Ferromagnetism, quantum anomalous Hall state and dissipationless chiral conduction in topological insulators

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A topological insulator (TI) with broken time reversal symmetry (TRS) by ferromagnetic perturbation of their Dirac surface states can display many exotic quantum phenomena including the quantum anomalous Hall (QAH) effect and dissipationless quantized Hall transport. The realization of the QAH effect in realistic materials requires ferromagnetic insulating materials that have topologically non-trivial electronic band structures. In a TI, the ferromagnetic order and TRS breaking is achievable through doping with a magnetic element or via ferromagnetic proximity coupling with a magnetic material. Our experimental success by both approaches showed excellent results along with some unanticipated observations: the proximity induced magnetism in TI exhibited stability far above the expected temperature range. We will discuss the robust QAH state and dissipationless chiral edge current flow achieved in the (doped) hard ferromagnetic TI system.[1,2] In the proximity approach due to the short range nature of the ferromagnetic exchange interaction, it affects only near the surface of a TI, while leaving its bulk states unaffected. This interfacial ferromagnetism is observed in a variety of bi-layers, providing a possibility to control this phenomenon.[3] Our results could be a significant step towards dissipationless transport for electronic applications, making such devices more amenable for metrology and spintronics applications. Furthermore, our study of the gate and temperature dependences of transport measurements may elucidate the causes of the dissipative edge channels and the need for very low temperature to observe QAH.

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References:

1. P. Wei et al., Phys. Rev. Lett. 110, 186807 (2013)
2. C. -Z Chang et al., Nat. Matl 13, 473 (2015); Phys. Rev. Lett. 115, 057206 (2015)
3. F. Katmis et al., Nature (to be published, 2016)