Topological spin texture-mediated unconventional Hall effect in a 2D ferromagnet

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Topological magnetic textures provide an attractive platform for future spintronic [1] and quantum information processing [2] devices. The discovery of 2D layered magnetic van der Waals (vdW) materials with strong spin-orbit interaction have opened the possibility for realizing a variety of non-collinear topological spin textures, down to the monolayer limit. Among 2D vdW ferromagnets (FMs), metallic Fe_3GeTe_2 (FGT, hereafter) is a promising candidate owing to its high Curie temperature [3], large magnetic anisotropy, and stabilization of skyrmion and chiral spin-spiral structures [4,5]. However, an understanding of the factors responsible for the stabilization of these exotic spin textures and associated magnetoresistive manifestations have remained elusive. Here, we clarify the underlying physics by investigating the impact of doping at the transition metal site of 2D FM FGT.

Single crystalline $(Co_xFe_{1-x})_3GeTe_2$ (x = 0, 0.05, 0.45, 0.55) samples and a reference sample (FGT) were grown by chemical vapor transport method. Magnetotransport measurements for applied $H \parallel c$-axis result in a sizeable anomalous Hall effect, possibly originating from the topological nodal lines in the band structure. On the other hand, applied $H \perp c$-axis results in an unconventional behavior with a prominent cusp-like feature in the transverse resistivity, which shifts to lower H values with increasing x. Concomitant magneto-optical Kerr effect measurements (with $H \perp c$-axis) indicate the emergence of an aggregate of skyrmion-bubble-like lattice structures along with trivial circular or stripe domain patterns. Complementary angle-dependent magnetotransport measurements show remarkable sensitivity, confirming the 2D nature of these topologically non-trivial spin configurations. Separation of the underlying magnetoresistive origins indicates a significant topological contribution, much larger than that previously observed either in vdW material [3] or other skyrmion-hosting material systems [6,7]. These results provide a deeper understanding of magnetoresistive responses originating from complex spin textures and offer a route towards the realization of non-collinear spin texture-based spintronic devices using vdW FMs.

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