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Unravelling magnetic domain behaviour using advanced Lorentz transmission electron microscopy

C. Phatak* [1,2]

[1] Argonne National Laboratory, [2] Northwestern University
*cd@anl.gov

Non-trivial, nanoscale magnetic spin textures such as skyrmions, and merons have garnered significant interest due to their intriguing fundamental physical properties and potential integration into next-generation spintronic applications [1]. Achieving a comprehensive understanding of these spin textures necessitates exploring both the material microstructure and the magnetic domain structure simultaneously. Lorentz transmission electron microscopy (LTEM) is ideally suited for this approach as it enables us to elucidate the fundamental role of inhomogeneities in microstructure as well as the effect of shape and size of nanostructures on the magnetic domain behavior. In order to obtain the quantitative information about the magnetization of the sample, it is essential to retrieve the phase shift of the electrons. Moreover, observation of domain behavior using in situ experiments under external stimuli such as temperature, electromagnetic fields and currents can provide information about the underlying energy landscape.

Ferromagnetic vdW materials have been shown to exhibit several nontrivial magnetic spin structures, such as the Bloch or the Néel-type stripe domains, skyrmions, merons, or bubble domains. We will present results on LTEM imaging of ferromagnetic insulator: CrBr3 and CrSiTe3, both of which have a Curie temperature close to 32 K [2]. Using in-situ cryo LTEM, we will elucidate the nature of the magnetic domains as a function of applied field and temperature. We will discuss the ordering behavior of bubble domains, their self-interactions, and effect of external stimuli such as strain on this material.

We will also discuss recent advances in phase retrieval for LTEM using neural-network based approaches. Using the forward model for the image formation, we will demonstrate the application of automatic differentiation to solve for the phase from a through-focus series of images and show that we are able to achieve a higher phase sensitivity and spatial resolution than previous techniques as well as extension of the method to single image phase retrieval [3].

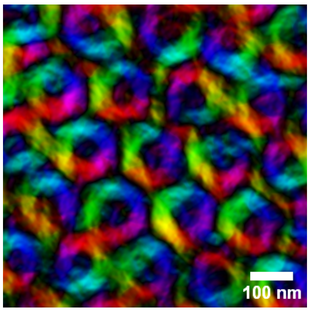

Figure 1. Bubble domains in CrBr3.

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[4] This work was supported by U.S. Department of Energy (DOE), Office of Science, Basic Energy Science, Materials Sciences and Engineering Division. Use of Center for Nanoscale Materials was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under contract no. DE-AC02-06CH11357.