Summary of thesis: Study of superconducting gap structure in prototypical heavy-fermion $CeCu_2Si_2$

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Strongly correlated electrons have been one of the most fascinating systems in modern physics. They exhibit a rich variety of exotic phenomena such as unconventional superconductivity, non-Fermi liquid, exotic orders and so on. The strongest electron correlation is realized in heavy-fermion (HF) compound, in which the quasiparticle effective mass is typically two or three orders of magnitude larger than the bare electron mass. In particular, such heavy quasiparticles often exhibit unconventional superconductivity in the vicinity of the magnetic instability, so-called quantum critical point (QCP).

$CeCu_2Si_2$ is a prototypical HF superconductor with T_c of 0.6 K discovered in 1979 [1]. The large specific heat jump at T_c indicates that the heavy electrons form Cooper pairs. The decrease of the Knight shift below T_c indicates the spin-singlet superconductivity [2]. Moreover, $T^{3/2}$ behavior in the resistivity and $T^{1/2}$ behavior in γ indicate that the superconductivity occurs in the vicinity of an antiferromagnetic (AF) QCP [3]. Unconventional nature of the superconductivity has been reported in some experiments, including the T-linear behavior of C/T [4], and no coherence peak just below T_c and the T^3 behavior in NMR relaxation rate $1/T_1$ [5]. Based on these results, the superconducting symmetry in $CeCu_2Si_2$ has been suggested to be d-wave with line nodes mediated by AF spin-fluctuations. On the other hand, recent specific heat measurements [6] suggested fully-gapped superconductivity. However, since the specific heat mainly detects the quasiparticle contribution in the heavy electron band, the possibilities of the existence of nodes in the light hole band cannot be excluded.

Here, to clarify the superconducting gap structure of $CeCu_2Si_2$, we performed the thermal conductivity (κ) measurements which sensitively probe the quasiparticle contribution in the light band. At the lowest temperatures in zero-field, κ/T extrapolated to $T = 0$ goes to zero within our experimental resolution or is at least an order of magnitude smaller than that expected for line nodes. Moreover, field dependence of κ/T shows that the magnetic field hardly affects the thermal conduction in the low field regime, which is in stark contrast to the nodal superconductor. Based on these results, we conclude the absence of gap nodes at any point on the Fermi surface. Furthermore, in order to clarify whether there is sign change in the superconducting gap, we performed the electron-irradiation experiments. We found a very small pair-breaking effect, which suggests there are no sign changes in the superconducting gap function.

These results imply that, contrary to long-standing belief, heavy electrons with extremely strong Coulomb repulsions can condense into a fully-gapped *s*-wave superconducting state, which has an on-site attractive pairing interaction [7].

References

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