Electron Holographic Measurement of the Three-Dimensional Electrostatic Potential Distribution of a Flat Capacitor

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Off-axis electron holography (EH), in contrast to most conventional transmission electron microscopy techniques (TEM), allows the measurement of the phase shift of the electron wave that has passed through a specimen. This phase shift can be used to provide information on local variations in magnetic induction [1] and electrostatic potential [2] within and around the sample.With a growing number of new in situ systems, there are seemingly endless possibilities to investigate these variations even externally triggered. Especially, the electrical switching of objects is an interesting stimulation mechanism. However, EH only provides direct insight to the projected potential. In order to obtain the three-dimensional electrostatic potential distribution of a flat capacitor, the phase shift is measured under different projection directions.

As a test specimen, a severed connection on a MEMS heating chip (Denssolutions wildfire series) is used. The separation of the conductor path was milled via focussed ion beam (FIB). The projected potential across this connection is measured, which is proportional to the externally applied voltage. By tilting the capacitor around its longitudinal axis, a series of projections for multiple angles is acquired.

Figure 1 illustrates the measurement process and the subsequent phase reconstruction of the series schematically. Due to the unusually large field of view and the thereby caused strong influence of beam-induced specimen charging, a special normalisation process for the measurements is required utilizing phase measurements of the short-circuited capacitor. Analogous to the measurement, a series of projections through the scalar electrostatic potential simulated by the three-dimensional finite-element-method (FEM) is made for multiple angles. In additional post processing (so-called "virtual biprism"), electrostatic stray-fields into the area of the reference wave are taken into account. The gradients of the reconstructed and simulated phases are compared.

In figure 2, an exemplary visualization of reconstructed phases of measured electron holograms and the corresponding post processed FEM simulations for three tilt angles are shown. The good visual agreement shows that this method is well suited for measuring three-dimensional electrical potential distributions of more complicated geometries.

References:

[1] Beleggia, M.; Kasama, T.; Dunin-Borkowski, R. E. The quantitative measurement of magnetic moments from phase images of nanoparticles and nanostructures–I. Fundamentals. Ultramicroscopy 2010, 110, 425−432.

[2] Twitchett, A.C., Dunin-Borkowski, R.E., and Midgley, P.A.: Quantitative Electron Holography of Biased Semiconductor Devices. Physical Review Letters 88 (2002) 238302.

