Topological insulators and topological superconductors

Recently, a new class of topological states has been theoretically predicted and experimentally realized. The topological insulators have an insulating gap in the bulk, but have topologically protected edge or surface states due to the time reversal symmetry. In two dimensions the edge states give rise to the quantum spin Hall (QSH) effect, in the absence of any external magnetic field. I shall review the theoretical prediction[1] of the QSH state in HgTe/CdTe semiconductor quantum wells, and its recent experimental observation[2]. The edge states of the QSH state supports fractionally charged excitations[3]. The QSH effect can be generalized to three dimensions as the topological magneto-electric effect (TME) of the topological insulators[4]. Topological insulators Bi2Te3, Bi2Se3 have been discovered theoretically and experimentally to have surface states consisting of a single Dirac cone[5,6,7]. I shall present a realistic experimental proposals to observe the magnetic monopoles on the surface of topological insulators[8]. Topological superconductors and superfluid have been theoretically proposed recently [9], in both two and three dimensions. They have a full pairing gap in the bulk, and their mean field Hamiltonian look identical to that of the topological insulators. However, the gapless surface states consists of a single Majorana cone, containing only half the degree of freedom compared to the single Dirac cone on the surface of a topological insulators. I shall discuss their physics properties and the search for these novel states in real materials.

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