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Manifestation of topological protection in transport properties of epitaxial Bi_2Se_3 thin films[1]

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A topological insulator is a new quantum state of matter which can be realized in some materials with a strong spin-orbit coupling. Due to the spin-momentum locking, massless Dirac fermions residing on the surface of a topological insulator are protected from backscattering and cannot be localized by disorder. However, such protection can be lifted in ultrathin films when the three-dimensionality of the sample is lost due to hybridization between top and bottom surfaces. Recently, using Molecular Beam Epitaxy, we succeeded in growing Bi_2Se_3 thin films of sufficiently high quality to present quantum oscillations in magnetotransport [1]. By measuring the Shubnikov-de Haas oscillations in a series of high-quality films, we revealed a systematic evolution of the surface conductance as a function of thickness and found a striking manifestation of the topological protection [2]: The metallic surface transport abruptly diminishes below the critical thickness of $\sim$6 nm, at which an energy gap opens in the surface state and the Dirac fermions become massive. At the same time, the weak antilocalization behavior is found to weaken in the gapped phase due to the loss of π Berry phase. Our results demonstrate the importance of the spin and momentum coupling in maintaining the topological protection of the surface carriers in topological insulators.

[1] A. A. Taskin, S. Sasaki, K. Segawa, and Y. Ando, Adv. Mater. **24**, 5581 (2012).
[2] A. A. Taskin, S. Sasaki, K. Segawa, and Y. Ando, Phys. Rev. Lett. **109**, 066803 (2012).

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