Paul-Lab

– Nanomagnetism and Advanced Scattering Techniques (NaM-AST)

PhD Project Proposal:

<u>Topological spin configurations in spin-engineered interfaces of rare-earth based nanolayers and multilayers</u>

State-of the art:

Topologically stabilized spin configurations like helices in the form of planar domain walls or vortex-like structures with magnetic functionalities are more often a theoretical prediction rather than experimental realization. Magnetic states corresponding to such modulated helices with integer number of twists, commensurate with the chain's length, are found to be topologically stable. Such stability comes without the presence of chiral Dzyaloshinskii-Moriya interaction relevant in skyrmions, where its shape protects it from trivial unwinding. The quantized energy spectrum within finite magnetic chains results in stabilizing topologically protected configurations of helices [1, 2], which can be created without the help of global fields or currents.

Importance:

Topologically stabilized spin configurations like helices in the form of planar domain walls or vortex-like structures with magnetic functionalities are more often a theoretical prediction rather than experimental realization. Magnetic states corresponding to such modulated helices with integer number of twists, commensurate with the chain's length, are found to be topologically stable. Such stability comes without the presence of chiral Dzyaloshinskii-Moriya interaction relevant in skyrmions, where its shape protects it from trivial unwinding. The quantized energy spectrum within finite magnetic chains results in stabilizing topologically protected configurations of helices [1, 2], which can be created without the help of global fields or currents.

Goals and their justification:

In this project, we aim at exploiting exchange bias effect in combining a rare earth material (RE) with an antiferromagnet (AF/FM) and envisage forming controlled topologically stable helices. The key issues to be addressed here are i) the connection between crystal structure and quality of non-collinear antiferromagnetic (AF) and magnetic properties of FM (RE and TM) by interface engineering within epitaxial and polycrystalline bilayers and multilayers. ii) A frustrated interdomain magnetic interaction is expected to lead to coexistence of spin-glass like ordering and helical spin modulation at the exchange-coupled AF-RE interface. iii) Changing the bias direction during field cooling of AF could introduce difference in chirality for the exchange-coupled RE layer, which will be studied. Earlier, off-specular intensity in the form of narrow sheets of coherent intensity indicating long range vertical correlations, related to the reminiscent of the helix-like magnetic structure in the bulk we reported [3].

Expected significance:

This study, in general, will provide a platform for the realization of future chiral-spintronic devices with RE–TM combination. Thus, the manipulation and/or control of domain dynamics within RE/AF and RE/RE systems without an electric or magnetic field would be interesting to explore using neutron reflectivity. The manipulation of domain walls and the modification of magnetic properties would also be promising for the realization of high-density magnetic memory and magnetic logic elements.

Method of investigation:

<u>Primary supervisor:</u> The samples are to be prepared using the magnetron sputtering unit in my thin-film lab at the GTIIT, which is under my academic supervision. They would be initially characterized using the MPMS3 magnetometer (in Paul-lab at the GTIIT) and the x-ray machine within the in-house facilities at the GTIIT. The magnetic domain configuration, thereby realized, would be investigated further via *polarized neutron scattering (PNR) at a large-scale facility like the neutron source MLZ (FRM II) within the MoU, that I have the recently cemented.*

<u>Secondary supervisor:</u> Theoretical model computation of equilibrium magnetic states of finite-size chain within the 1D model of planar spins considering ferromagnetic exchange, magnetic anisotropies. Considering a number of π-walls or 2π-walls within the discrete chain, a global minimum for the non-collinear configurations could be sought to realize.

<u>References:</u>

1. S. Fust, S. Mukherjee, N. Paul, J. Stahn, W. Kreuzpaintner, P. Böni, **Amitesh Paul,** *Sci. Rep.* **6**, 33986 (2016).
2. Jingfan Ye, Thomas Baldauf, Stefan Mattauch, Neelima Paul, **Amitesh Paul,** *Communications Physics*, **2**, 114 (2019).
3. **Amitesh Paul,** *Sci. Rep.*, **6**, 19315 (2016).

Project collaboration: CI: Dr. Amitesh Paul, GTIIT, Shantou, China; PI: Dr. M. C. Toroker, Haifa, Technion, Israel, PI: Dr. Peter Müller-Buschbaum, Garching, Germany.

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