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Transport Studies of Topological Insulators and Superconductors[1]

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A topological state of matter is characterized by a topological feature of the quantum-mechanical wavefunction in the Hilbert space. In 3D topological insulators (TIs), a non-trivial Z_2 topology of the bulk valence band leads to the emergence of Dirac fermions on the surface. Similarly, in 3D topological superconductors (TSCs), a non-trivial winding number of the superconducting wavefunction leads to the appearance of Majorana fermions on the surface. The Dirac or Majorana fermions in those topological states of matter are of fundamental interest, but there have been significant materials problems that hindered their experimental studies so far: In the case of TIs, most of the materials identified as such are poor insulators in the bulk, making it difficult to probe the peculiar surface transport properties; in the case of TSCs, no concrete example has yet been discovered. In this talk, I will present our recent contributions to address these issues. For TIs, we discovered that the chalcogen-ordered tetradymite TI material Bi_2Te_2Se presents a high bulk resistivity, allowing one to observe clear surface quantum oscillations [Z. Ren *et al.*, PRB **82**, 241306(R) (2010)]; more recently, we discovered that the bulk-insulating nature can be further improved in the solid-solution system $Bi_{2-x}Sb_xTe_{3-y}Se_y$, making it possible to achieve the surface-dominated transport in a bulk crystal and observe both Dirac holes and electrons via Shubnikov-de Haas oscillations [A. A. Taskin *et al.*, PRL **107**, 016801 (2011)]. For TSCs, we developed a new synthesis technique for a candidate TSC, $Cu_xBi_2Se_3$, to obtain single-crystal samples with a high shielding fraction [M. Kriener *et al.*, PRL **106**, 127004 (2011); PRB **84**, 054513 (2011)]. Using these crystals, we have recently succeeded in observing the surface Andreev bound state which gives evidence for an unconventional superconductivity; since the unconventional superconductivity in $Cu_xBi_2Se_3$ can only be topological (thanks to the simple and peculiar band structure), one can conclude with confidence that this material is the first concrete example of a TSC [S. Sasaki *et al.*, PRL **107** (2011)]. Work in collaboration with A. A. Taskin, Z. Ren, S. Sasaki, and K. Segawa.

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