A genuine approach permitting to control resistivity in topological matter

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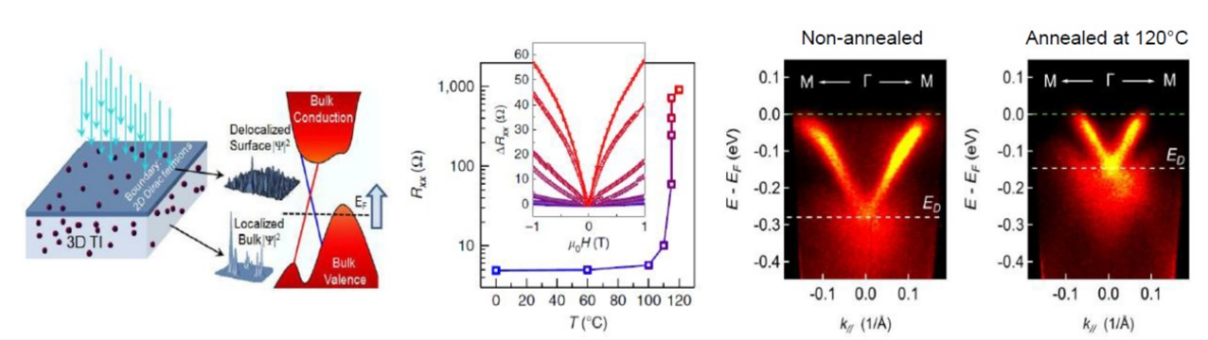
The last years, there has been a remarkable increase of interest on novel quantum states of matter based on strong spin-orbit coupling. It began with the theoretical prediction of the three-dimensional topological insulators (TIs) that is a new class of materials that are fully gapped in the bulk, but with unusual gapless "protected" surface states. The protection arises from the linear energy-momentum dispersion, with the surface states near the Fermi level residing on a single "massless" 2D Dirac cone. These systems have been thought being the Holy Grail in the fields of spintronics and fault-tolerant quantum computing. However, the access to these 2D quantum states is yet a challenge, due to the difficulty of separating surface contribution from the non-zero conductivity of the bulk. Approaches such as nanostructured synthesis/growth, doping, compositional tuning, or band-gap engineering via device gating were unable to sufficiently eliminate the bulk conduction of TIs.

Researchers from LPS, Ecole Polytechnique and City University of New York went recently through a novel approach based on inducing controlled disorder in prototype materials like Bi_2Se_3, Bi_2Te_3, and Bi_2Te_2Se by charged particle irradiation. Stable charged point defects in the bulk of layered TIs has proven handy as they permitted to compensate intrinsic charged defects, thus achieving topological compounds that they are really insulating in their bulk. In order to study the energy-momentum dispersion of Dirac electrons in an irradiation-induced doped topological insulator, researchers from LPS made use of an experimental approach based on angle-resolved photoemission spectroscopy. We have demonstrated that irradiation with electron beams up to 2.5 MeV allows to compensate these defects, thus bringing the Fermi level back into the bulk gap and reach the charge neutrality point. Controlling the beam fluence, we could tune bulk conductivity from p-(hole-like) to n-type (electron-like), crossing the Dirac point and back, while preserving the Dirac energy dispersion. Annealing at temperatures above 100 °C, we could shift the Fermi level back to charge neutrality point and, further, retrieve its initial p-type conductivity.



Left: Bi_2Te_3 samples irradiated with an electron dose of 1.7 C/cm^2 turn their conductivity from p-type to n-type. Middle: Annealing protocol with time steps of 30 min implemented to tune the crystal in the charge neutrality point. Right: ARPES images from sample before annealing and after annealing at 120 °C. Before annealing, the irradiated sample is n-type with Dirac point located at ED ~290(10) meV with respect to the Fermi level EF while annealing up to 120 °C it reaches the charge neutrality point with a Dirac point up-shifting to a binding energy of 160(10) meV.

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