Revealing Skyrmions at High Magnetic Field in Inversion-Symmetry-Broken Iridate-Manganite Superlattices

Skoropata, E., Ok, J.M., Brahlek, M., Lee, H.N. (Oak Ridge National Laboratory, Materials Science and Technology Division).

Introduction

The motion of itinerant electrons are strongly coupled to local spin configurations, thus exhibiting dramatic effects in low-energy transport properties. Recently, the topological Hall effect (THE) that arises from the interaction of charge carriers with a scalar spin chirality has attracted much attention as a highly effective means to characterize the Skyrmion phase [1-3], which is difficult to characterize by conventional magnetometry studies of the magnetization. Our recent work on $[(SrIrO_3)_n/(SrMnO_3)_n]_m$ superlattices revealed charge-transfer driven interfacial magnetism resulting from enormously strong interfacial coupling between the 3*d*-5*d* oxides [4,5]. Exchanging one of the *A*-site cations (Sr→La) and forming $[(SrIrO_3)_n/(LaMnO_3)_n]_m$ superlattices creates symmetry breaking that leads to strong interface-induced Dzyaloshinskii-Moriya interactions (DMI) and the emergence of a THE over a remarkably large range of applied fields. Detailed magnetotransport experiments were used to study the origin and stability of the chiral magnetic state.

Experimental

We grew high quality epitaxial $[(SrIrO_3)_n/(LaMnO_3)_n]_m$ superlattices using pulsed laser deposition. Micromagnetic simulations, and theoretical modeling indicate the formation of Néel Skyrmions from interfacial induced DMI. We measured the Hall resistivity of an $SrIrO_3/LaMnO_3$ superlatttice using a 31 T DC magnet at Cell 9 at the NHFML.

Results and Discussion

Recently, we examined the magnetotransport properties of high quality $LaMnO_3/SrIrO_3$ superlattices. The temperature dependence of the Hall resistivity $\rho_{xy}(H)$ is shown in **Fig. 1**. The topological Hall resistivity ρ_{THE} due to the skyrmion phase was isolated from the anomalous Hall effect ρ_{AHE} and the ordinary Hall effect ρ_{OHE} that are linear in *M* and *H*, respectively, from a linear fitting of $\rho_{xy}(H)$ in the high *H* region (shown in the bottom of Fig. 1). Due to the inability to saturate $\rho_{xy}(H)$ using field ranges accessible with conventional lab-based instruments, measurements at the High Field Magnet Lab are essential to isolate the ρ_{THE} definitively and to identify clearly the stability region of the chiral magnetic state.

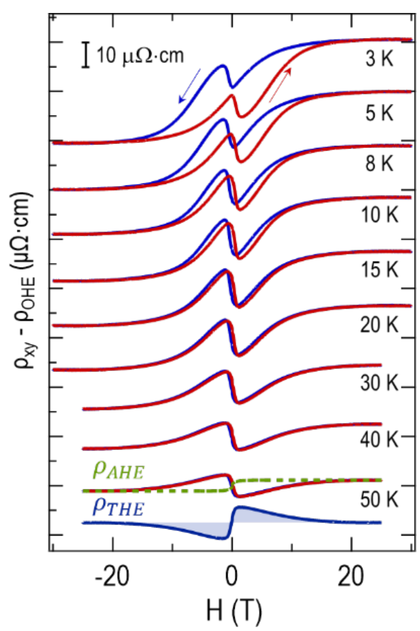

Fig. 1: Temperature dependence of the Hall resistivity $\rho_{xy}(H)$ of an $LaMnO_3/SrIrO_3$ superlattice. The topological Hall resistivity ρ_{THE} at 50 K was obtained by extrapolating the ordinary ρ_{OHE} and anomalous ρ_{AHE} components to the linear region of $\rho_{xy}(H)$.

Conclusions

Our results show that the $LaMnO_3/SrIrO_3$ system hosts skyrmions with stability over an exceptionally large range of applied fields. The ability to establish robust skyrmion phases is an issue of high importance, since the development of skyrmion based devices depends critically on the advancement of strategies to control the skyrmion phase stability region.

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References

[1] Nagaosa, N. *et al.*, Rev. Mod. Phys., **82**, 1539 (2010).
[2] Bruno, P. *et al.*, Phys. Rev. Lett., **93**, 096806 (2004).
[3] Neubauer, A. *et al.*, Phys. Rev. Lett., **102**, 186602 (2009).
[4] Nichols, J. *et al.*, Nat. Commun., **7**, 12721 (2016).
[5] Okamoto, S. *et al.*, **17**, 2126 (2017).