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INFLUENCE OF GEOMETRIC IMAGE DISTORTIONS ON ELECTRON HOLOGRAPHY OF MAGNETIC FIELDS

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Abstract

Off-axis electron holography is a powerful technique for recovering the phase shift of a high-energy electron wave that has passed through a thin specimen in the transmission electron microscope (TEM). The phase shift is, in turn, sensitive to the electrostatic potential and the in-plane components of the magnetic induction within and around the specimen, projected in the electron beam direction. In order to measure the magnetic contribution to the phase shift, the microscope has to be operated in Lorentz mode and the electrostatic contribution to the phase shift has to be removed, for example by taking the difference between phase images recorded before and after turning the sample over.

We have modified a Fischione on-axis tomography holder (model 2050), in order to be able to turn over samples that have different geometries (including conventional 3 mm grids, focused ion beam prepared needles and chips fabricated on silicon nitride membranes) inside the TEM. The holder is equipped with a home-built wireless inclinometer that allows the tilt angle of the holder to be measured with an accuracy of better than 0.1º. Experiments have been performed at 300 kV on an FEI Titan 60-300 kV TEM that was operated in Lorentz mode and has a large (11 mm) (C-TWIN) pole piece gap.

The procedure for turning the sample over revealed significant image distortions, which resulted in alignment artefacts in the recovered magnetic contribution to the phase shift. Preliminary measurements of the distortions at low and medium magnification were made from both conventional TEM images and electron holographic phase images. We used approaches for measuring and correcting for the distortions similar to those reported in the literature for strain measurement at high magnification [1] and for imaging large biological samples at low and medium magnification [2]. For calibration of the distortions at low and medium magnification, a specific experimental challenge results from the difficulty of finding a sample with known features distributed over the field of view. Therefore, we made use of algorithms for automatic feature recognition. We also adapted existing algorithms for distortion correction to match the needs for magnetic imaging using off-axis holography.

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[2] Kaynig, V.; Fischer, B.; Müller, E. & Buhmann, J. M., Fully automatic stitching and distortion correction of transmission electron microscope images, Journal of Structural Biology, 2010, 171, 163 – 173.