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Meeting-report

Lorentz Scanning Transmission Electron Microscopy Holography (LSTEMH) Measurement of Domain Walls in Fe/Gd Multilayers

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Here, we report use of scanning transmission electron microscopy holography, or STEMH, to image nanomagnetic features. Nanomagnetic phenomena can be imaged via Lorentz transmission electron microscopy (LTEM), which turns off the objective lens to enable a magnetic-field-free sample plane. However, disabling the most powerful lens of the microscope comes at the cost of the subnanometer resolution possible in conventional TEMs. Without full microscope capability, we cannot simultaneously understand the interplay of nanomagnetic domains and atomic structure, hampering the advent of low energy spintronics devices. Novel approaches to move beyond this limitation in recent years include using ptychography [1] and simulation-assisted analysis [2]. We use STEMH to directly measure magnetic-induced phase shifts in Fe/Gd multilayer thin films.

Whereas normal LTEM mode sets a plane wave incident on the sample, STEM raster scans a point beam and collects the current scattered through the sample to the detector at each beam stop. STEM holography is a 4DSTEM technique which records interference fringes containing sample amplitude and phase information at each beam stop. A nanofabricated diffraction grating placed in the condenser aperture of the microscope splits the beam into two or more beams incident on the sample, forming our interferometer. This experimental geometry is depicted in Fig. 1A. Off-axis electron holography similarly uses an electron biprism to create interference fringes in TEM mode, but with more stringent requirements on source coherence. Atomic resolution STEMH was demonstrated in [3], but, like other techniques, Lorentz STEMH (LSTEMH) prohibits the full use of the objective lens. This increases the size of the probe at the sample, reducing resolution but expanding the operable field of view due to increased probe separation. LSTEMH was proposed in [4] and first demonstrated in [5].

We used LSTEMH to measure magnetic stripe domains in Fe/Gd multilayers using the TEAM I microscope at the National Center for Electron Microscopy at Lawrence Berkeley Laboratory. 120 layers of Fe/Gd were held between exterior capping layers of Ta, as shown in the schematic in Fig. 1B. The sample sits on holey SiN so one beam may pass through vacuum as a reference probe. Fig. 2A shows an electron phase map of magnetic stripe domains at remanence. The in-plane magnetic induction shown in Fig. 2B is derived from the aforementioned phase map [6].

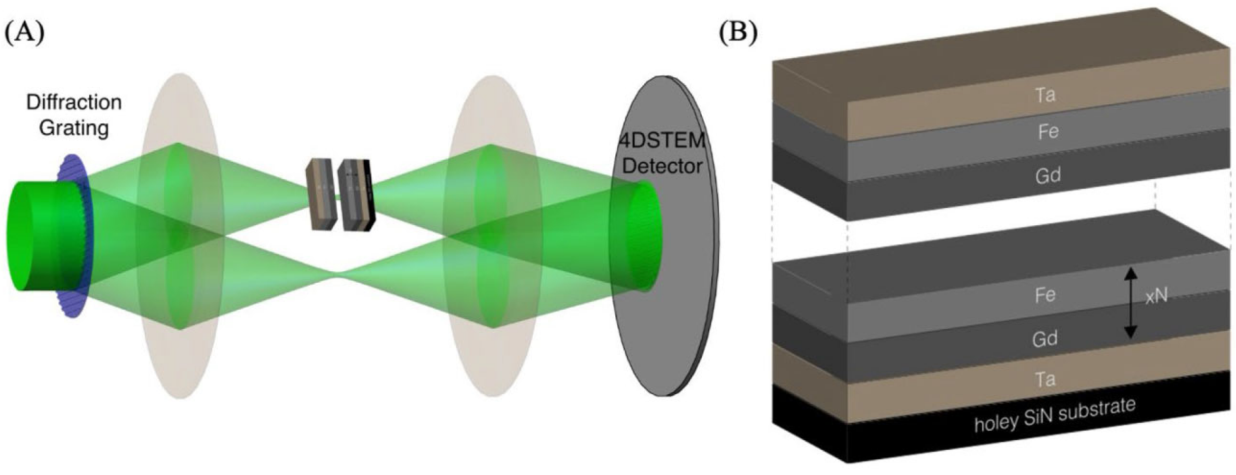

Fig. 1. (A) The experimental geometry of Lorentz STEM Holography (LSTEMH) and (B) the Fe/Gd multilayer sample LSTEMH was used upon.

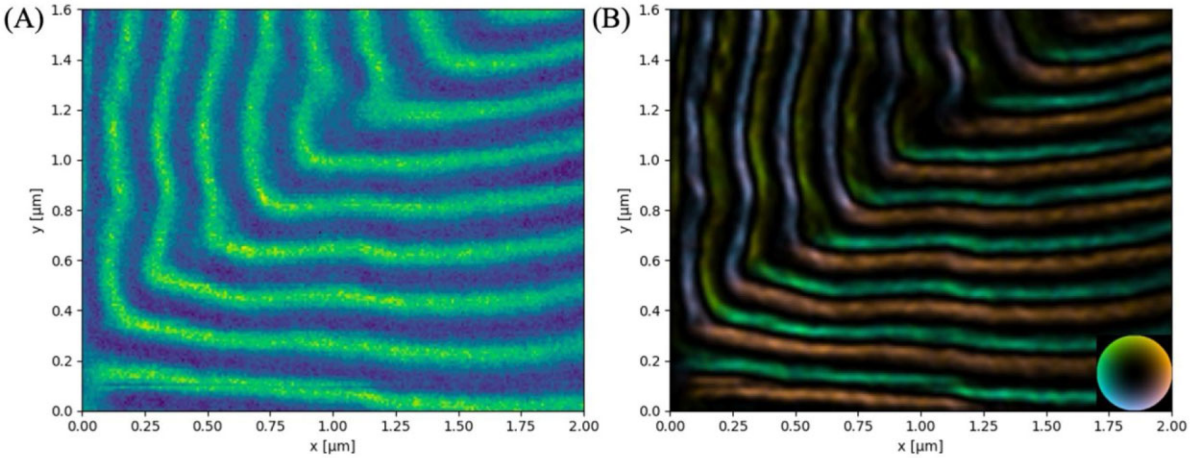

Fig. 2. STEMH measurement of magnetic domain walls in Fe/Gd multilayers. (A) depicts the phase acquired by transiting electrons and (B) depicts the in-plane magnetic induction, with color representing direction and brightness representing amplitude.

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