Topological Superconductivity Discovered on Surface of an Iron-based Superconductor

Topological superconductor is one of the most popular topics in condensed matter physics. Its exotic quasi-particle excitation, known as Majorana mode, can be used to build topological quantum computer. According to previous theoretical and experimental studies, topological superconductivity can only be found in either an intrinsic chiral p-wave superconductor or a heterostructure combining topological insulator and BCS superconductor structures. Of them, the p-wave case is very sensitive to disorder of the material.

The heterostructure case, however, is difficult to fabricate and has suffered interface problem. Generally, they all need ultra-low temperature (below 4.2 K, which is the evaporating temperature of He-4) to achieve topological superconducting states. That makes topological superconductivity a rare case in laboratory and not so robust under multiple manipulation.

Four years ago, ZHANG Peng and Prof. DING Hong from the Institute of Physics (IOP), CAS found some signatures that the upper p band in iron-based superconductor FeSe could fall down and invert its

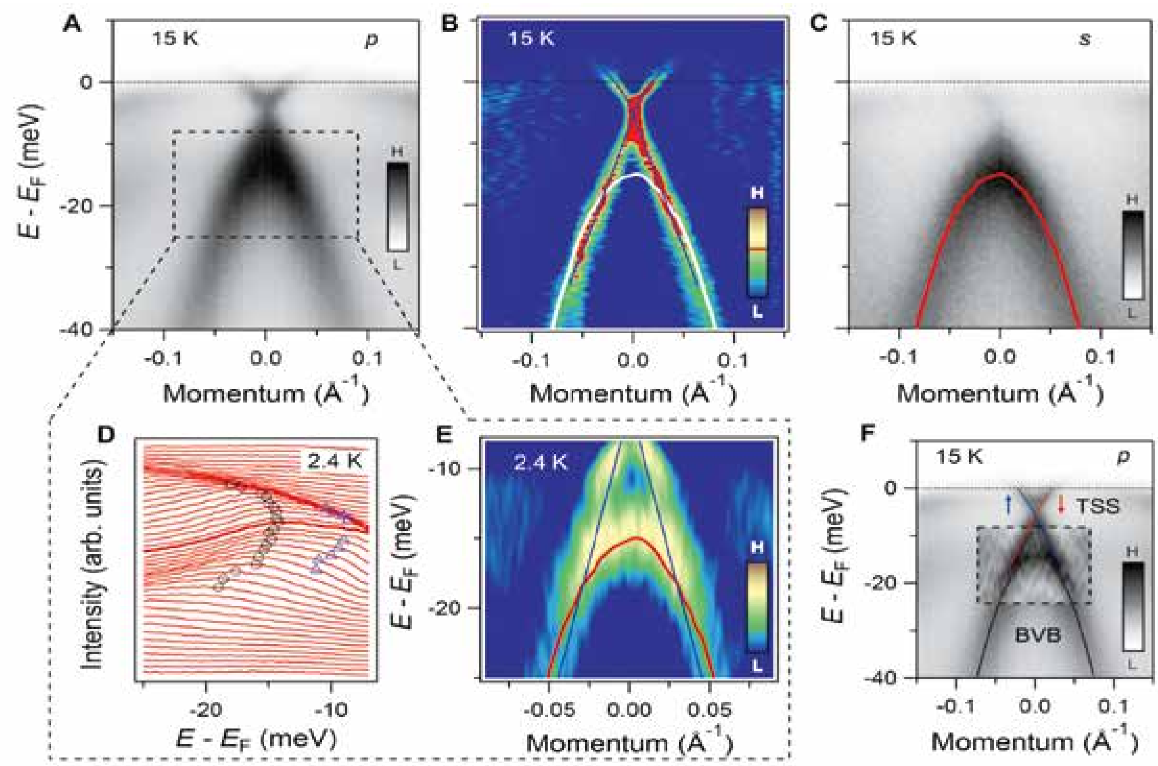

Fig. 1 Observation of Dirac-cone type topological surface bands (Image by Institute of Physics)

position with dxz band with Te substitution. With the collaboration with Prof. FANG Zhong and DAI Xi's group for theoretical research, they found this band inversion is topological nontrivial and topological surface state should exist in this high temperature superconductor. That creates an opportunity to combine these two ingredients in one single crystal and eliminate problems encountered in previous proposals. They show another road to realize higher temperature topological superconductor on the surface of Iron-based superconductor with topological non-trivial band structure.

Recently, by making use of laser-based high resolution angle resolved photoemission spectroscopy (HR-ARPES) and spin-resolved angle resolved

