

Vortex bound states and Majorana mode in $\text{FeTe}_{0.55}\text{Se}_{0.45}$ and $\text{Bi}_2\text{Te}_3/\text{FeTe}_{0.55}\text{Se}_{0.45}$ hetero-structures

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Topological superconductor is a timely and frontier topic in condensed matter physics. By measuring the spatial evolution of tunnelling spectra on the surface of $\text{FeTe}_{0.55}\text{Se}_{0.45}$, we observed the long sought discrete Caroli-de Gennes-Matricon bound states^[1] within some vortex cores. By analyzing the energies of the lowest level and the interval between the energy levels, we found that the iron based superconductor $\text{FeTe}_{0.55}\text{Se}_{0.45}$ has the shallow band with the Fermi energy of about 5-20 meV, indicating the possibility of a crossover from BEC-BCS. Furthermore we have measured the vortex core bound states on many other vortices in different areas and/or different samples, and found that, in some vortices there is a strong bound state peak locating at zero energy. With the rather symmetric shape at the gap edge, we would conclude that it may correspond to the Majorana mode^[2]. With increase the magnetic field, the zero energy mode of the vortices locating at the same position is systematically suppressed. Meanwhile, we also find that the probability of observing the zero energy mode decreases with increasing the magnetic field. We find no clear connection between the surface concentration of Te/Se ratio. By increasing temperature, the zero energy mode is suppressed quickly and merged into the side peak in the occupied state at about 4K.

We deposit Bi_2Te_3 thin film on the $\text{FeTe}_{0.55}\text{Se}_{0.45}$ substrate and get the proximity induced superconductivity. By using the quasiparticle interference technique, we demonstrate clear evidence of twofold symmetry of the superconducting gap. The gap minimum is along one of the main crystalline axis following the so-called Δ_{4y} notation. This is also accompanied by the elongated vortex shape. Within the vortex core, along the stretched direction, a zero energy peak appears and stays until going out of the vortex. Our results reveal the direct evidence of superconductivity with two-fold symmetry in Bi_2Te_3 thin film^[3].

References

- [1] Mingyang Chen, Xiaoyu Chen, Huan Yang, Hai-Hu Wen et al. Nat. Commun. 9, 970 (2018).
- [2] Xiaoyu Chen, Mingyang Chen, Huan Yang, Hai-Hu Wen et al. to be published.
- [3]Mingyang Chen, Xiaoyu Chen, Huan Yang, Zengyi Du, Hai-Hu Wen. Science Adv. 4, eaat1084 (2018)

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