Landau-level spectroscopy of helical Dirac fermions in a topological insulator Bi_2Se_3

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Topological insulators are emerging materials which have energy gap in the bulk but possess robust gapless edge (2-dimensional case) or surface (3-demensional case) states [1,2]. In 3-dimensional case, the surface state is characterized by Dirac fermions which would give rise to unique quantum phenomena in a magnetic field [3]. Although the Dirac surface state has been confirmed by angle-resolved photoemission spectroscopy (ARPES) experiments, magnetic-field effects on a topological insulator are poorly understood because ARPES is not magnetic-field compatible and contributions from bulk bands dominate magneto-transport properties.

Here we use scanning tunneling spectroscopy to study the Dirac surface state of a topological insulator Bi_2Se_3 under magnetic fields [4]. Bi_2Se_3 crystals are naturally doped with electrons and the Dirac point is located ~0.3 eV below the Fermi level. Under magnetic field perpendicular to the cleaved surface, a series of Landau levels (LLs) has been observed in the tunneling spectrum. Remarkably, there is a field-independent LL at the Dirac point, which is a hallmark of Dirac fermions. We developed a scaling analysis scheme of LLs based on the Bohr-Sommerfeld quantization condition which allowed us to determine the energy-momentum dispersion of the surface state. Near the Fermi energy, complicated fine structures mixed with LLs appear in the spectra, which may be responsible for the anomalous magneto-fingerprint effect [5]. We anticipate that these observations provide spectroscopic basis for understanding the nature of topological insulators under magnetic fields.

This work has been done in collaboration with K. Igarashi, M. Kawamura, H. Takagi and T. Sasagawa.

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