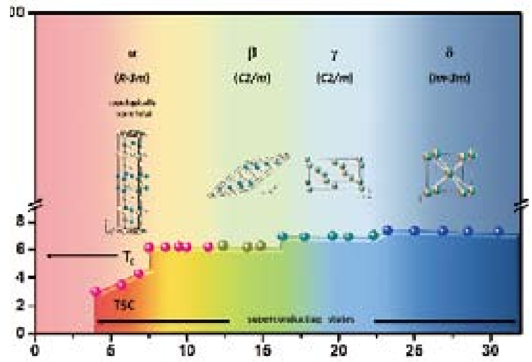
Superconductivity in Topological Insulator Sb_2Te_3 Induced by Pressure

Representing new states of quantum matter, topological insulators are characterized by an insulating gap in the bulk state and a robust metallic surface or edge state protected by time-reversal symmetry. Topological surface states have been theoretically predicted and experimentally observed in three-dimensional materials such as A_2B_3-type compounds of Bi_2Se_3, Bi_2Te_3, and Sb_2Te_3. Similar to topological insulators, topological superconductors are expected to have a full pairing gap in the bulk and gapless surface states that can support Majorana Fermions at the edge states. Electronic excitations related to topological states, particularly Majorana Fermions, are potentially useful in topological quantum computing and have thus attracted increasing attention.

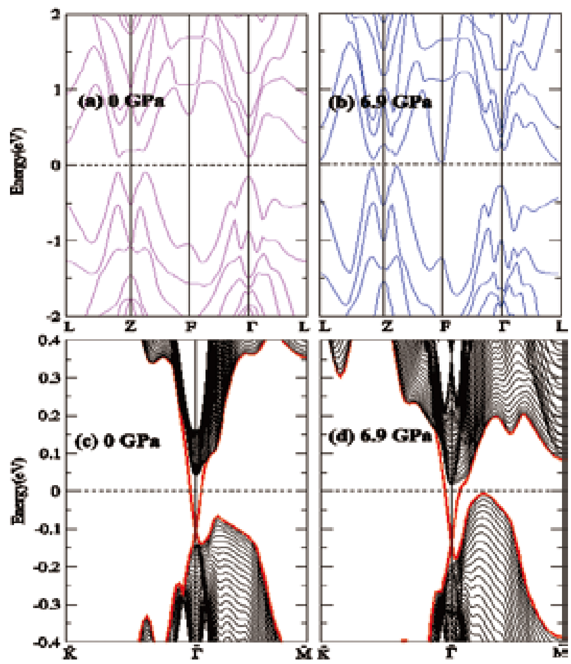
The research group led by Prof. JIN Changqing, from Beijing National Laboratory for Condensed Matter Physics at the Institute of Physics, Chinese Academy of Sciences (IOP), focuses on studies of topological insulators and topological superconductors, especially by using high pressure methods in the past several years. They have discovered superconductivity in the ambient structure of undoped topological compound Bi_2Te_3 via using integrated *in situ* high pressure measurements, which opened up a new research approach (Zhang *et al*., 2011) — using physical means to study topological superconductors.

Recently, Prof. JIN Changqing's group, systematically studied evolutions with pressure of the structure, electrical properties and topological properties of Sb_2Te_3 and found superconductivity in Sb_2Te_3 with pressure above 4GPa while the first phase-transition pressure was above 12.9 GPa, which indicated that the pressure-induced superconductivity observed at the pressure range of 4 GPa to 12.9 GPa indeed came from the ambient phase. Hall effects at different pressures show that there is an electronic phase transition around 7.5GPa where carriers change from the p-type at lower pressure to n-type at higher pressure.

The first principle calculations in collaboration with FANG Zong's group from the Condensed Matter Theory and Materials Computation Laboratory at IOP, based on experimental measurements of the crystal lattice show that Sb_2Te_3 retains its Dirac surface states within the low-pressure ambient phase where superconductivity was observed, indicating a strong relationship between superconductivity and topology nature. Assuming that the bulk phase becomes an S wave superconductor by applying



Superconducting phase diagram of Sb_2Te_3 single crystals as a function of pressure. (Image by Prof. JIN Changqing *et al*.)



Bulk (upper panels) and (111) surface states (lower panels) of Sb_2Te_3 under 0 GPa (left panels) and 6.9 GPa (right panels) (Image by Prof. JIN Changqing *et al*.)

pressure, a proximate effect changes the surface state into a superconducting one. The superconductivity at the surface state with a well-defined Dirac cone could be topological related with p+ip wave function symmetry.

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Reference

Zhang, J. L. *et al*., (2011), Pressure-induced superconductivity in topological parent compound Bi_2Te_3, *PNAS* 108, 24–28.