Application Note

Observation of topological superconductivity on the surface of an iron-based superconductor

Topological superconductors are predicted to host exotic Majorana states that obey non-Abelian statistics and can be used to implement a topological quantum computer. By using high-resolution spin-resolved and angle-resolved photoelectron spectroscopy, P. Zhang et al., Science 10.1126/science.aan4596 (2018), are likely the first to show that the surface states of $FeTe_{0.55}Se_{0.45}$ are 2D topologically superconducting. The result is illustrated in Figure 1.

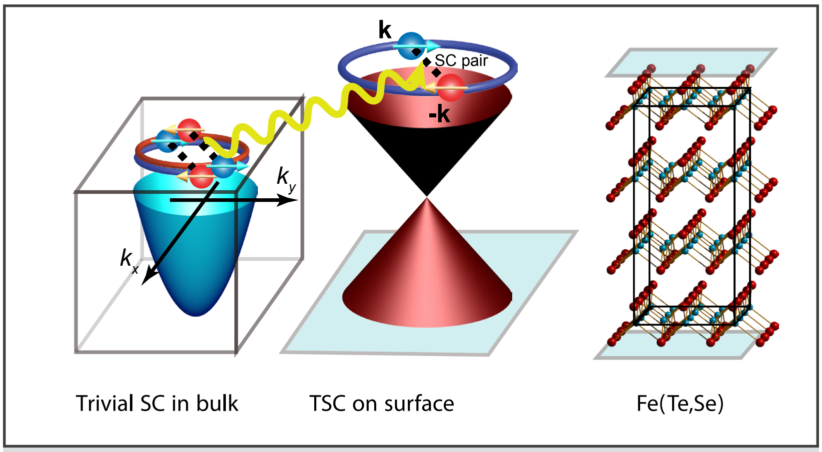


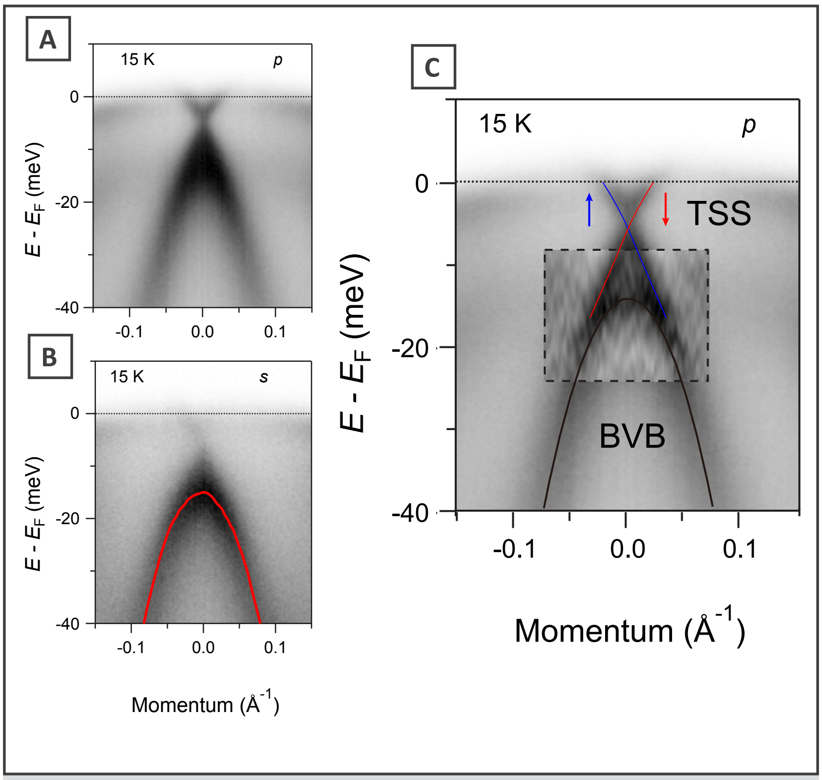
Figure 1: Illustration and summary of the results proving the topological Fe based superconductor.

