Photoresponse in magnetic topological insulators

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Doping topological insulators (TIs) with magnetic elements causes essential modifications in their originally mass-less surface states, providing a new path towards exotic physics and future applications. Examples are the quantized magnetoelectric effects [1] and quantum anomalous Hall (QAH) effects [2,3], which would materialize dissipation-less electronics. The nonequilibrium electron/spin dynamics at the modified Dirac states induced by doped magnetic moments are still elusive, possibly unveiling additional functions of TIs, such as highly-efficient photon to spin-current conversion. Furthermore, with the progress of film fabrication techniques including superlattices and modulation dopings [4], variety of cooperative phenomena between two surface states (top and bottom of a film) would be explored.

In this paper, we discuss several optical phenomena observed recently in thin films of (magnetic) topological insulators; (i) generation of large zero-bias photocurrent resulting from magnetic modifications of the Dirac states, (ii) enhancement of photogalvanic current by chemically tuning the Fermi energy, and (iii) topological magnetoelectric effects (topological Faraday and Kerr rotations).

When a TI is doped with magnetic elements, such as Cr, its easy-axis anisotropy induces an energy gap at the Dirac point [5] [Fig. 1(a)]. The surface-state dispersion recovers to be mass-less by the application of in-plane magnetic field (e.g., B_y), due to the in-plane helical nature of its spin state, and further shifts/deforms through the Zeeman effect [Fig. 1(b)]. In this situation, the photoexcitation at $+k_x$ and $-k_x$ becomes non-equivalent, even for non-polarized photons, leading to a finite spin-polarized photocurrent j_x [6]. We realized that this zero-bias photocurrent dramatically increases for the mid-infrared photoexcitation [Fig. 1(c)], pointing to the relevance of surface-state dispersion and strong influence of bulk-surface scatterings. It is also demonstrated that it is critical to precisely control the Fermi energy to observe intrinsic nature of TIs. For example, the photogalvanic current [7,8] shows a pronounced peak when we tune the Fermi energy across the Dirac cone [9], and topological magnetoelectric effects appear in the QAH regime [10].

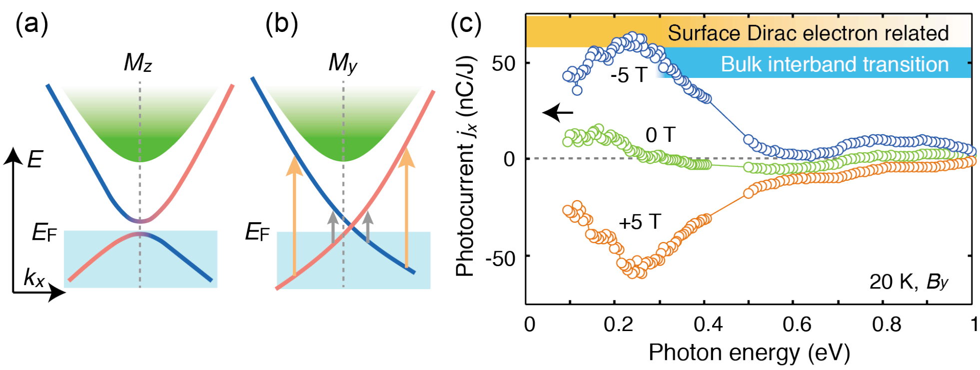

Fig. 1. (a) Dirac mass gap induced by the easy-axis anisotropy of magnetic dopants. (b) Closing of the mass gap and shift/deformation of surface-state dispersions. (c) Photocurrent observed under the in-plane magnetic field. A peak structure around 0.25 eV reflects the asymmetry of optical transitions in *k*-space as shown in (b).

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