Quantum oscillations and Hall anomaly of surface electrons on Topological Insulators

N. PHUAN ONG, Princeton University

The investigation of Topological Insulators (TI) by transport experiments is a challenge, because the surface currents cannot be well-resolved when the bulk conductance is dominant, as in most crystals. I will review the progress starting from Ca-doped Bi$_2$Se$_3$, and proceeding to Bi$_2$Te$_3$ and to Bi$_2$SeTe$_2$. Using Ca dopants in Bi$_2$Se$_3$, we succeeded in lowering the Fermi energy $E_F$ into the bulk gap. However, in non-metallic crystals, the substantial dopant-induced disorder precluded observation of Shubnikov-de Haas (SdH) oscillations. Fortunately, $E_F$ in undoped Bi$_2$Te$_3$ can be tuned into the gap by heat treatment. The non-metallic samples display a bulk resistivity $\rho = 4$-$12$ m$\Omega$cm at 4 K. In these crystals, weak SdH oscillations are observed below 10 K. We confirmed that these oscillations arise from a 2D Fermi Surface by tilting the magnetic field $H$. From the behavior of the SdH amplitude versus temperature $T$ and $H$, we infer a surface Fermi velocity $v_F = 3.7$-$4.2 \times 10^5$ m/s, and a high surface mobility $\mu = 10,000$ cm$^2$/Vs. The high mobility of the surface electrons is confirmed by the appearance of an unusual weak-field anomaly in the Hall conductance $G_{xy}$. I will discuss recent progress in further lowering the bulk conductance in the new TI Bi$_2$Se$_3$, in which a Se layer is sandwiched between two Te layers in each quintuplet unit cell. In these crystals, $\rho$ at 4 K is a factor of 1000 larger ($6$ $\Omega$cm). The interesting pattern of SdH oscillations in this new system will be reported.

Collaborators: D.X. Qu, J. M. Checkelsky, Y. S. Hor, J. Xiong, R. J. Cava

$^1$Supported by NSF-MRSEC DMR 0819860. High-field experiments were performed in the National High Magnetic Field Lab., Tallahassee.