Abstract

The in-plane thermal conductivity of overdoped iron-arsenide superconductor BaFe$_{1.73}$Co$_{0.27}$As$_2$ ($T_c = 8.1$ K) single crystal was measured down to 80 mK. In zero field, the residual linear term $\kappa/T$ is negligible, suggesting a nodeless superconducting gap in the $ab$-plane. In low magnetic field, $\kappa/T$ increases sharply, very different from conventional s-wave superconductors Ba$_{1-x}$K$_x$Fe$_2$As$_2$ and BaFe$_{1.9}$Ni$_{0.1}$As$_2$ near optimal doping. This anomalous $\kappa(H)/T$ may reveals an exotic superconducting gap structure in overdoped BaFe$_{1.73}$Co$_{0.27}$As$_2$: the vanishing hole ($\beta$) pocket has a much larger gap than the electron ($\gamma$ and $\delta$) pockets which contain most of the carriers. Such an exotic gap structure is an evidence for superconducting state induced by interband interactions, in which the band with the smaller density of states has a larger gap.

I. Introduction

- Near optimal doping samples show multiple isotropic nodeless gaps, studied by ARPES and heat transport. [2-4]
- In this work, we measured the overdoped BaFe$_{1.73}$Co$_{0.27}$As$_2$ sample to clarify doping evolution of the superconducting gap structure on the electron-doped side of the phase diagram.

II. Resistivity

FIG. 1: In-plane resistivity of BaFe$_{1.73}$Co$_{0.27}$As$_2$ in $H = 0$ and 14.5 T. The zero-resistance point of the resistive transition is at $T_c = 8.1$ K in zero field.

III. Thermal conductivity

FIG. 2: Low-temperature thermal conductivity of BaFe$_{1.73}$Co$_{0.27}$As$_2$ in magnetic fields applied along the $c$-axis ($H = 0, 1, 2, 4, 9, 14.5$ T). The solid lines are $\kappa/T = a + bT$ fits. The dashed line is the normal state Wiedemann-Franz law expectation $L_0/\rho_0$ with $L_0$ the Lorenz number $L_0 = 2.45 \times 10^8$ W Ω K$^{-2}$.

IV. Field dependence of thermal conductivity

FIG. 3 Normalized residual linear term $\kappa(H)/T$ of BaFe$_{1.73}$Co$_{0.27}$As$_2$ as a function of $HH_T$. For comparison we also plot Nb (s-wave), InBi (dirty s-wave), NbSe$_2$ (multi-band s-wave), Ti-2201 (d-wave) and BaFe$_{1.9}$Ni$_{0.1}$As$_2$.

FIG. 4 A calculation of normalized $\kappa(H)/T$ for different gap size ratios. [5]

- Multi-band s-wave NbSe$_2$: the gap on the $\Gamma$ band is $\sim 1/3$ of the gap on the other two band and $H$ first suppresses the superconductivity on the Fermi surface with smaller gap. The even sharper increase in $\kappa(H)/T$ in BaFe$_{1.73}$Co$_{0.27}$As$_2$ may result from an extreme case of multigap structure, in which the gap of one band is much smaller than others (e.g., 1/4 or 1/5).
- Based on this trend of band-structure evolution from ARPES, there should be a very small hole ($\beta$) pocket, together with two large electron ($\gamma$ and $\delta$) pockets which contain most of the carriers in BaFe$_{1.73}$Co$_{0.27}$As$_2$ Sample.
- We note a recent calculation of $\kappa(H)/T$ with unequal size of isotropic s-wave gaps has successfully fit the experimental data and supports our interpretation. [FIG 4]

IV. Summary

We have used low-temperature thermal conductivity to clearly demonstrate nodeless superconducting gap in overdoped iron-arsenide superconductor BaFe$_{1.73}$Co$_{0.27}$As$_2$.

The $\kappa(H)/T$ increases sharply at low field and may reveal an exotic superconducting gap structure: the vanishing hole ($\beta$) pocket has a much larger gap than the electron ($\gamma$ and $\delta$) pockets, although the electron pockets have much larger density of states. Such an exotic gap structure is an evidence for the theory of interband superconductivity, thus of great importance to understand the superconducting state in FeAs-based superconductors.

References: