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Identification of Topological Spin Textures in Frustrated Fe_3Sn_2 Magnetic System

Jiang Cui[1], Hongkui Zheng[1], John Watt[2] and Kai He[3]

[1]Clemson University, United States, [2]Los Alamos National Laboratory, Connecticut, United States, [3]Clemson University, Clemson, South Carolina, United States

Since the groundbreaking discovery of intrinsic ferromagnetism in atomically thin two-dimensional (2D) van der Waals (vdW) $Cr_2Ge_2Te_6$ and CrI_3 materials [1, 2], there has been intensive interest in identifying and understanding the topological spin textures in 2D vdW systems. It is expected that topologically nontrivial spin textures can be excited from the spin-polarized ground state. However, only a handful of studies have so far been reported to visually identify the skyrmion-like quasiparticle states using Lorentz transmission electron microscopy (TEM) [3-6]. Despite the recent progress in this field, the knowledge about the detailed correlations between the intrinsic topological spin characters and the extrinsic tuning factors, such as lattice geometry and the number of vdW layers, still remains poorly understood and less explored.

In a specific 2D vdW magnetic system, Fe_3Sn_2 possesses layered Kagome lattice, which induces the geometrical frustration in correlative spin alignments. It has been found that such unique spin-orbit and spin-lattice coupling can give rise to topological skyrmion spin textures at finite temperature and magnetic field [7, 8]. Here, we aim to use cryogenic Lorentz TEM to investigate the spin textures of Fe_3Sn_2 at low temperatures. In order to reveal the dependence of the number of vdW layers, we have prepared the Fe_3Sn_2 sample into different controlled thicknesses (i.e., 40, 60, and 80 nm) using the focused ion beam (FIB) technique, as shown in Figure 1a. The as-prepared Fe_3Sn_2 sample is a high-quality single crystal, as confirmed by high-resolution TEM (HRTEM) and selected area electron diffraction (SAED), shown in Figure 1b and c. With the given intrinsic magnetocrystalline anisotropy and the same thickness the FIB lamella, we expect that the room-temperature stable stripe domain appear in the identical domain width. However, our Lorentz TEM observation (Figure 1d) indicates that two types of stripe domains with distinct domain widths were formed within the same 40 nm thick slab of the FIB sample. This unexpected result may imply that some external tuning factors could show the predominant impact on the formation of spin textures, which may also influence the topological characters of skyrmion-like excitation states. Further investigation is needed to validate this hypothetic question and clarify the underlying mechanism for the fundamental spin-orbit coupling in 2D vdW systems [9].

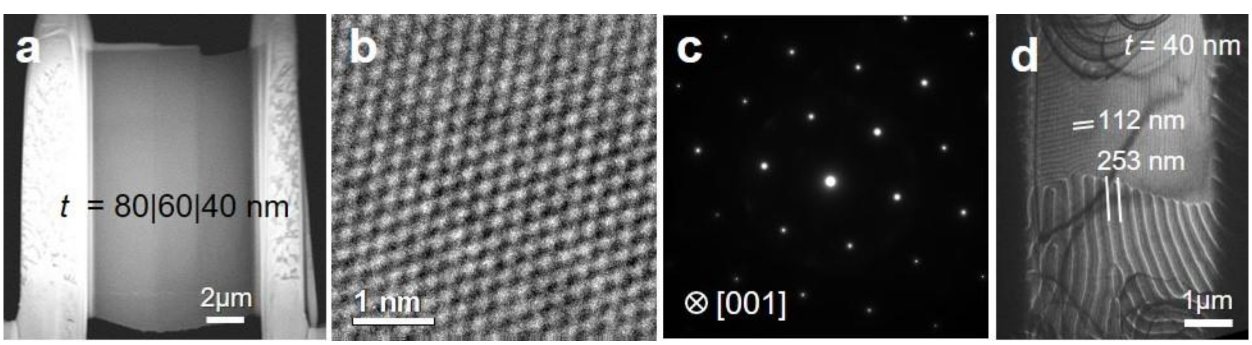

Figure 1. Figure 1. (a) FIB sample of Fe3Sn2 with varied thickness of 40 nm, 60 nm, and 80 nm. (b) HRTEM image and (c) SAED pattern of Fe3Sn2 sample. (d) Lorentz TEM image of 40 nm thick Fe3Sn2 showing the stripe domain structures with different domain widths.

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