DIRAC FERMIONS IN GRAPHENE AND TOPOLOGICAL INSULATORS

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Graphene represents the first material system which has been extensively investigated experimentally, whose electronic properties can be described in terms of two-dimensional Dirac electrons. The theoretical investigation of graphene has also led to the discovery of a new class of materials, that are known as topological insulators. Specifically, starting from graphene, the existence of two-dimensional topological insulators was predicted first, and the concept was subsequently extended to the three-dimensional case. In these 2D and 3D topological insulators which originate from the effects of strong spin-orbit interaction- an energy gap between valence and conduction bands is present in the bulk, and coexist with robust gapless edge states. The nature of the edges states depends on the dimensionality. In 2D topological insulators, the edge states are 1D helical quantum modes which propagate ballistically (as long as time-reversal symmetry is present). In 3D topological insulators, the "edge" states are 2D Dirac fermions that "live" on all surfaces of the material. Owing to the presence of these Dirac surface fermions, it can be expected that the low-energy transport properties of 3D topological insulators should have a close resemblance to those of graphene. Unfortunately, transport experiments to probe and control surface transport in 3D topological insulators have proven to be difficult, due to non idealities present in the existing materials. Recently, we have succeeded in the realization and investigation of nano-devices based on Bi_2Se_3 currently the best candidate for the investigation of 3D topological insulators. In this talk we will discuss similarities and differences between Dirac electrons at the surface of 3D topological insulators and graphene, by comparing the results of experiments that we performed to probe the gate voltage dependent magneto transport and superconducting proximity effect in these Bi_2Se_3 devices.