Topologically protected spin chirality beyond room temperature

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Topological magnetic heterostructures are promising layers with unique unidirectional magnetotransport properties and band structures that enable a wide range of new physics and advanced spin polarised devices. Here, we grew magnetically coupled heterostructures of topological insulators (Bi_2Se_3) sandwiched between two ferromagnetic insulator (FMI) layers (EuS) to create FMI/TI/FMI tri-layers and elucidated the induced spin chirality using Lorentz transmission electron microscopy (LTEM), superconducting quantum interference device hysteresis and temperature-dependent magnetism measurements (SQUID), polarized neutron reflectometry (PNR) and micromagnetic modelling.

The robust (unique) interfacial DMI brings the magnetic order of the system above room temperature. This steady-state magnetization profile through the TI is not commensurate with the crystal or interface chemical structure. The conical phase is located along the growth direction, (000L), where the total moment rotates depending on the interaction strength. The conical phase is getting more energetically stable at much lower temperatures of 4 K (below the Curie temperature of EuS) because of the local moment saturation. The modulated phase is a consequence of competing magnetic interaction between bulk EuS and interface magnetism due to DMI, resulting in a particular topological spin configuration at higher temperatures. Above the Curie temperature, the bulk in-plane component of magnetism due to EuS smears out and the out-of-plane component along the growth direction remains. Finally, the trilayer structure undergoes a phase transition to either a ferromagnetic or a skyrmion phase, where real space observation is confirmed by Lorentz transmission electron microscopy. Such an exotic state of matter exists up to room temperature and above and is quite stable against any external perturbations.

The origin of magnetism observed in the LTEM, SQUID and PNR data at different temperatures has been investigated by developing micromagnetic models based on the Landau-Lifshitz-Gilbert formalism. Experimental observations of the chiral spin were reproduced using micromagnetic models and their numerical solutions. Phase diagrams of the triangular skyrmion lattice at 0 K and room temperature have been generated with a variety of saturation magnetizations and DMI settings. The parameter window M_s and DMI that stabilizes the skyrmion lattice in the models are consistent with the earlier experimental temperature dependent SQUID results [1] with M_s~17 ± 5 kA/m and D_i (DMI) ~ 4.56 ± 0.78 μJ/m^2, which was not measured directly previously.

The experimental and modelling results suggest that the chiral nature is driven by the interfacial DMI between adjacent FMI and TI. The coupling strength of the two interfaces increases the possibility of forming a non-collinear spin texture and a skyrmion lattice. Our results might pave the way for engineering new strong interlayer coupling effects in topological magnetism for room temperature operation.

References

[1] F. Katmiş, Nature, 533(2016) 513-6.