



Topological Insulators: Chapter 7. Visualizing Topological Surface States and their Novel Properties using Scanning Tunneling Microscopy and Spectroscopy ... Concepts of Condensed Matter Science)

Haim Beidenkopf, Pedram Roushan, Ali Yazdani

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Topological insulators are materials in which spin-orbit coupling is strong enough as to invert the ordering of bulk bands about the insulating bulk gap. While the bulk properties of these materials are not much different than any other insulating material their topological classification ensures the existence of exotic states on their surfaces. These surface electrons behave as massless relativistic particles obeying Dirac dynamics which locks their spin degree of freedom to their momentum thus reducing by half their phase space relative to any other fermionic state. Furthermore, the helical spin-texture associated with their Dirac nature greatly restricts scattering of surface states as long as time-reversal symmetry is preserved. In particular it forbids backscattering and therefore immunizes the topological surface electrons from localizing. Scanning tunneling microscopy (STM) and spectroscopic mappings have played a key role in the characterization of these unique properties of the topological surface states. By visualizing electronic standing wave patterns next to impurities it was verified that the helical surface states do not backscatter. On the other hand, the Dirac electrons were found to be susceptible to the electrostatic charging of these scatterers, which induce spatial fluctuation of the Dirac energy and spectrum. Nevertheless, the unusual resilience of the helical surface states to disorder was strikingly demonstrated by measuring their high transmittance in an atomic-scale Fabry-Perot interferometry set up. The latter is a consequence of the existence of the topological surface states on all surface terminations which stems directly from the bulk topological classification. In the following chapter these insightful contributions of STM to the field of topological insulators will be discussed in detail alongside with future directions.

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