Quantum Fluctuations in Ultrathin Sb Films

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Introduction -

Our research is motivated by predictions that quantum confined antimony is an elemental topological insulator (an insulating interior with conducting surfaces protected from localization by time reversal symmetry). Our effort employs ultra-thin films of Sb grown on GaSb (111) substrates with good crystalline quality via molecular beam epitaxy.

Experimental -

We have performed transport measurements as a function of field and temperature as the thickness of the Sb layer is varied. As the inset to Figure 1 shows, in contrast to the metallic dR/dT>0 behavior observed for thicker Sb films, the resistance of ultrathin films increases with decreasing temperature. Additionally, these ultrathin films display suppressed conduction as would be expected from successful quantum confinement; this can be seen in Fig. 1 in which the measured conductance of the samples falls below the estimated conductance of thinned bulk slab. Moreover the conductance of the samples for thicknesses greater than 1nm is linear in thickness extrapolating to a finite conductance at zero film thickness as would be expected for surface state transport. There is an abrupt conduction transition for films below 1nm in thickness that agrees well with theoretical work predicting a topological to trivial insulator transition for films. Figure 2 displays the magneto-resistance for a 2nm film. The traces taken in a tilted magnetic field collapse onto a single curve (see inset) when plotted vs. perpendicular field indicating the 2D character of the conducting states, however as the magnetic length even at 18 Tesla is still greater than the film thickness, we cannot use this observation alone to discriminate between surface and 2D bulk bands.

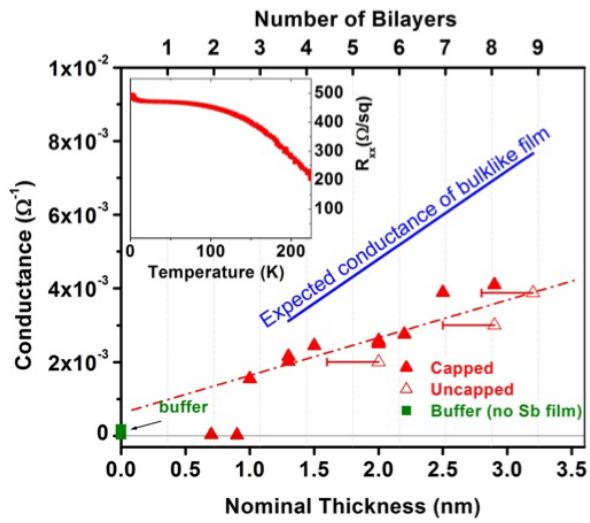

Fig.1 Film conductance at 20K vs. thickness. Films extrapolate to a finite conductivity at zero film thickness. Inset: Typical resistance vs. temperature trace.

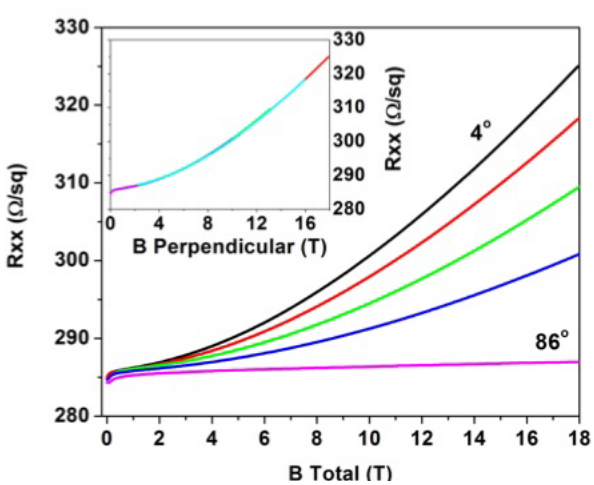

Fig.2 Magneto-resistance of 2nm film for a variety tilt angles. Inset: The traces collapse onto a common curve when plotted vs. perpendicular field showing the 2D nature of the transport.

Most recently we have used e-beam lithography to fabricate quantum wires and observed universal conductance fluctuations. Ongoing experiments will use the same devices to search for Aharonov-Bohm oscillations associated with conducting paths around the perimeter of the quantum wires. This would provide unequivocal evidence of surface dominated transport in an elemental topological insulator.

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