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Quantum anomalous Hall effect in magnetically doped topological insulator

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Abstract

It this talk, I will introduce the concept of the quantum anomalous Hall effect and its experimental realization in a topological insulator. I will also discuss the potential applications of the quantum anomalous Hall effect in low dissipation electron transport.

1. Introduction

It has long been expected that quantum Hall effect (QHE) [1] may occur without Landau levels so that neither external magnetic field nor high sample mobility is required for its studies and applications. Such a QHE without Landau levels can be realized in a ferromagnetic insulator with non-trivial topological character as the quantized version of the anomalous Hall effect, i.e. the quantum anomalous Hall effect (QAHE) [2-9]. In spite of several theoretic proposals, the experimental progress was little until the discovery of topological insulators (TIs) in recent years [6,7].

2. General Instructions

To realize the QAHE in a TI, one needs prepare thin films of the TI with well-controlled thickness, introduce long-range ferromagnetic order in it in insulating regime, and tune its Fermi level accurately into the magnetically induced gap [4-9]. With molecular beam epitaxy, we prepared on $SrTiO_3(111)$ substrates thin films of Cr-doped $(Bi,Sb)_2Te_3$ TIs with well-controlled composition, thickness and chemical potential. The films show long-range ferromagnetic order even if bulk carriers are depleted, which suggests existence of ferromagnetic insulator phase [10].

In such thin films, the QAHE was finally realized at 30 mK [11]. A quantization plateau of the Hall resistance at h/e^2 at zero magnetic field was observed in both magnetic field and gate-voltage dependent curves. The Hall resistance plateau is accompanied by a considerable drop in the longitudinal resistance, which indicates reduced dissipation of electron conduction channels (Fig. 1). The longitudinal resistance can be further reduced to zero by localization of dissipative channels by a magnetic field. We also investigated the temperature and thickness dependence of the QAHE, trying to find out the reason why such an extreme low temperature and a magnetic field are needed to realize dissipationless electron transport.

3. Conclusions

The experimental observation of the QAHE provides a foundation for many other novel quantum phenomena predicted in TIs such as Majorana modes. It also opens a route to practical applications of quantum Hall physics in low-energy-consumption electronics.

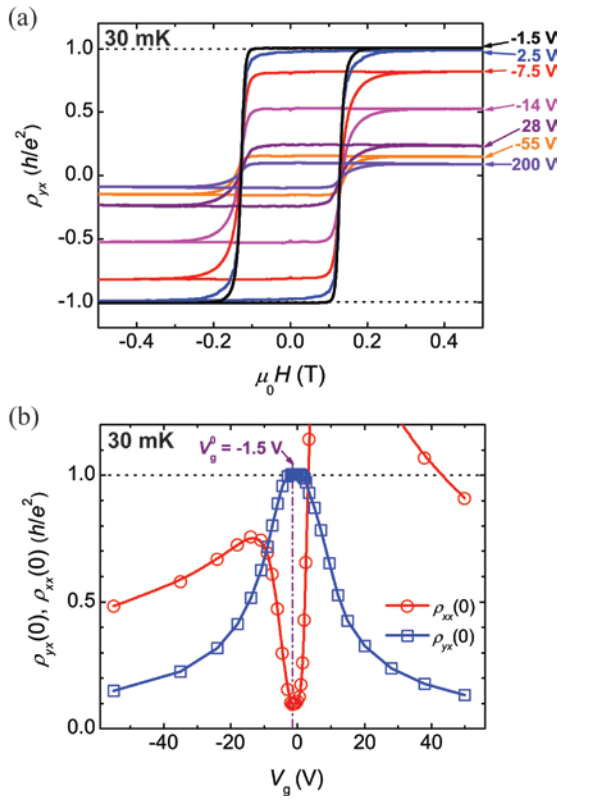

Fig. 1 The QAH effect measured at 30 mK. (a) Magnetic field dependence of ρ_{yx} at different V_gs. (b) Dependence of $\rho_{yx}(0)$ (empty blue squares) and $\rho_{xx}(0)$ (empty red circles) on V_g.

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References

[1] K. v. Klitzing, G. Dorda, and M. Peper, Phys Rev Lett **45** (1980) 494.

[2] F. D. M. Haldane, Phys Rev Lett **61** (1988) 2015.

[3] N. Nagaosa, J. Sinova, S. Onoda, A. H. MacDonald, and N. P. Ong, Rev Mod Phys **82** (2010) 1539.

[4] X. L. Qi, Y. S. Wu, and S. C. Zhang, Phys Rev B **74** (2006) 085308.

[5] X. L. Qi, T. L. Hughes, and S. C. Zhang, Phys Rev B **78** (2008) 195424.

[6]C. X. Liu, X. L. Qi, X. Dai, Z. Fang, and S. C. Zhang, Phys Rev Lett **101** (2008) 146802.

[6] M. Z. Hasan and C. L. Kane, Rev Mod Phys **82** (2010) 3045.

[7] X. L. Qi and S. C. Zhang, Rev Mod Phys **83** (2011) 1057.

[8] R. Yu et al., Science **329** (2010) 61.

[9] K. Nomura and N. Nagaosa, Phys Rev Lett 106 (2011) 166802.

[10] C. -Z. Chang et al. Adv Mater **25** (2013) 1065.

[11] C. -Z. Chang et al. Science **340** (2013) 167.

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