Investigation of Magnetic-field Effect on Topological Insulators Surface States

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Introduction

Topological insulators (TIs) have been predicted to have metallic edge or surface states with a linear, Dirac-like dispersion relation in addition to a normal bulk band structure [1]. The most remarkable characteristic is that these edge or surface states remain robust against time reversal invariant disorders since the directions of the spin and the momentum are locked due to the strong spin-orbit interaction [2, 3]. Thus there are exciting opportunities for constructing novel electronic and spintronic devices that consume much less energy than the current CMOS technology.

Experimental

We have fabricated 3D topological insulators of $(Bi_{0.57}Sb_{0.43})_2Te_3$ thin film by molecular beam epitaxy (MBE). Standard hall bar devices with top gate electrodes have been fabricated. We then measured the low temperature magnetoresistance (MR) as a function of two variables – the perpendicular magnetic field and the top gate bias voltage. We have used a superconducting magnet SCM2, and resistive magnets in cell 8 and cell 12.

Results and Discussion

We observed a variety of MR peaks, the so-called Shubnikov-deHaas (SdH) oscillations, due to the quantized Landau level of the surface states. From the gate bias dependence, we can distinguish between the top and bottom surface conduction channels. The conductance of the top surface can be systematically tuned by gate bias, while that of bottom surface is independent to gate voltage, due to very high dielectric constant of TI materials.

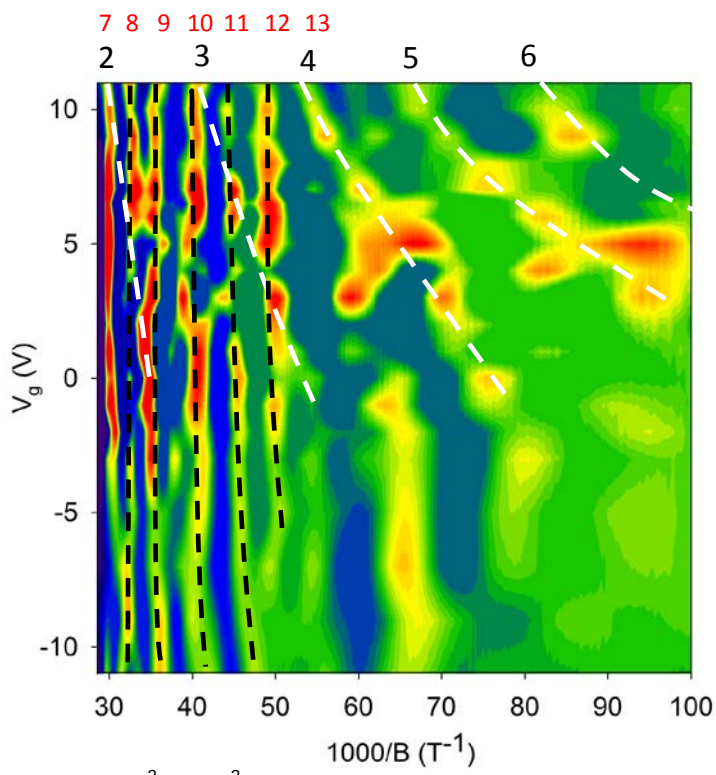

Figure 1. $-d^2R_{xx}/dB^2$ as a function of 1/B and V_G. At positive gate voltages, some of the Landau levels (LLs) exhibits systematically shift (white dashed lines), representing the change of top surface carrier density, while some of the landau levels do not show any gate dependent shift (black dashed lines), representing the bottom surface carrier density. The black and red numbers are the LLs of top and bottom surface states, respectively. At negative bias, the LLs of top surface are shadowed by bulk holes.

Conclusion

Our results not only demonstrate the presence of top and bottom surface states in 3D TIs, but also pave a pathway for the realization of quantum spin Hall effect in topological insulators which requires a selective control of spin transports on top/bottom surfaces.

Acknowledgements

We would like to thank the support from the Defense Advanced Research Projects Agency (DARPA) under the grant no. N66001-12-1-4034 and N66001-11-1-4105.

References

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