Topological Insulator Research Made Important Progress

According to different structure of electronic states, materials are divided traditionally into two types, namely, "metals" and "insulators". Topological insulators, however, are new states of quantum matter. It is very different from traditionally defined "metals" and "insulators". The electronic state of its body is an insulator with energy cap, and its surface is metal state without energy gap. This surface metal state without energy gap is also very different from the surface state in the general sense in that is it due to unsaturated bind on the surface or due to surface reconstruction. The surface state of topological insulator is completely determined by the topological structure of body electron state of the material. It is determined by symmetry, and independent from specific structure of the surface. Just because the surface metal state is determined by symmetry, it is very stable, almost not affected by impurity and disordering in the material. In addition, the basic property of topological insulator is the combined result of "quantum mechanics" and "the theory of relativity". Due to coupling effect of self-spinning orbit, there will form a surface electronic state of no energy gap, self-spin identified protected by temporal reverse symmetry on the surface. This surface state forms a kind of 2-D electronic gas without effective mass (which is different from 2-D electronic gas of approximate effective mass, such as the widely used 2-D electronic gas in field effect semiconductors), which needs to be described by Dirac equation, not Schrödinger equation. These charming and important properties provide topological insulator with great possibilities of important applications in electronic technology in the future. Searching for strong topological insulator materials with sufficiently large body energy gap and stable chemical properties thus become important focus and difficulties in current research.

Dr. Zhang Haijun. Research Professor Dai Xi and Research Professor Fang Zhong and their research group T03 at the State Lab of Condensed Matter Physics in the Institute of Physics of CAS made important progress recently in this research. In collaboration with Professor Zhang Shousheng of Stanford University in the US, they predicted a new type of strong topological insulator material system (Bi_2Se_3, Bi_2Te_3 and Sb_2Te_3). They made systematic studies by theoretical and computational methods on the physical mechanism of these materials becoming strong topological insulators, found the KP Hamilton value describing the Dirac point, and calculated quasi APRES electronic spectra. This type of topological insulator has special advantageous properties. First, the material has pure chemical phase. It is very stable and easy to synthesize. Second, there is only one Dirac point in the surface state. It is the simplest strong topological insulator. This simplicity is a good platform for studying the theoretical model. Third, and a very attractive point is that the body energy gap of the material is very large, especially Bi_2Se_3, which is about 0.3 eV (equivalent to 3600 K), much larger than room temperature energy scale. This also means that it is possible to make self-pinning electronic device at room temperature energy consumption. Their work has been published in *Nature Physics* 5, 438—442 (2009), and has been supported by the Chinese Academy of Sciences, NSFC, and national key programs of basic research development and international S&T programs.

While publishing theoretical work, relevant experimental studies have also made important progress, and verified theory. The first case is that Professors M. Z. Hasan and R. J. Cava of Princeton University of the US reported observation of Dirac point of surface state in Bi_2Se_3 (*Nature Physics*, 5398(2009)). The second case is that the research group of Fang Zhong and Dai Xi in collaboration with Z. X. Shen of Stanford University observed single Dirac point on the surface in Bi_2Te_3 material using ARPES (*Science* (2009), received).