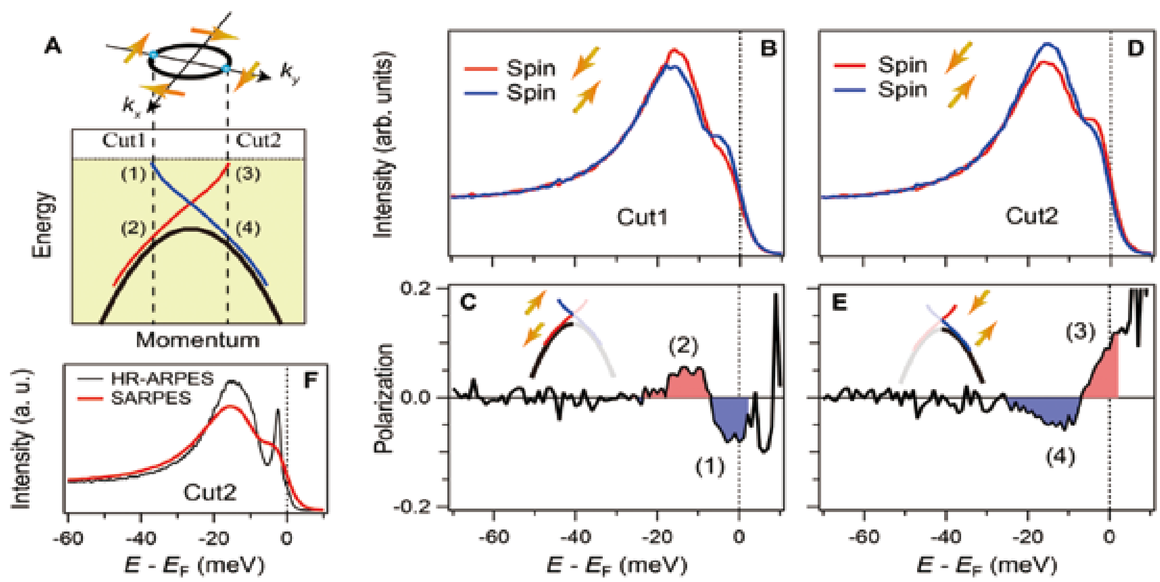

Fig. 2 The spin-momentum locking observed on topological surface states (Image by Institute of Physics)

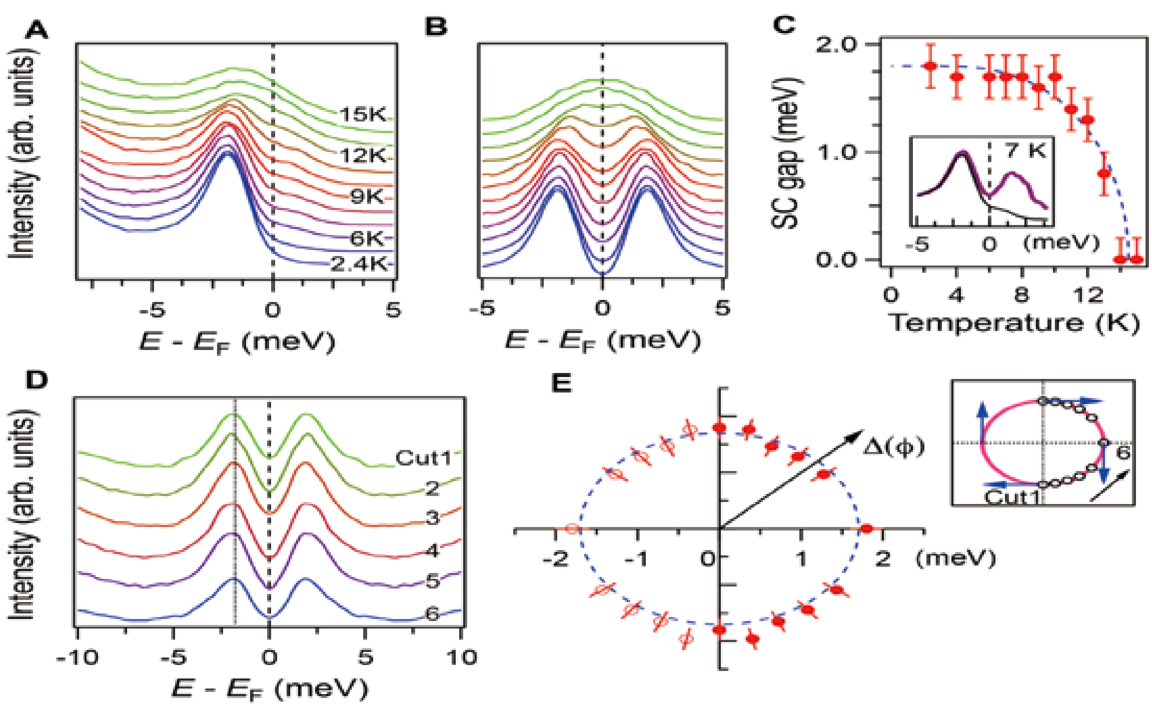

Fig. 3 The s-wave superconducting gap on the topological surface states (Image by Institute of Physics)

photoemission spectroscopy (SARPES), Dr. ZHANG, who is also a postdoc with Prof. SHIN Shik's group at Tokyo university, Prof. DING and collaborators measured the electronic states inside the spin-orbital coupling gap, which is less than 20 meV in iron-based superconductor Fe(Te,Se), and observed clear Dirac-cone type surface states. They found that these Dirac-cone type bands are spin-momentum locking, which is a main feature of topological surface state. The orbital character of each band was also verified by measuring band structure under different light polarization configurations.

Subsequently, they found that surface states open isotropic superconducting gap when cooling down below superconducting critical temperature. The evolution of gap size under different temperature is quite a mimic of BCS type behavior. That shows proximity induced s-wave superconducting gap opening on spin non-degenerated topological surface states in one single crystal. It fulfills a theoretical model proposed by Liang Fu and Charles Kane, indicating that this superconductivity is effective spinless p-wave and Majorana bound states exist on its vortex core.

The easy growth of high quality single crystal and relatively high superconducting critical temperature make Fe(Te,Se) a good platform to study the behavior of Majorana bound states and even, in the future, fabricate efficient devices for topological quantum computation.

This study entitled "Observation of topological superconductivity on the surface of an iron-based superconductor" was published in *Science*.

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