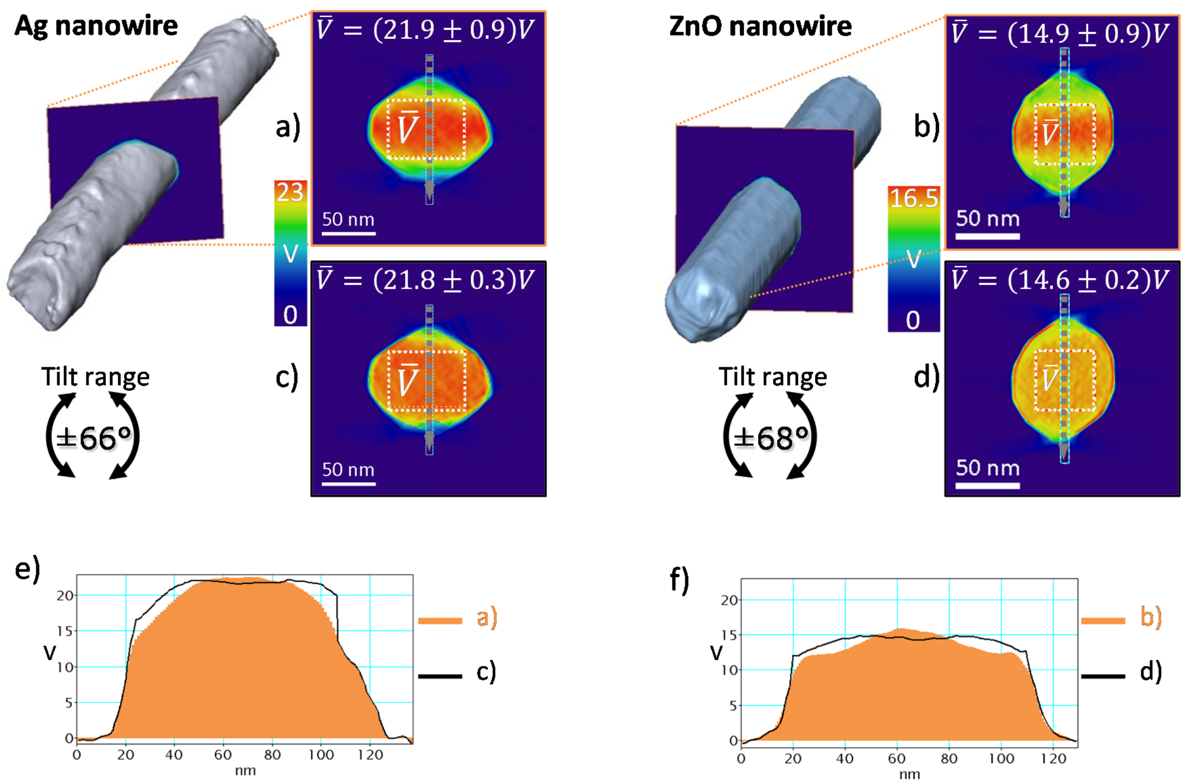

Fig. 2: 3D reconstruction with reduced missing wedge artifacts on the example of an Ag NW and a ZnO NW. a,b) Slice through 3D potential. c,d) Same slice as in (a,b) but normalized with the reconstruction of the projected thickness. e,f) Line profiles corresponding to the gray arrows in a-d).