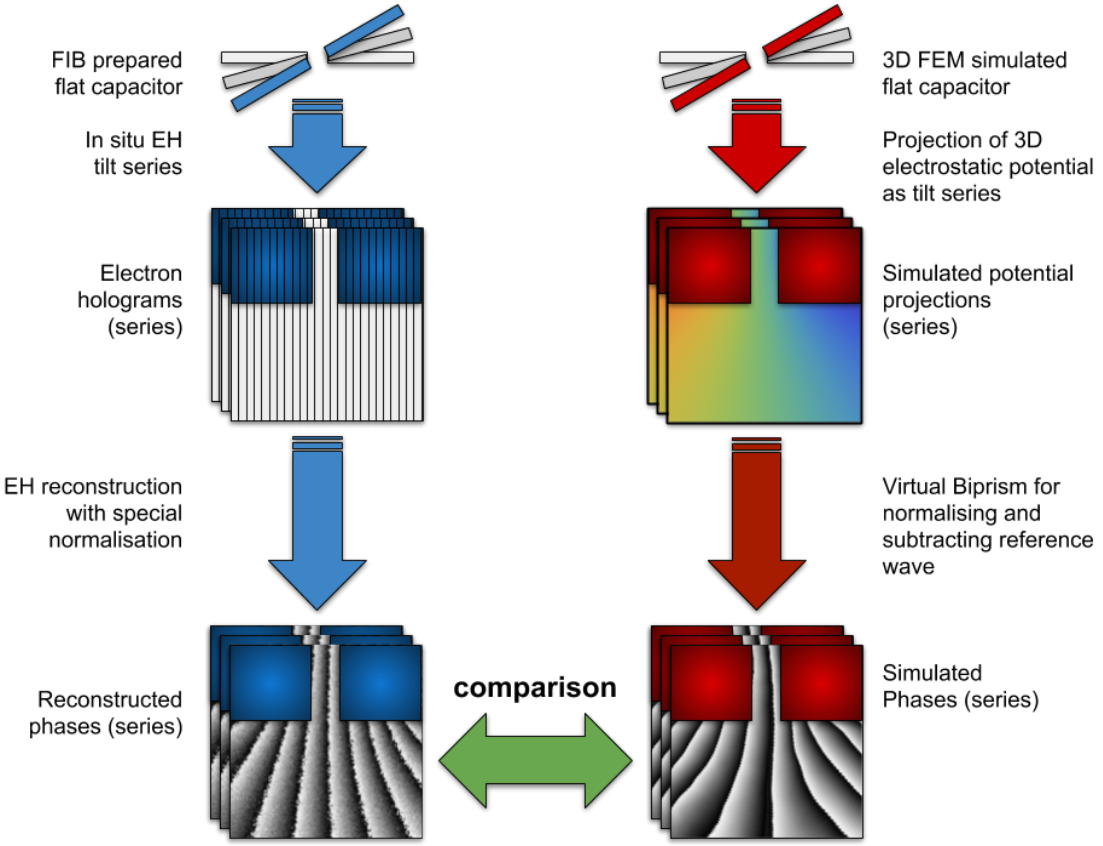

Figure 1: Schematic overview of the EH measurement process, the 3D FEM simulation including post processing and their comparison.

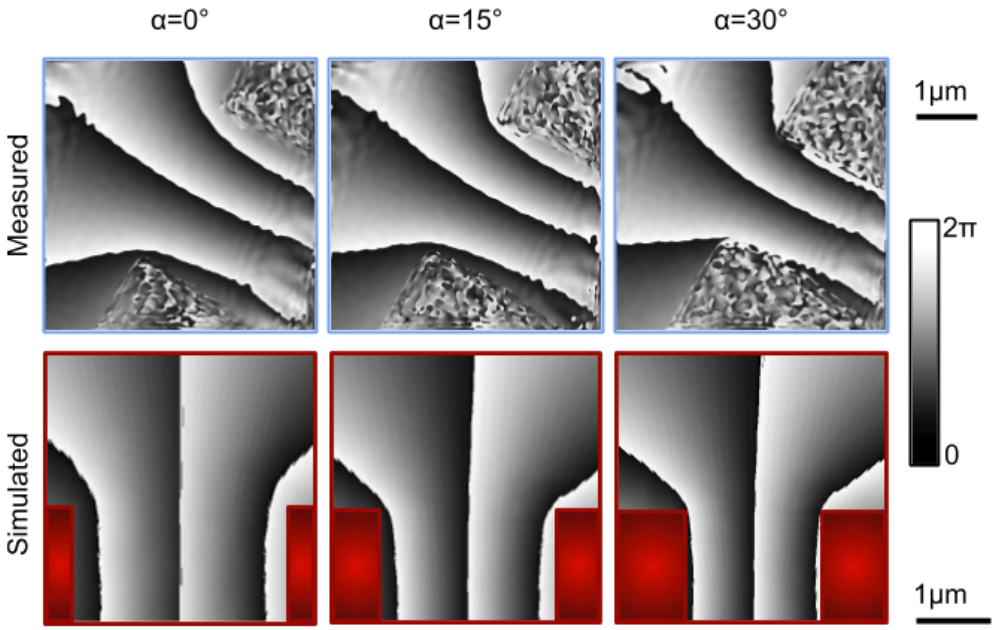

Figure 2: Exemplary visualization of reconstructed phases of measured electron holograms and the corresponding post processed FEM simulations for three tilt angles.