Topological Hall effect in Dirac semimetal

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Magnetic skyrmions are chiral spin textures whose non-trivial real space topology is often created by an interfacial anisotropic Dzyaloshinkii-Moriya exchange interaction (DMI) that originates from spin-orbit coupling and broken inversion symmetry [1]. They have been observed in a wide variety of bulk single crystals such as MnSi [2] and thin films such as $Fe_{1-x}Co_xSi$ [3]. More recently, magnetic skyrmions have been probed at ferromagnet/topological insulator interfaces [4] and in magnetic Weyl semimetals [5]. This motivates similar explorations of skyrmion formation in Dirac semimetals (DSMs). We investigate the formation of skyrmions at the interface of a canonical DSM (Cd_3As_2) and a ferromagnetic semiconductor ($In_{1-x}Mn_xAs$) with perpendicular magnetic anisotropy. Our calculations indicate nonzero spin susceptibility in such heterostructures due to Rashba spin-orbit coupling from broken inversion symmetry, implying the DM interaction necessary for skyrmions. To experimentally test this ideas, we grew $Cd_3As_2/In_{1-x}MnAs$ bilayers (Fig. 1a) and mapped out the behavior of the Hall effect as a function of temperature, magnetic field, and gate voltage in electrostatically top gated devices. Below T = 6 K, we observe an emergent gate-tunable topological Hall effect (THE) indicated by an excess Hall resistance (Fig. 1b). This signature is most pronounced at the charge neutrality point, suggesting the formation of a Dirac-electron mediated chiral spin texture at the DSM/ferromagnet interface. Our study provides a new platform to study the interplay between the topological states in DSMs and the chiral spin textures associated with the THE. Supported by the NSF Graduate Research Fellowship Program (Grant No. DGE1255832).

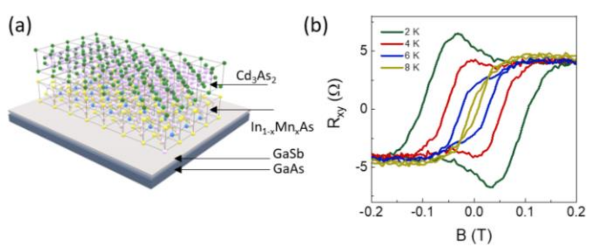

Fig. 1. (a) Device structure. (b) Hall resistance (R_{xy}) at different T showing excess R_{xy}

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Supplementary Pages

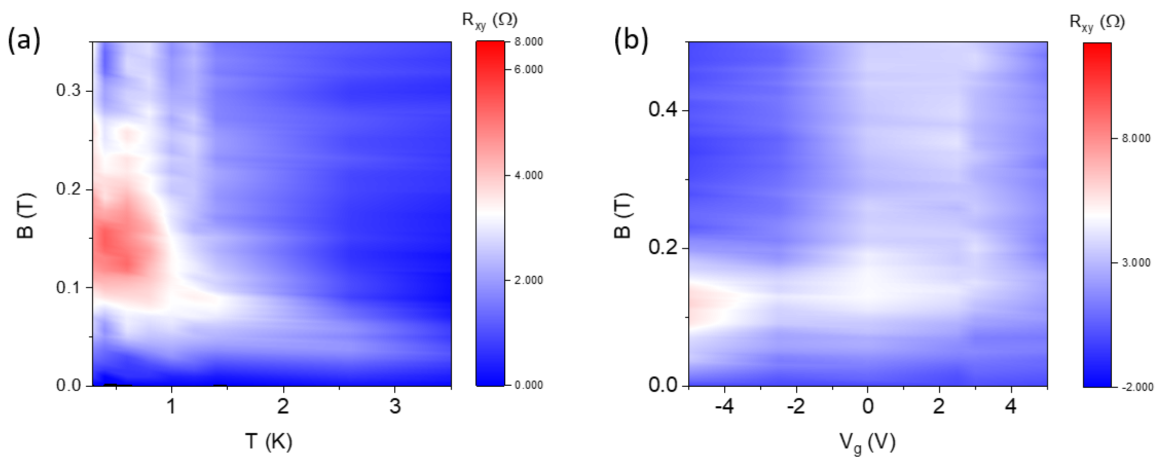

Figure 2. (a) Temperature-dependence of Hall resistance (R_{xy}) showing the excess resistance reduces as temperature is reduced. (b) Gate-voltage dependence of R_{xy} showing the excess resistance is most pronounced close to the charge neutrality point of the heterostructure.