Doping-level dependent polarity reversal of terahertz photo-conductance in topological insulators.

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Topological insulator (TI) is a new quantum material, where the insulating bulk state and Dirac-like topological surface state (TSS) coexist [1]. Despite its novel topological property, however, the screened TSS response by the bulk states causes challenges to apply in optoelectronics and electronics.

Recently, a molecular beam epitaxy (MBE) technique enables to grow the bulk insulating Bi_2Se_3 on a buffer layer, which effectively eliminates the bulk screening effect [2]. Furthermore, it is also possible to change the doping level below/above the Dirac point, by which one can investigate both the carrier dynamics of TSS and the effect of bulk states.

In this work, we show that the photoinduced terahertz responses are significantly different depending on the fermi level of Bi_2Se_3 TI. With near-IR pump (1.03 eV) and terahertz spectroscopy [Fig. 1(a)], we discovered that the terahertz photo-conductance response is opposite between the bulk insulating and the p-type Bi_2Se_3 after pump-probe delay of 10 ps [see Fig. 1(b) and (c)]. In bulk insulating Bi_2Se_3, the negative photo-conductance originates from the Dirac surface metallic property (blue line in Fig. 2(b)) [3]. However, in p-type Bi_2Se_3, the TSS negative metallic response is completely masked by the positive response of the bulk (red line in Fig. 2(b)). Our work highlights that the dynamic interplay between the photo-iduced Drude spectral weight and the scattering rate plays an important role in understanding the low-energy photoresponse of TI.

References

[1] M. Z. Hasan and C. L. Kane, Rev. Mod. Phys., 82 (2010) 3045
[2] N. Koirala et al., Nano Lett., 15 (2015) 8245
[3] S. Sim et al., Phys. Rev. B, 89 (2014) 165137; R. Valdés Aguilar et al., Appl. Phys. Lett., 106 (2015) 011901

Figures

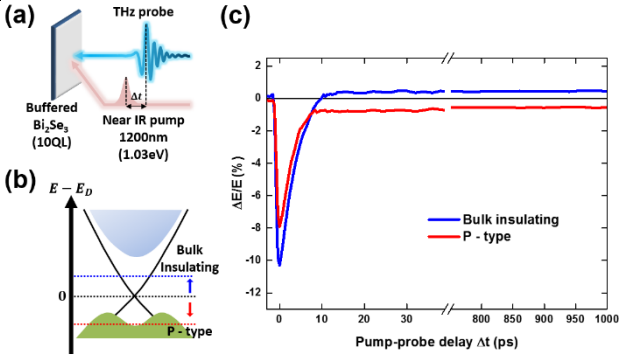

Figure 1: Transient THz responses at 77 K. (a) Schematic of Near IR-pump THz-probe experiment. (b) Schematic band structure for bulk insulating and P – type Bi_2Se_3. (c) Normalized ΔE_T as a function of pump-probe time delay (Δt).

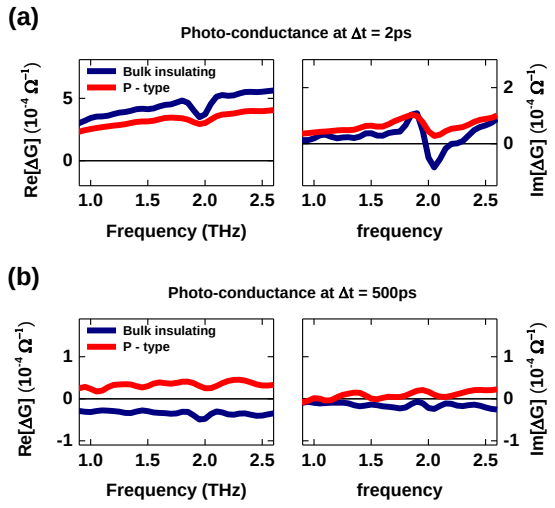

Figure 2: Complex THz sheet photo-conductance of bulk insulating and P-type Bi_2Se_3 at Δt = 2ps (a) and Δt = 500ps (b).