To experimentally prove that $FeTe_xSe_{1-x}$ (x ~ 0.5) is a topological superconductor with intrinsic topological surface states and s-wave superconductivity on the surface, one needs to observe the following three phenomena in spectroscopic measurements:

1) Dirac-cone type surface states,
2) helical spin polarisation of the surface states which locks the spin direction perpendicular to the momentum direction,
3) s-wave SC gap of the surface states when T < TC.

Previously the topological surface band was never directly observed, owing to the small energy and momentum scales. The SOC gap is estimated to be about 10 meV in the calculations, which makes it extremely difficult to resolve the Dirac-cone type surface states in angle-resolved photoelectron spectroscopy (ARPES).

High resolution laser-ARPES measurements were performed on a system with our R8000 electron analyser and a 6.994 eV laser. The energy resolution was set to ~ 1.4 meV. Spin-resolved laser-ARPES measurements were carried out using a our DA30-L analyser with a 3D type VLEED detector and a VUV laser system delivering 6.994 eV photons. The energy resolution was set to ~ 5.5 meV.



Observation 1: Demonstration of the Dirac-cone type surface states. A and B, show high resolution cuts of the band structure around Γ with *p* and *s*-polarised photons, respectively. The overall band structure is summarised in C, clearly demonstrating a Dirac surface state very close to E_F.

