Passage from Spin-Polarized Surface States to Unpolarized Quantum Well States in Topologically Nontrivial Sb Films

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The semimetal Sb, a parent compound of the topological insulator Bi_{1-x}Sb_x (0.07< x< 0.2), shares the same nontrivial topological order as the alloy system. Whereas the surface spin structures of bulk topological insulators provide a promising basis for spintronic applications, thin films are more relevant to actual device architecture. Our ARPES measurements of ultrathin Sb films, fabricated in-situ with high structural quality, reveal novel electronic and spin properties. Theoretically, the spin polarized surface states of Sb must connect, by analytic continuation, to discretized quantum well states in thin films, which are spin degenerate in centrosymmetric systems. Our results clearly demonstrate this passage from polarized to unpolarized states in Sb films. The underlying physics is crucial for understanding the charge and spin transport properties of this system. The interplay of quantum confinement and spin separation offers a path forward for utilizing topological materials for thin film spintronic applications.

Fig. 1 (a) ARPES data taken with 22 eV photons from a 30 BL (bilayer) Sb film. The solid curves indicate schematically the surface bands (A and B) above the Fermi level based on a comparison between theory and data. The dotted curve (labeled Q) indicates the topmost quantum well subband below the gap. (b) Calculated band structure for a freestanding 30 BL Sb slab with spin-orbit coupling included. (c) Calculated band structure with spin-orbit coupling excluded. The projected bulk band region is shaded.

References