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Revealing the Antiferromagnetic-to-Ferromagnetic Interlayer Exchange Coupling Transition in Magnetic Insulator–Topological Insulator–Magnetic Insulator Heterostructures

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Topological insulators (TIs) are a class of materials that hosts insulating bulk states and topologically protected metallic surface states, arising from strong spin-orbit coupling and time-reversal symmetry1,2. When time-reversal symmetry is broken—such as by introducing magnetism—these surface states can become gapped, giving rise to novel quantum phases like quantum anomalous Hall effect (QAHE)3. While early approaches relied on magnetic doping to induce such phases, they often suffered from disorder—such as dopant inhomogeneity and magnetic fluctuations—that ultimately reduced the quantization temperature of the QAHE1.
To overcome these challenges, inducing magnetism in a topological insulator via magnetic proximity coupling is a compelling alternative2. A single septuple layer (SL) of MnBi2Te4 is a promising two-dimensional ferromagnetic insulator that enables such proximity coupling with TIs like nearly lattice matched Bi2Te3 with quintuple layer (QL) unit. Here, we conducted electrical transport on 1 SL MnBi2Te4/n QL Bi2Te3/1 SL MnBi2Te4 sandwich heterostructures (n = 0 to 4) to investigate the role of Bi2Te3 spacer thickness in tuning interlayer magnetic interactions. Magnetotransport reveals that even a single QL of Bi2Te3 is sufficient to switch the intrinsic interlayer antiferromagnetic coupling in two septuple layer (2 SL) MnBi2Te4 to ferromagnetic interlayer order, evidenced by Hall hysteresis and the absence of spin-flop transitions. Increasing n leads to a monotonic decrease in coercivity and Curie temperature, reflecting progressively weaker interlayer coupling, with a simultaneous enhancement in anomalous Hall response at n = 4. These findings reveal magnetic-field-driven spin reconfiguration governed by exchange interactions, highlighting this atomic-scale spacer engineered heterostructure as a compelling platform for spintronic applications and tunable symmetry-broken topological quantum phases.
References
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