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Multiband superconductivity in $KCa_2Fe_4As_4F_2$

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Introduction. The physics of superconductivity has been experiencing a new youth over the past decade. This was largely facilitated by the discovery and intense research of iron-based superconductors (IBSC) and hydrides, but also by progress in fundamental and applied research on cuprates.

In this work we report on a combined study of the gap structure, order parameter symmetry and superfluid density behavior with a help of complimentary techniques – Andreev reflection spectroscopy on symmetrical superconductor-normal metal-superconductor (S-n-S) point contact and self-field critical current temperature behavior.

Experimental detalis.

Measurements details. Transport measurements were performed in a helium cryostat system with a temperature controller that stabilizes temperature within ±0.01 K. Current-Voltage Characteristics (IVCs) were measured using custom made low noise variable gain amplifier followed by a National Instruments acquisition system.

Magnetic ac-susceptibility measurements were performed with a Quantum Design MPMS XL-7 SQUID magnetometer.

Synthesis and characterization. In this work, the bulk $KCa_2Fe_4As_4F_2$ was synthesized from the metallic Ca, K, FeF_3 powder, As pieces, and pre-synthesized FeAs as starting materials in a stoichiometric ratio 6:3:2:2:10.

The cell parameters established by the XRD are $a = 3.8612(2)$, $c = 30.9367(13)$ ÅA with $R_p = 6.4\,\%$, that coincide with the data given in the literature [1]. The volume of 1111 and 122 impurity phases was estimated to be about 10 % by the RIR method.

Results and discussion. There are limited amount of techniques that investigate the superconducting energy gap in polycrystalline samples. One of such methods is the Intrinsic Multiple Andreev Reflections Spectroscopy (IMARE) of symmetric contacts, which has been widely used to study gaps in Iron- based systems [2, 3].

Discussion. Energy gap structure. The structure, symmetry type and angular behavior of the order parameter, is a key question in the physics of unconventional superconductivity. The conclusions based on indirect energy gap measurements, such as temperature dependence of the superfluid density [4] may suffer from mathematical shortcomings of model analytics. Such as, there are too many free fitting parameters as we usually see in case of multigap superconductors, especially if one or two gaps have angular dependence in momentum space.

In our Andreev reflections experiment, with 9 different bulk samples and over a hundred of spectra measurements we established that the shape of the reflection dip is symmetrical, showcasing an *s*-wave symmetry in each of the order parameters. The same conclusions were stated in ARPES investigations [5], where the data show that all the obtained energy gaps exhibit no signs of *d*-wave symmetry. However, we were able to distinguish only two energy gaps, which differs from the ARPES results. This can be explained by the fact that (i) in the ARPES data several gaps on different branches of the Fermi surface practically have almost equivalent values and (ii) we were probably unable to determine another gap because of the polycrystalline nature of our samples and some impurities in them.

Conclusion. We established a two-gap superconductivity in $KCa_2Fe_4As_4F_2$ ($T_c = 34\,\mathrm{K}$), with $\Delta_L = 6.8 \pm 0.5\,\mathrm{meV}$ and $\Delta_S = 3.2 \pm 0.3\,\mathrm{meV}$. Symmetrical shape of the Andreev reflection dips in the spectra, reveal that both order parameters have *s*-wave symmetry. It was confirmed by the fitting of superfluid density temperature dependence obtained by measurements of self-field critical current.

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Conflict of interest. The authors declare that they have no conflicts of interest.

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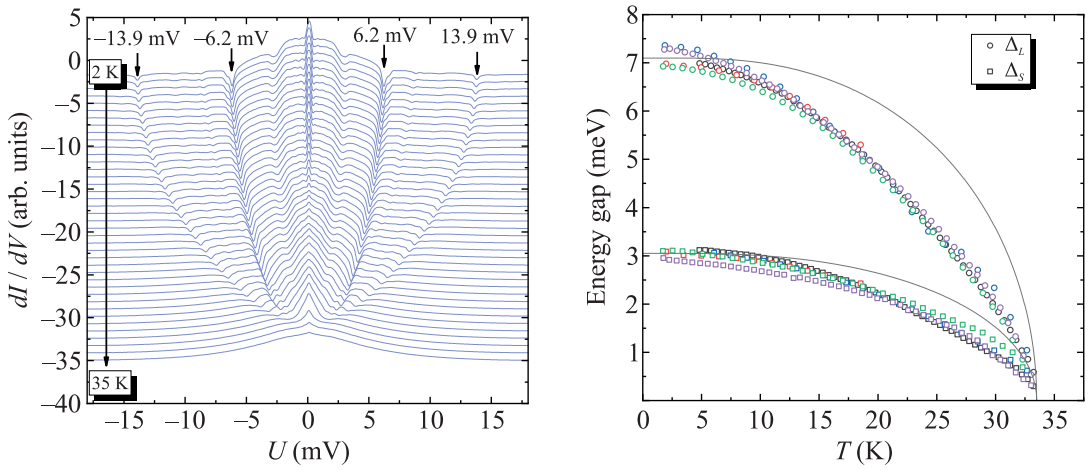

Fig. 1. (Color online) Left panel: temperature evolution of spectrum. Right panel: temperature dependence of large (circles) and small (squares) energy gaps derived directly from spectra from Fig. 2 (right panel). BCS-like curves presented by gray lines

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