Realization of a vertical topological p–n junction in epitaxial Sb_2Te_3/Bi_2Te_3 heterostructures

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There has been considerable amount of research carried in order to precisely tune the position of the Fermi level E_F in topological Dirac cones. First, this can be achieved by surface doping which, however, does not lead to a suppression of the bulk conductivity. Another successful path is to gradually tune the composition in a ternary (or even quaternary) alloy, like $(Bi_{1-x}Sb_x)_2Te_3$. Since typical epitaxially grown layers of Bi_2Te_3 (Sb_2Te_3) turn out to be of n- (p-)type charge character, which are dominated by electron (hole) transport in the bulk, this alloying leads to an effective compensation of charge and thus to a shift of the chemical potential and tunable surface states and eventually also suppression of the bulk conductivity. Similarly, bringing together two different binary TI films to create a vertical topological p–n junction should also lead to compensation of charge within the depletion layer formed at their interface. However, the effect of such a topological p–n junction on the topologically protected surface states or the surface electronic structure in general has not been reported so far.

Here we report on the Fermi level engineering in such a topological bilayer made of Bi_2Te_3 and Sb_2Te_3 [1]. We present a direct experimental proof, by angle-resolved photoemission, of the realization of a vertical topological p–n junction made of a heterostructure of two different binary 3D TI materials Bi_2Te_3 and Sb_2Te_3 epitaxially grown on Si(111). We demonstrate that the chemical potential is tunable by about 200meV when decreasing the upper Sb_2Te_3 layer thickness from 25 to 6 quintuple layers without applying any external bias. The origin of observed shifts can be described within the one-dimensional Schrödinger-Poisson formalism for the ultrathin junction between two layers of n- and p-type character, including additional charge due to TI surface states.

Acknowledgments
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References

[1] M. Eschbach et al., "Realization of a vertical topological p-n junction in epitaxial Sb_2Te_3/Bi_2Te_3 heterostructures", Nature Communications 6, 8816 (2015).