Protecting topological surface states with organic monolayers

Applying topological insulators (TIs) in devices has attracted considerable interest from the scientific community due to the exotic physical properties of Tis and their potential for spintronics applications. The unique topological surface states (TSS) explicitly define the relation between electron spin and momentum. The existence of spin-momentum-locked metallic surface states makes controlling the spin signal through currents possible. In addition, electron transport through three-dimensional (3D) TIs generates a fully spin-polarized current inside the bulk bad gap. To minimize the influences on the TSS, such as electron doping and scattering, a buffer layer that forms smooth interfaces and prevents interactions between electrodes is required during fabrication processes.

We propose and demonstrate a new approach (Figure 1) that exploits an organic monolayer as a buffer layer to fabricate smooth interfaces and to prevent disturbances in the TSS during metal deposition. In our study, we use the organic molecule perylene-3,4,9,10-tetracarboxylic-dianhydride (PTCDA) to form the buffer layer on the 3D TI Bi_2Se_3 with Fe atoms as surface dopants that represent the disturbance of electrodes.

Scanning tunneling microscopy and spectroscopy (STM and STS) are used to investigate the PTCDA/Bi_2Se_3 and Fe deposited PTCDA/Bi_2Se_3 systems. In the PTCDA/Bi_2Se_3 system (Figure 2), due to the weak interactions between the PTCDA molecules and the Bi_2Se_3, the Bi2Se3 TSS is conserved on top of the well-ordered PTCDA assembly layers. By depositing Fe atoms on the Bi_2Se_3, the electron doping effect and Coulomb scattering between the TSS and the Fe atoms are addressed in the STS results. After introducing a PTCDA monolayer between the Fe and the Bi_2Se_3, the above-mentioned effects are eliminated.

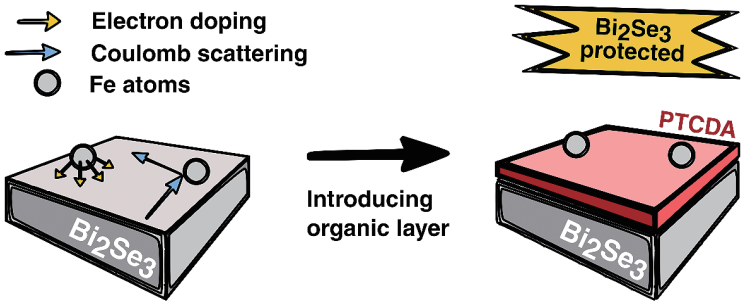

Figure 1. Illustration of the idea of using an organic monolayer as a buffer layer between the electrode and the TI surface.

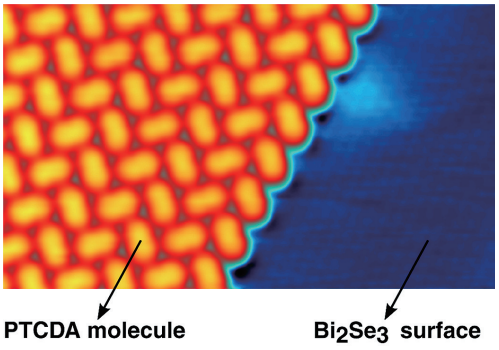

Figure 2. STM image of a self-assembled PTCDA layer on a Bi_2Se_3 surface with atomic resolution. (16×8 nm^2, V_{bias} = 1.0 V, $I_{setpoint}$ = 1.5 nA)

Our results indicate that in the presence of the PTCDA buffer layer, the Fe atoms hybridized with the PTCDA molecules instead of interacting with the Bi_2Se_3. Accordingly, the TSS is protected from the Fe deposition. Our findings provide a new approach for the construction of a buffer layer that exhibits a smooth interface and prevents interactions between dopants and TI surfaces.

Reference

Hung-Hsiang Yang, Yu-Hsun Chu, Chun-I Lu, Christopher John Butler, Raman Sankar, Fang-Cheng Chou and Minn-Tsong Lin. (2015). Organic Monolayer Protected Topological Surface State, *Nano Letters*, 15(10), 6896-6900. DOI: 10.1021/acs.nanolett.5b02811

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