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Magnetic states in Fe nanoparticles imaged by off-axis electron holography

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Magnetic nanoparticles of a certain size show single domain magnetic properties. In an intermediate regime between single and multi domain behaviour, such particles may exhibit magnetic configurations that are vortex-like. The critical size for this transition from single domain to vortex behaviour is crucial for determining the net magnetic moments carried by magnetic nanoparticles, i.e. for applications. Since the magnetic anisotropy of a particle is influenced strongly by its surface properties, it is difficult to predict this critical size. Here, we present images of such vortex states measured directly on oxide passivated single crystalline Fe nanoparticles with diameters of 20-40 nm using off-axis electron holography. Holograms were acquired in Lorentz mode using a Philips CM300 microscope equipped with a 1024 pixel CCD camera located at the end of a Gatan Imaging Filter. The biprism voltage was 200 V, corresponding to a holographic interference fringe spacing of 2.9nm. A magnetic field (2 T) was applied to the sample parallel to the direction of the electron beam and the holograms were recorded with the particles at remanence. Quantitative information about the magnetic induction and the magnetic radius of each particle was deduced by fitting the measured phase profiles to simulations.