Fermiology of iron-based superconductors via quantum-oscillation and magnetoresistance measurements

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Since the origin of superconductivity is the formation of Cooper pairs by electrons on the Fermi surface, knowing the Fermi surface of superconductors is essentially important in understanding their superconductivity. We have been working on the Fermiology of iron-based superconductors by measuring quantum oscillation (QO) and magnetotransport. In this talk, I will focus on two parent compounds, CaFeAsF and FeSe.

CaFeAsF is a variant of the 1111 compounds, in which LaO layers in LaFeAsO are replaced by CaF layers. It is a typical parent compound of iron-based superconductors, exhibiting a structural and an antiferromagnetic transition as cooled. At the latter transition, electronic bands are folded. Our QO measurements revealed that the resultant Fermi surface consisted of a hole cylinder at the center of the Brillouin zone and a pair of Dirac electron cylinders [1]. The carrier density was extremely low, 10^{-3} per Fe. These are consistent with a theoretically predicted nodal spin-density-wave state [2].

FeSe is a unique parent compound which does not order antiferromagnetically but becomes superconducting below ~9 K. Because of the absence of antiferromagnetism, band folding does not occur. Nevertheless, the Fermi surface in the low-temperature orthorhombic phase is very different from that in the room-temperature tetragonal phase. Our QO data showed that the low-temperature Fermi surface consisted of one hole cylinder at the zone center and one electron cylinder at a zone corner, which contrasted strikingly with band-structure calculations predicting three hole and two electron cylinders [3].

QO frequencies in two-dimensional metals vary as $1/\cos\theta$ as the magnetic field is tilted from the c axis irrespective of toward which in-plane direction the field is tilted, where θ is the tilting angle from the c axis. This means that we cannot obtain information about the in-plane anisotropy of the Fermi surface from QO measurements on two-dimensional metals. This motivated us to measure interlayer resistivity in magnetic field. We can determine the in-plane anisotropy by measuring the interlayer resistivity as a function of the in-plane field direction. I will present results obtained by applying this method to CaFeAsF [4] and FeSe.

Finally, if time allows, I will mention bulk transport evidence for twin-boundary pinning of vortices in FeSe [5].

The work presented in this talk is collaboration with the authors of refs. 1, 3, 4, and 5. Especially, high-quality single crystals of CaFeAsF and FeSe were prepared by Gang Mu (Shanghai Institute of Microsystem and Information Technology) and Shigeru Kasahara (Okayama University), respectively. MANA is supported by World Premier International Research Center Initiative (WPI), MEXT, Japan.

References (Times New Roman 10 pt)
[1] TT et al., PRX 8, 011014 (2018). [2] Y. Ran et al., PRB 79, 014505 (2009). [3] TT et al., PRB 90, 144517 (2014). [4] TT et al., PRB 106, 184503 (2022). [5] TT et al., PRB 109, 014518 (2024).