Observation of a Sign Inversion of the Anomalous Hall Effect in the Ferromagnetic Topological Insulator $(V,Bi,Sb)_2Te_3$

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A variety of novel exotic quantum states of matter have been theorized and experimentally discovered over the years, with the quantum anomalous Hall state [1,2] that emerges in ferromagnetic topological insulators sticking out as one of the most promising in terms of potential applications. Research focused on ferromagnetic topological insulators is being widely promoted among others due to possible applications in metrology, topological quantum computing, as well as more academic interests such as highly unusual axion electrodynamic response.

Despite massive interest in the quantized anomalous Hall effect, a full understanding of the basic anomalous Hall effect is not yet achieved in V and Cr doped $(Bi,Sb)_2Te_3$ material systems. Generally the community agrees on the fact that there are three major contributions to the anomalous Hall effect: (a) The intrinsic contribution, (b) the side jump mechanism, and (c) skew-scattering [3]. Also there appears to be an agreement on the fact that some of the individual contributions may have an opposite sign, and the anomalous Hall effect sign inversion seems to be the best indication of this fact. Every material system exhibiting the anomalous Hall effect reported on so far exhibits either a positive or negative sign of the anomalous Hall effect at constant temperature, constant electrostatic conditions and within a single magnetic phase of the system.

Here we report on the magneto-transport investigation of the magnetically doped $(Bi,Sb)_2Te_3$ / $(V,Bi,Sb)_2Te_3$ topological insulator hetero-structures for various thicknesses, magnetic doping content and layer stacking order. By varying the V incorporation and the magnetic layer thickness, a sign inversion of the anomalous Hall resistivity is observed. The sign of the anomalous Hall effect in $(V,Bi,Sb)_2Te_3$ reveals transition as a function of both the layer thickness and the magnetic dopant content while maintaining the ferromagnetic order in the system at the same time, in contrast to any behavior reported in materials exhibiting the anomalous Hall effect to date.

[1] R. Yu et al., *Science* **329**, 61 (2010)
[2] C.-Z. Chang et al., *Science* **340**, 167 (2013)
[3] N. Nagaosa et al., *Rev. Mod. Phys.* **82** (2010)