Magneto-optical Spectroscopy of Topological Insulators Bi_2Te_3 and Bi_2Te_2Se

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Introduction

Topological insulators (TI) are materials where strong spin-orbit coupling produces metallic states only at their surfaces. [1-3] Since these surface states are protected from backscattering by time-reversal invariance they are predicted to have a number of novel properties. For instance, the spin of an electron is intimately tied to its velocity in these compounds. Therefore TIs provide a new route to spintronics. [3] Nonetheless, it is difficult to isolate contributions from the surface states in the measured properties of TIs. In particular, unintentional doping and anti site defects in Bi_2Te_3, a quintessential TI, cause the bulk to conduct. Thus, electronic signatures of the surface states are concealed in zero-field transport and optics measurements. Magneto-optical reflectance however, can reveal cyclotron resonance of the surface states, thus becoming a novel surface sensitive probe.

To improve the surface state contribution to conductivity, recent experimental progress in the synthesis of TIs has led to more resistive novel ternary compounds, such as Bi_2Te_2Se (BTS). Indeed, ARPES measurements have shown that the Fermi level of BTS is in the gap, and low temperature resistivities of 6 $\Omega^{-1}cm^{-1}$ have been measured. [4,5] Despite this great resistance, quantum oscillations are still observed at low temperatures, and attributed to the surface states. This makes BTS a promising candidate for the study of surface states. Above 40K, however, quantum oscillations diminish and the Hall coefficient changes sign, indicating a change in dominant carrier mobility from electrons to holes. Optical spectroscopy research in the Burch group has revealed that electron phonon coupling in BTS suppresses the surface conductivity around 40K, thus causing the change in sign of the Hall coefficient. [4-6] Thus, using magneto-optical spectroscopy to break time-reversal symmetry (and destroy backscattering protection of surface states) is an excellent technique to explore the electronic properties of BTS surface in greater depth

Experimental

Magneto-reflectance spectroscopy over the range 40-4000 cm^{-1} was performed on both Bi_2Te_3 and BTS at the NHMFL in Tallahassee, FL, using a 17.5T superconducting DC magnet, SCM 3.

Results and Discussion

Figure 1a shows how the plasma edge of Bi_2Te_3 splits between cyclotron active and inactive carriers as a function of field strength. However, surface state Landau level transitions were not observed. **Figure 1b** shows the far infrared magneto-reflectance of BTS, normalized by 0T reflectance. Although the observed field dependence is too weak to conclusively discuss the bulk and surface state field dependence, future measurements at the NHMFL using stronger fields promise more definitive results.

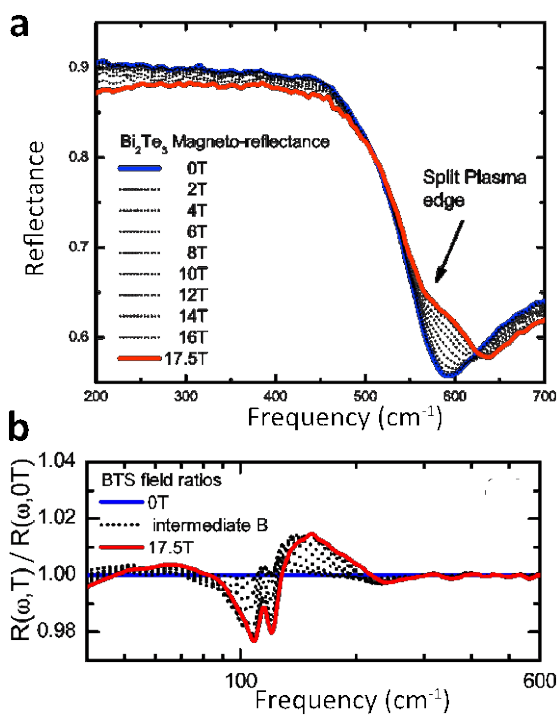

Figure 1 | a, Magneto-reflectance of Bi_2Te_3 reveals a split plasma edge at 17.5T. **b**, Reflectance ratios of BTS at different fields show surprisingly few and weak features.

Conclusions

While Bi_2Te_3 did not show evidence of surface state Landau level transitions, BTS shows weak field dependence exactly in the frequency range to which the surface state Drude is observed in zero-field measurements. Hence, future magneto-reflectance measurements at stronger fields hold great promise.

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