In situ Lorentz differential phase contrast scanning transmission electron microscopy of bilayer $SrRuO_3$/$SIrO_3$ films hosting the skyrmion phase

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Much interest has been put on development of magnetic materials for data storage and computation in next generation devices. One of the most promising classes has been materials with the skyrmion phase. Skyrmions are topological spin structures that can be stabilized near or even above room temperature and in zero field in some materials making them potentially very useful in a broad range of device applications. The benefit of skyrmion-based devices is their potential for ultra-high-density and critical currents 4-5 orders of magnitude lower than current domain wall-based devices. Skyrmions are stabilized by the competition between exchange interactions, which promote parallel spin configurations, and the Dzyaloshinskii-Moriya (DM) interaction, which promotes canted spin configurations. The DM interaction is only present in materials with broken inversion symmetry and/or broken mirror symmetry, which can arise due to the presence of interfaces. Skyrmion systems with only broken inversion symmetry like FeGe form the Bloch-type skyrmion, which has a vortex-like spin configuration. Skyrmions with purely interfacial DM form Néel-type skyrmions with the so-called hedgehog spin configuration, which is radially symmetric. While the form of each skyrmion is different, both are of interest for device applications.

One system that has been predicted to have Néel-type skyrmions that are smaller than 10 nanometers is bilayer $SrIrO_3$/$SrRuO_3$ grown on (001) $SrTiO_3$. Using aberration corrected scanning transmission electron microscopy (STEM), we report the growth of very uniform films via off-axis magnetron sputtering with 2 unit cells of $SrIrO_3$ on 10 unit cells $SrRuO_3$. These films exhibit strong topological Hall signal, commonly taken as evidence of the presence of skyrmions.

The magnetic structure of Néel-type skyrmions makes them very difficult to observe using traditional Lorentz transmission electron microscopy when compared to Bloch-type skyrmions. We therefore develop *in situ* Lorentz differential phase contrast STEM, which has been shown to be sensitive to Néel type skyrmions through simulations. Using plan view specimens (i.e. [001] oriented) and variable applied magnetic field and temperature, we investigate the presence of skyrmions in this system, as well as the effect of microstructural and compositional defects on skyrmion stability.