Intravalence Band Transitions in Gapless Topological Insulators

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The Nature web site lists the following definition: "Topological insulators are materials that are insulating in their interior but can support the flow of electrons on their surface. The underlying cause is time-reversal symmetry: their physics is independent of whether time is flowing backward or forward."

From an optics perspective, the key phrase here is "time-reversal symmetry". While regular semiconductors have a p-type valence band and an s-type conduction band with band ordering p-p-s, topological insulators like alpha-tin show parity inversion: Because of strong relativistic effects in the electronic band structure of alpha-tin, the s-antibonding band has moved between the split-off hole band and the heavy/light hole bands. This Darwin shift leads to a p-s-p band ordering with parity inversion, which makes alpha-tin a topological insulator. Due to the degeneracy of the heavy and light hole bands, alpha-tin is also a gapless semiconductor, like HgTe, HgSe, and alloys of related materials.

Because of this important band structure difference, intravalence band absorption is forbidden (i.e., weak) in conventional semiconductors like Ge, GaAs, or AlSb, but leads to a strong peak in ellipsometry spectra of epitaxial alpha-tin layers at 0.41 eV. The dependence of this intravalence band absorption as a function of temperature, substrate, and doping with germanium will be discussed. The lineshape of this absorption peak is rather curious and cannot be explained with degenerate carrier statistics (Burstein-Moss shift), excitonic effects, or carrier screening. Most likely, more arcane details of Kane's k.p band structure theory for InSb need to be considered, such as nonparabolicity of the bands and k-dependent optical dipole matrix elements. Important clues buried in the temperature dependence of the dielectric function of InSb near the band gap will be important to understand the intravalence band absorption in gapless topological insulators.

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