MAR11-2010-000932

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Landau-level spectroscopies of a topological insulator

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Topological insulators such as Bi_2Se_3 are characterized by massless Dirac surface state which would give rise to unique quantum phenomena in a magnetic field. Although it was experimentally verified by many ARPES experiments that the surface electrons are indeed massless, there has been a lack of studies exploring their quantum properties due to the inevitable contribution from the bulk electrons in a real material. Using surface-sensitive STM/STS technique, we selectively probed the surface massless electrons in Bi_2Se_3. Under magnetic field perpendicular to the cleaved surface, a series of Landau levels (LLs) has been observed in the tunneling spectra. 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 [1]. Width of the LL peaks in the spectra becomes smaller near the Fermi energy, which may suggest that electron-electron correlation plays a role. In addition to the narrowing of LLs, the spectra near the Fermi energy exhibit complicated fine structures, which may be responsible for the anomalous magneto-fingerprint effect [2]. This work has been done in collaboration with K. Igarashi, M. Kawamura, H. Takagi and T. Sasagawa.

[1] T. Hanaguri *et al.*, Phys. Rev. B **82**, 081305(R) (2010).
[2] J. G. Checkelsky *et al.*, Phys. Rev. Lett. **103**, 246601 (2009).