DMR-2010792

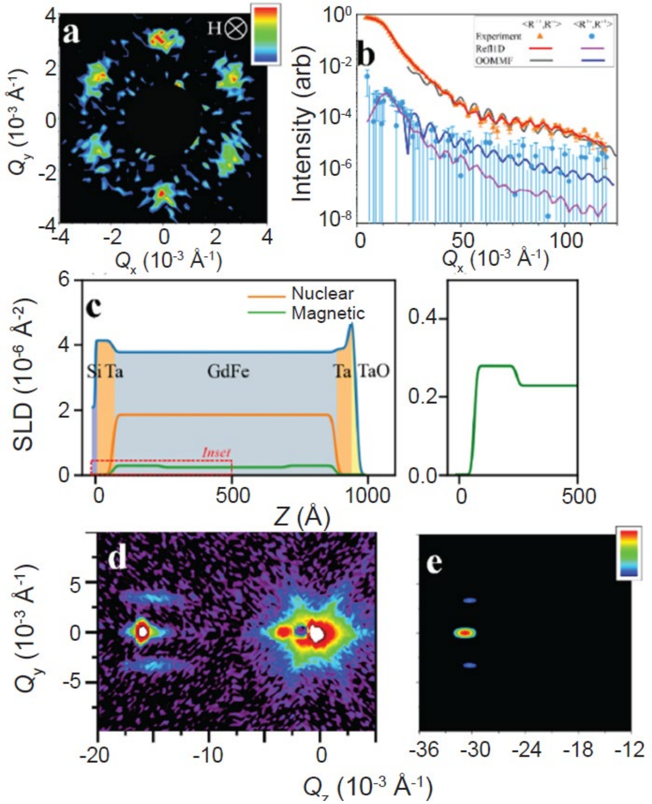
Three-Dimensional Structure of Hybrid Skyrmions

Dan Neumann, National Institute of Standards and Technology

Magnetic skyrmions are chiral spin textures that are topologically protected. Due to their unique properties, they are being considered for spintronic applications such as magnetic data storage and information technologies. A new hybrid version of skyrmions is particularly effective at reducing stray magnetic fields within the system, thus increasing stability. This structure nominally consists of Nèel-type wrapping of the spins (with magnetic moments along the radial direction) at the ends of the skyrmion tubes and with Bloch-type wrapping (with moments along the azimuthal direction) in the center. Researchers at the University of Tennessee performed small angle neutron scattering (SANS) and grazing incidence diffraction measurements on vSANS, along with polarized neutron reflectivity (PNR), to extract the three-dimensional magnetic structure of the hybrid skyrmions that form in Fe/Gd multilayers.

Analysis of the PNR data , which provide a depth profile of the nuclear and magnetic structure, reveal that the net magnetization is larger at the ends of the tubes in the Nèel cap regions. The boundary between Nèel and Bloch regions was characterized by iterative fitting of the GISANS results with scattering calculated from 3-D spin configurations generated by micromagnetic models. Through the tube, the magnetization gradient is spread over 13 – 18 nm, but the rotation angle changes more gradually from radial at the ends to azimuthal in the tube center. This 3-D analysis of hybrid skyrmions provides quantitative details of the topological structure that can be leveraged to improve stability for applications.

W.L.N.C. Liyanage, N. Tang, L. Quigley, J.A. Borchers, A.J. Grutter, B.B. Maranville, S.K. Sinha, N. Reyren, S.A. Montoya, E.E. Fullerton, L. DeBeer-Schmitt, and D.A. Gilbert. Physical Review B **107**, 184412 (2023). DOI: 10.1103/PhysRevB.107.184412



Data for a Gd/Fe skyrmion thin film. (a) vSANS scattering pattern; (b) PNR profile; (c) nuclear and magnetic profile; (d) GISANS pattern; (e) simulated GISANS pattern.