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Observation of chiral currents at the magnetic domain boundary of a topological insulator

YIHUA WANG, Stanford University

The broken time-reversal symmetry (TRS) states on the surface of a three-dimensional topological insulator (3D-TI) promise many exotic quantum phenomena. Breaking TRS opens a band gap on the surface Dirac cone and transforms the metallic surface into a Chern insulator. The TRS-broken surface states coupled to a superconductor are predicted to lead to Majorana fermions, which are the fundamental ingredients of topological quantum computation. Just as the surface Dirac cone is a signature of the non-trivial topological bulk band structure of a time-reversal invariant 3D-TI, bulk-boundary correspondence dictates that the TRS-broken surface states with a nonzero Chern number is manifested by a gapless chiral edge state (CES) at the domain boundary. In the special case where the domain boundary is the edge of the sample surface, CES along the edge leads to a quantized anomalous Hall conductance, which was recently measured in a magnetically doped 3D-TI. More generally, a magnetic domain boundary on the surface of TI hosts a CES, which is yet to be directly demonstrated because any local change of conductivity due to the CES does not affect conductance globally. Here we use a scanning superconducting quantum interference device (SQUID) to show that in a uniformly magnetized topological insulator - ferromagnetic insulator (TI-FMI) heterostructure current flows at the edge of the surface of the topological insulator when the Fermi level is gate-tuned to the surface band gap. We further induce micron-scale magnetic structures using the field coil of the SQUID and show that there emerges a chiral edge current at the magnetic domain boundary. In both cases the magnitude of the chiral edge current depends on the chemical potential rather than the applied current. Such magnetic nano-structures, which can be readily created on a TI in an arbitrary geometry, provide a versatile platform for detecting topological magnetoelectric effects and may allow the engineering of magnetically defined quantum bits and spin-based electronics. Hybridization with conventional superconductors may open the door to topological quantum computation.