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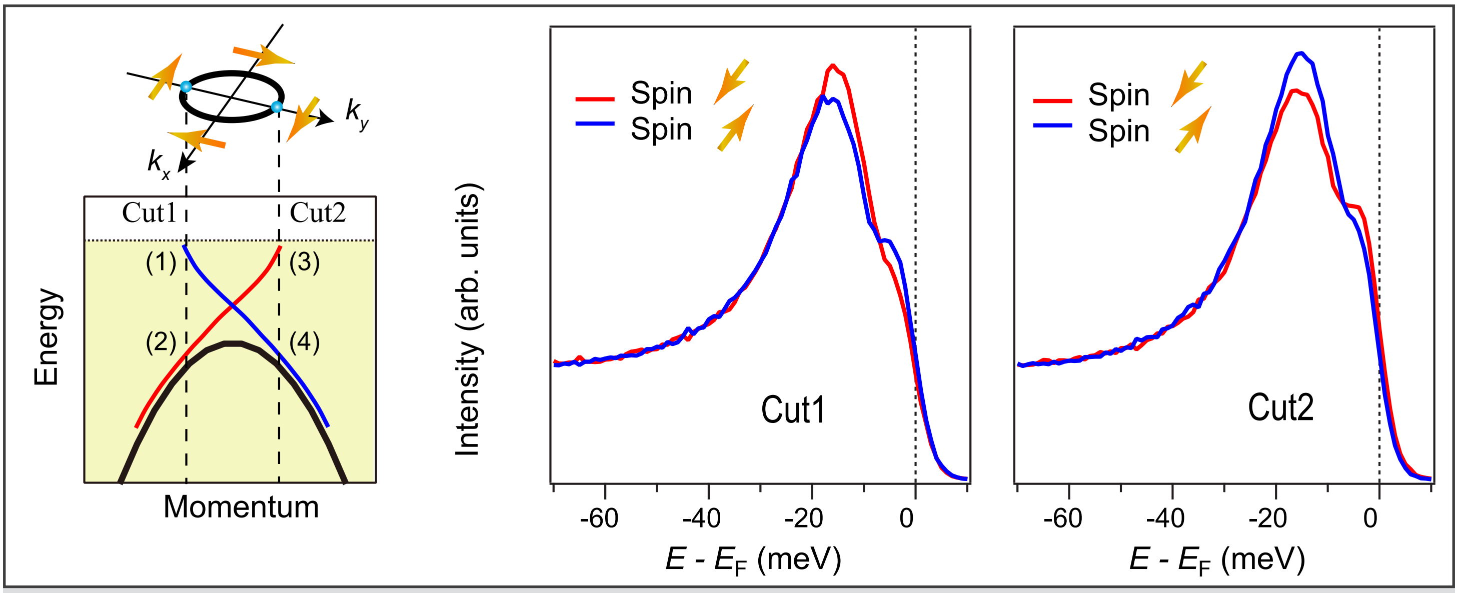
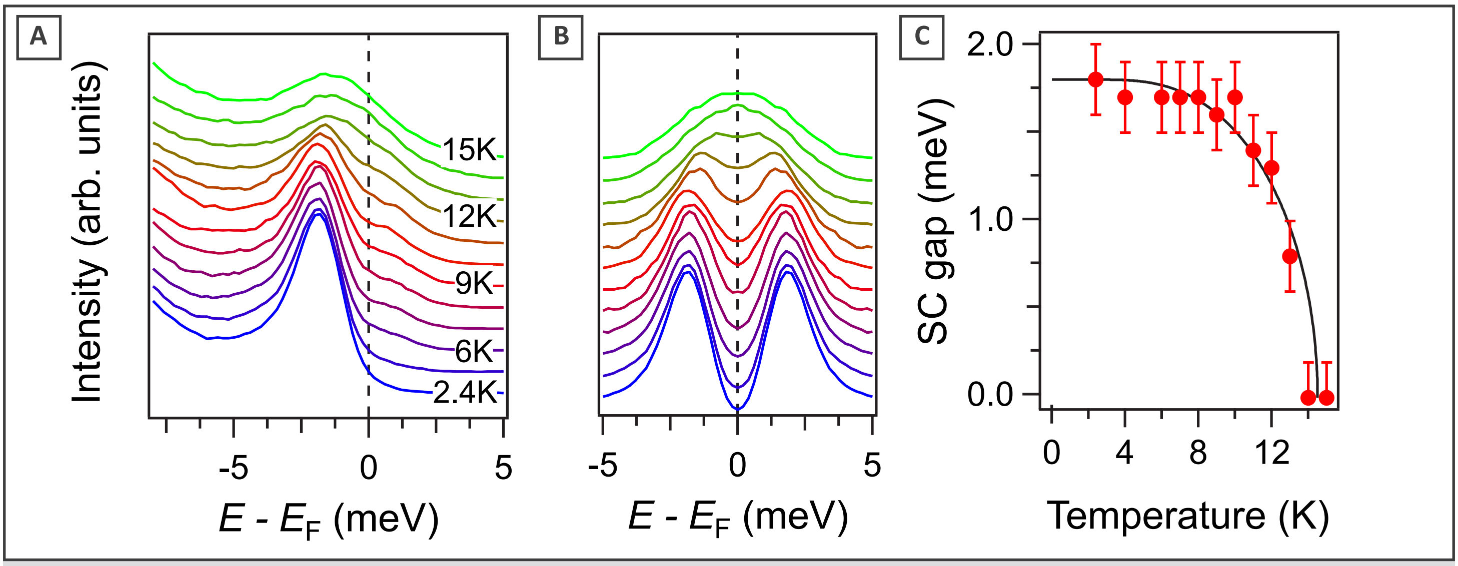


Observation 2: High resolution spin-resolved experiments to check the spin polarisation of the Dirac-cone type band. Two EDCs at the cuts indicated in A were measured. If the Dirac-cone type band indeed comes from the spin-polarised surface states, the EDCs at Cut1 and Cut2 should show reversed spin polarisations, which they are proven to be in B and D.



Observation 3: The final piece of evidence: the opening of an s-wave gap for the topological surface band.
Fig. A displays the evolution of one EDC from the surface band with temperature.
The symmetrized EDCs in Fig. B show the gap closing above TC.
Fig. C shows the SC gap size as a function of temperature.

Data courtesy:
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