Electrical resistivity of CeTIn$_5$ (T=Rh,Ir) under high pressure

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Abstract

We have researched the superconducting natures of CeTIn$_5$ (T=Rh,Ir) under high pressure in terms of electrical resistivity and superconducting phase in pressure-temperature phase diagram were determined for both samples and those exist in a wide pressure range (1.5 GPa $\leq P \leq$ 6.5 GPa : CeRhIn$_5$, 0 GPa $\leq P \leq$ 5.2 GPa : CeIrIn$_5$).

Key words: superconductivity; pressure; electrical; resistivity

Recently new heavy fermion superconductors, CeTIn$_5$ (T=Rh, Ir) were discovered [1,2]. The crystal structures for both samples are tetragonal HoCoGa$_5$-type structure. In CeRhIn$_5$ antiferro(AF)-magnetic order at ambient pressure is eliminated by the pressure at 1.4 GPa and induced the superconductivity at around 2 K above 1.6 GPa. CeIrIn$_5$ undergoes superconducting transition at two different temperatures in each measurement at ambient pressure. Electrical resistivity measurement indicates the zero-resistivity at 1.2 K, while it indicates the bulk superconducting transition at $T_c=0.4$ K by Meissner effect of the magnetic susceptibility or the jump in the heat capacity.

We have already investigated the $T_c$-$P$ phase diagram in CeRhIn$_5$ [3,4] and the natures in CeIrIn$_5$ under high pressure have been reported by magnetic susceptibility and specific heat [5], however, above 2 GPa no measurements have achieved yet. In this work, we perform the additional measurement of resistivities in CeRhIn$_5$ and CeIrIn$_5$ in order to verify the $T_c$-$P$ phase diagram.

Electrical resistivity measurements under high pressure over 3 GPa were accomplished by the diamond-anvil-cell (DAC) [6]. The commercial oil (Daphne oil 7373) [7] is used as the pressure medium. Single crystals of CeIrIn$_5$ and CeRhIn$_5$ were grown up by Indium-flux-method and high purity of samples with residual resistivity ratios of 106 for CeRhIn$_5$ and 72 for CeIrIn$_5$ were cut out and selected for the purpose of these measurements. The electrical currents run parallel to the c-planes for both samples.

The low temperature resistivities in CeTIn$_5$ (T=Rh, Ir) do not obey $T^2$ law of the Landau Fermi liquid behavior in our measurement pressure range. In CeRhIn$_5$ $T$-dependence of resistivity in low temperature show $T$-linear which means the 2D AF fluctuation by SCR theory [8]. Typically at 4.0 GPa in CeRhIn$_5$ $T$-linear behavior reveal in $T_C \leq T \leq 8$ K [Fig. 1]. In CeIrIn$_5$ $T$-dependences indicating $T^{1.5}$ at 2.2 GPa and 3.1 GPa reveal in $T_C \leq T \leq 4$ K and $T_C \leq T \leq 6$ K, respectively and especially at 3.1 GPa and the magnetic field of 3 T where the superconductivity completely disappears the power of resistivity is 1.5 at least over 0.3 K [Fig. 2]. In all pressure range resistivity exponents of CeIrIn$_5$ in low temperature region are within the bound of $1.2 \leq n \leq 1.7$ ($\rho=\rho_0+aT^n$) at low temperature limits. These behaviors are approximately compatible with 3-D AF fluctuation in SCR theory. The difference might originates from the variation of the ratio of crystal lat-
Fig. 1. (a) Resistivity at low temperature at 4.0 GPa in CeRhIn₅, which indicate T-linear variation. (b) Logarithmic plot of resistivity at 3.3 GPa and 3.0 T in CeIrIn₅, of which exponent is 1.5 at least over 0.3 K.

Fig. 2. Pressure-temperature phase diagram of superconductivity in (a) CeRhIn₅ and (b) CeIrIn₅. Tₐ was determined at zero resistivity temperature. Superconducting phase diagram in CeRhIn₅ is different from previous work. Superconductivity phase in CeIrIn₅ exists from 0 GPa to 5.8 GPa and has the maximum around 2.2 GPa ≤ P ≤ 3.1 GPa.

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References