Strong Zero-Field Topological Hall Effect in B20-FeGe Thin Film and Oxide Bilayer Skyrmion Systems

Fengyuan Yang[1], James C. Gallagher[1], Keng-Yuan Meng[1], Jack T. Brangham[1], Hailong Wang[1], Bryan D. Esser[2], and David W. McComb[2]

[1] *Department of Physics, The Ohio State University, Columbus, OH, 43210, USA*

[2] *Center for Electron Microscopy and Analysis, Department of Materials Science and Engineering, The Ohio State University, Columbus, OH, 43212, USA*

Magnetic skyrmions have attracted significant interests in recent years due to their intriguing magnetic interactions and potential for magnetic storage applications. B20 phase materials enable magnetic skyrmions due to the bulk spin-orbit coupling (SOC) and non-centrosymmetric structure. One major effort in this emerging field is the stabilization of skyrmions at room temperature and zero magnetic field. We grow high quality FeGe epitaxial films of 100, 65, and 36 nm thicknesses on Si(111) by UHV off-axis sputtering [1]. The Hall resistivity hysteresis loops show three regions of distinct features: 1) a linear background at large fields (> 2 T) due to the ordinary Hall effect, 2) a magnetic reversal behavior at intermediate fields that follows the magnetization hysteresis loop due to the anomalous Hall effect, and 3) a hysteresis loop within ±3000 Oe due to the topological Hall effect (THE). The THE signals were extracted by subtracting out the anomalous and ordinary Hall effect. The THE reaches near 1,000 nOhm cm at 250 K, the highest reported to date. In particular, a large remanent topological Hall resistivity (77% of the maximum THE signal) was observed at zero magnetic field and 5 K. This substantial topological Hall effect at zero field shows a robust skyrmion phase without the need of an external magnetic field. In addition, a class of skyrmion materials has recently emerged in oxide bilayers due to strong interfacial Rashba SOC that could enable skyrmions of 10 nm. We grow $SrRuO_3/SrIrO_3$ epitaxial bilayers which exhibit high crystalline ordering and dominant topological Hall effect (see Fig. 2). Remarkably, we observe dominant THE in a single 2 nm thick $SrRuO_3$ layer, demonstrating that the skyrmions can be stabilized in single FM oxide thin films. This work was primarily supported by the U.S. DOE under Grant No. DE-SC0001304 and in part by NSF under Grant No. DMR-1507274 and No. DMR-1420451.

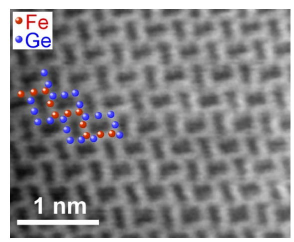

Fig. 1. High resolution STEM image of FeGe film reveals the B20 ordering of Fe and Ge atoms.

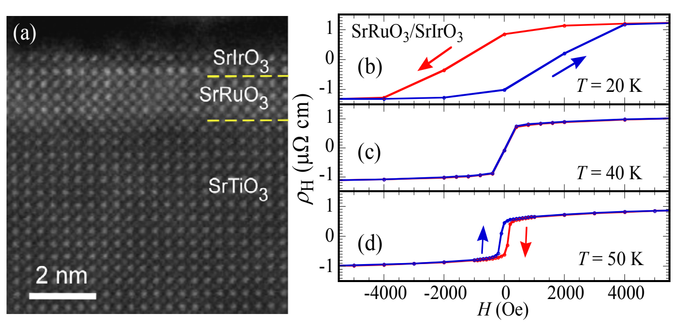

Fig. 2. (a) STEM image of $SrRuO_3/SrIrO_3$ bilayer. Hall resistivity of $SrRuO_3/SrIrO_3$ at (b) 20 K (anomalous Hall dominates), (b) 40 K, and (c) 50 K (topological Hall effect dominates as revealed by the reversal of ρ_H before reaching zero field).

[1] J. C. Gallagher, et al. Phys. Rev. Lett. 118, 027201 (2017).