Gate-tunable ferromagnetism in epitaxially grown Dirac semimetal-ferromagnetic semiconductor heterostructures

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The coexistence of time-reversal and inversion symmetry in Dirac semimetals (DSMs) is responsible for topologically protected, spin-degenerate bulk states with Dirac dispersion. Breaking either of these symmetries results in a Weyl semimetal with broken Kramers degeneracy [1]. We explore this concept by using molecular beam epitaxy to interface a canonical DSM, Cd_3As_2, with a ferromagnetic semiconductor, $In_{1-x}Mn_xAs$ with perpendicular magnetic anisotropy (Fig 1 (a), (b)) [2]. Measurements of the anomalous Hall effect (AHE) in top-gated Cd_3As_2/ $In_{1-x}Mn_xAs$ devices show that the ferromagnetic Curie temperature is highly gate-tunable (Fig. 1 (c)-(f)). We map out the AHE in these heterostructures as a function of sample structure and chemical potential. To gain additional insights into the exchange interactions at the heterointerface, we carry out polarized neutron reflectometry (PNR) measurements down to cryogenic temperatures. Preliminary analysis of the PNR data indicates a complex magnetic profile, with potential for a net magnetization within the Cd_3As_2. Work supported by NSF-DMR-2407130 and No. DGE1255832.

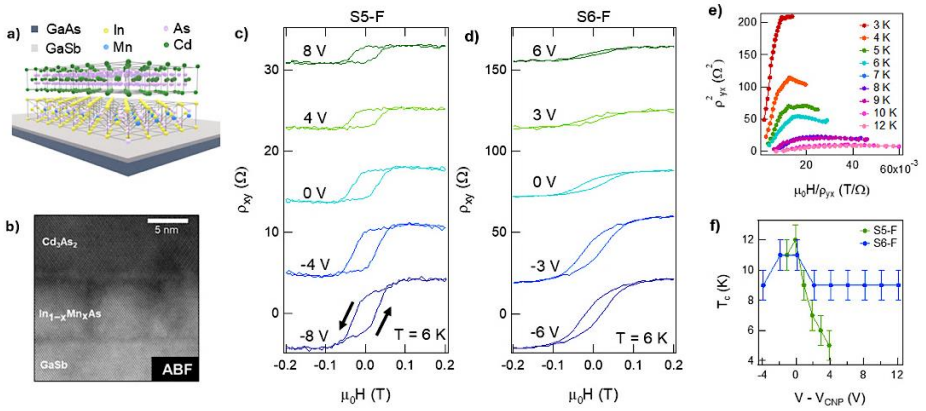

Figure 1.(a) Schematic of heterostructure grown. (b) Cross-sectional HR-TEM view of a Cd_3As_2/ $In_{1-x}Mn_xAs$ heterostructure. (c), (d) Hall resistivity (ρ_{xy}) as a function of the magnetic field showing gate-tunable AHE in S5-F and S6-F, respectively. The curves have been shifted vertically for clarity. (e) Arrot plot of S5-F with V_g fixed at -5V. (f) T_C as a function of V_g offset to the V_{CNP}.

[1] S. Baidya and D. Vanderbilt, Phys. Rev. B **102**, 165115 (2020)

[2] S. Islam, E. Steinebronn *et al., arXiv*: 2403.18485