Band engineering to achieve a wide band gap topological insulator

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Three dimensional topological insulators (3D TIs) are being widely researched today for their attractive and unique transport properties [1]. These materials present a bandgap in the bulk and highly conducting metallic surface states. Heterostructures of these TIs are predicted to show promising properties [2]. We have recently shown that a short period superlattice of two TI materials, such as Bi_2Se_3 and Sb_2Te_3, can present promising electrical properties, for example a decrease in carrier concentration in the bulk and an increase of resistance as a function of the superlattice period. This can be explained by the formation of a bulk bandgap in the superlattice due to confinement effects in each of the layers, as a result of their "broken gap" band alignment. A question remains as to the presence of the topological surface states in such a short period superlattice structure. To investigate this, magnetoconductance measurements were performed for the superlattice structure with the smallest periodicity; one that showed the reduced bulk conductivity previously observed (Fig. 1a). Fitting these data to the typically used Hikami-Larkin-Nagaka theory [3] suggests the presence of two two-dimensional conduction channels in the small period superlattice as expected for a 3D TI layer. Angle dependent magnetoresistance measurements (Fig. 1b) and a fit of the dephasing length (l_φ) dependence on temperature (Fig. 1c) both give further supporting evidence of the preservation of the topological surface states. Thus, we conclude that this short period Bi_2Se_3-Sb_2Te_3TI-TI superlattice behaves as a designer 3D TI with different properties to the two individual TI constituents, which are conducting in the bulk. Tight binding calculation for such short period TI-TI superlattices were performed and the results suggest that for the appropriate combination of materials, it may be possible to achieve a "designer" 3D TI with a bulk bandgap that is larger than the gaps of either of the component TI materials.

[1] Y. Xia et al., Nat. Phys. 5, 398 (2009)
[2] K.M. Masum-Habib et al., Phys. Rev. Lett. 114, 176801 (2015)
[3] S. Hikami et al., Prog. Theor. Phys. 63, 707 (1980)

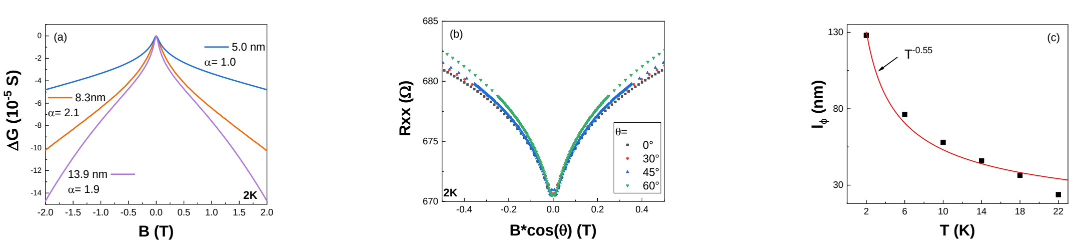

Figure 1: a) Magnetoconductance of samples with different superlattice period thickness. b) Angle dependent magnetoresistance and c) Dephasing length (l_φ) as a function of temperature of the 5 nm period superlattice.

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