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Electron Microscopy Spin Analysis of Topological Magnetic Domains in Amorphous Fe/Gd Thin Films

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We report on mapping 3D magnetic domain wall structure of amorphous Fe/Gd multilayer thin films using a combination of electron microscopy techniques. Micromagnetic simulations suggest that domain walls have a hybrid structure in which the center of the domain wall is Bloch-like with random helicity transitioning to Néel-like walls at the top and bottom surfaces with fixed helicity.

To probe the domain structure, we apply both Lorentz transmission electron microscopy (LTEM) and scanning electron microscopy with polarization analysis (SEMPA). LTEM images are processed to show the x- and y-components of the magnetic induction through the bulk of the sample, whereas SEMPA images show all three vector components of the magnetization at the top surface of the sample. In this way, 3-dimensional reconstructions of the magnetization can be realized [1].

The SEMPA instrument, based on an Auger microscope, leverages spin-polarized secondary electrons ejected from the top nanometer of a sample [2]. These secondary electrons are collected and their average spin vector is analyzed using a Mott scattering process, revealing the left-right and up-down polarization for both in-plane and out-of-plane electrons.

While LTEM images indicate a net Bloch-type arrangement in domain walls averaged through the Fe/Gd film thickness, SEMPA shows Néel-like domains closure caps at the film surface. We characterize this wall chirality following the convention established by Chen *et al*. [3]. The z-components of magnetization for several domains are shown in Fig. 1. A comparison of the average magnetization vectors in the plane of the sample is shown in Fig. 2, where the difference in LTEM and SEMPA observations indicate an out-of-plane, twisting component.

We have thus confirmed Bloch wall formation in the bulk topped with Néel caps at the surface [4].

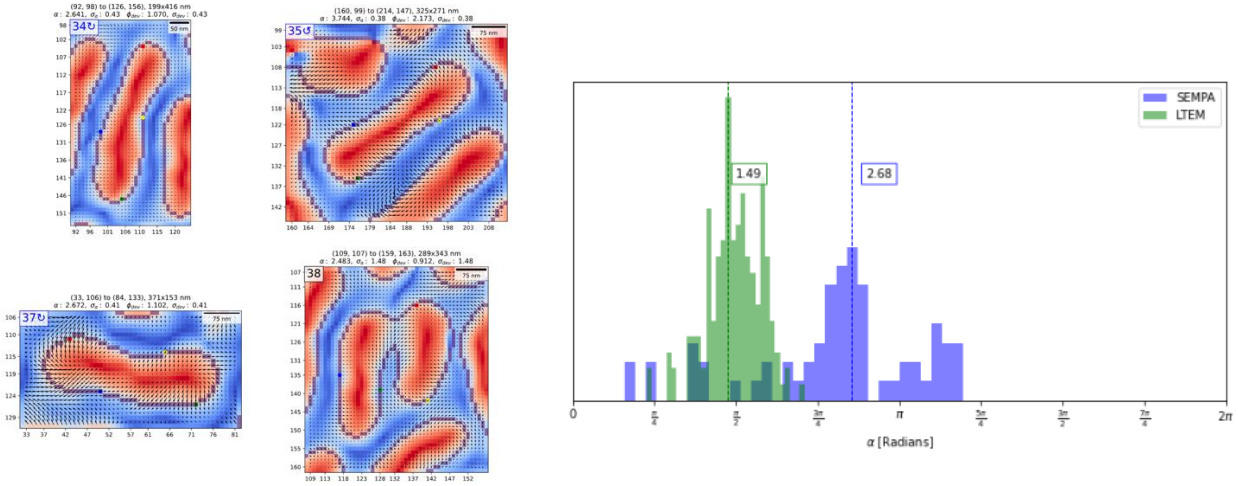

Figure 1. (Left) Worm domains in amorphous Fe/Gd showing in-plane magnetization from SEMPA data. Red is out of the page, blue into the page. (Right) In-plane magnetization relative to increasing out-of-plane magnetization showing expected π/2 radians average from LTEM, indicating Bloch walls, and larger deviations averaging 3π/4 radians from SEMPA, indicating Néel caps.

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