Type of presentation: Invited

IT-11-IN-5757 Towards atomic resolution and three-dimensional mapping of electrostatic potentials and magnetic fields using off-axis electron holography

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The ability to achieve high phase sensitivity with close-to-atomic spatial resolution in off-axis electron holographic measurements is offered by the latest generation of ultra-stable transmission electron microscopes, which are equipped with high brightness electron sources and aberration correctors. In this talk, I will discuss recent developments in the quantitative and three-dimensional characterization of electrostatic potentials and magnetic fields with close-to-atomic spatial resolution using electron holography. I will begin by describing two complementary approaches that can be used to measure the electrostatic potentials and electric fields of electrically-biased metal needles as a function of applied voltage in the electron microscope. The phase shift can be analyzed either by fitting the recorded phase distribution to a simulation based on lines of uniform charge density or by using a model-independent approach involving contour integration of the phase gradient to determine the charge enclosed within the integration contour. Both approaches typically require evaluation of the difference between phase images recorded at two applied voltages, in order to subtract mean inner potential (and magnetic) contributions to the phase. I will then describe recent progress in the development of a model-based approach that can be used to reconstruct the three-dimensional magnetization distribution in a specimen from a series of phase images recorded using electron holography. The approach involves the projection of three-dimensional magnetization distributions onto two-dimensional grids to simulate phase images of three-dimensional objects from any projection direction. This forward simulation approach is then used in an iterative model-based algorithm to solve the inverse problem of reconstructing the three-dimensional magnetization distribution in the specimen from a tilt series of phase images. Such a model-based approach avoids many of the artifacts that result from the use of classical tomographic techniques. Finally, I will consider challenges associated with the use of chromatic aberration correction of the Lorentz lens in the TEM to achieve higher spatial resolution in magnetic characterization. When considering experiments aimed at the retrieval of weak phase shifts, it is important to remember that the sample must remain clean, that electron-beam-induced charging can contribute to the measured phase shift and that the quantitative interpretation of phase shifts measured from crystalline specimens can require comparisons with dynamical simulations. If time permits, I will conclude with recent progress in the application of off-axis electron holography to obtain results during ultrafast switching processes in situ in the electron microscope.

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