Magnetic Skyrmions in an FeGe Nanostripe Revealed by *quantitative* Electron Holography

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Real-space imaging of complex skyrmion spin configurations using Lorentz microscopy (LM) in the transmission electron microscope (TEM) has enabled the direct observation of skyrmion lattice formation and transformations between different magnetic states with nanometre spatial resolution[1]. However, the finite size and the inherently weak magnetization of such magnetic nanostructures impose great experimental challenges for LM. In particular, Fresnel fringe contrast at the specimen edge makes extremely difficult to use LM to obtain magnetic signals in samples that have lateral dimensions of below 10 nm. In contrast, off-axis electron holography (EH) in the TEM, which allows electron-optical phase images to be recorded directly with nanometre spatial resolution and high phase sensitivity, provides easier access to magnetic states in nanostructures. Digital acquisition and analysis of electron holograms and sophisticated image analysis software are then essential in studies of weak and slowly varying phase objects such as magnetic skyrmions[2].

Here, we use both LM and EH to study magnetic skyrmions in a B20-type FeGe nanostripe. The use of liquid nitrogen specimen holder (Gatan, Inc.) allows the specimen temperature to be varied between 95 and 370 K, and the objective lens of the microscope can be used to apply magnetic fields to the specimen of 0 to 1.5 T. The aim of our study is to resolve the fine magnetic structures of geometrically confined skyrmions and to understand their formation process. Figures 2(a-b) show Lorentz images of a typical FeGe nanostripe, in which a helix to skyrmion transition occurs in response to an applied magnetic field. We will present the details of magnetic transitions between different magnetic states and discuss the quantitative magnetization analysis of the skyrmion structure.

References

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