# Anisotropic superconductive transition of $CeRu_3B_2$

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**Abstract**

The superconducting state ($T_c \sim 1$ K) of valence fluctuation compound $CeRu_3B_2$ (space group is P6/mmm) is meaningful, especially when it is compared with the superconducting state of $CeRu_2$ where an anomalous magnetization curve has been observed. However, all of the previous experiments for $CeRu_3B_2$ were done on the polycrystalline samples. We made the single crystal of $CeRu_3B_2$ and measured its resistivity and susceptibility along a- and c-axes. The present work shows anisotropic superconducting transitions at $\sim 1$ K.

*Key words:* superconductivity; valence fluctuation; anisotoropy

## 1. Introduction

Ternary compounds with the general chemical formula $RET_3B_2$ where RE = rare earth element and T = Ru, Rh, Os and Ir have been investigated due to their unusual magnetic and superconducting properties [1]. Especially, $CeRu_3B_2$ [2] and $CeOs_3B_2$ [2,3] are interesting because they are valence fluctuating compounds with superconductivity. The crystal structure of these compounds has been identified as the hexagonal $CeCo_3B_2$ structure with the space group P6/mmm. The unit cell volumes of the $CeT_3B_2$ compounds are reduced from the value expected for trivalent Ce, which can be estimated by interpolation between the unit cell volumes of the neighboring compounds formed with trivalent La and Pr.

The magnetic and superconductive properties of $CeRu_3B_2$ were investigated by several authors [2–4]. The magnetic susceptibility $\chi$ of $CeRu_3B_2$ shows nealy temperature-independent enhanced Pauli paramagnetic behavior. From specific heat measurements, the electronic $\gamma$ value was a modest 15.6 mJ/mol $K^2$, and $CeRu_3B_2$ appeared to be conventional bulk superconductors in which Ce was in a strongly mixed valent state [2]. These properties of $CeRu_3B_2$ are quite similar to those of a typical valence fluctuating superconductor $CeRu_2$. One intriguing feature common to a class of heavy fermion superconductors including valence fluctuation compounds $CeRu_2$ in mixed state is known as the "peak effect", where significant hysteresis and a peak structure are observed in the dc magnetization over a field range $H^* < H < H_{c2}$ (where $H_{c2}$ is the upper critical field) [5,6].

In this paper we present our result of resistivity and susceptibility measurements for the single crystal of $CeRu_3B_2$ which show that the superconducting transition seems to be anisotropic character.

## 2. Experimental

The polycrystalline sample was prepared by arc-melting appropriate amounts of the elements (99.99% pure Ce, and 99.9% pure Ru, and 99.9999% B) in an argon atmosphere. The single crystal was grown by the Czochralski method in a tri-arc furnace. Subsequently, the single crystal was wrapped in Ta foil

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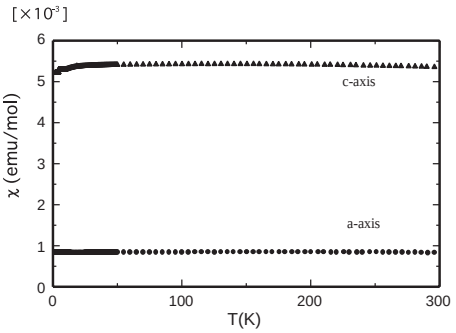


Fig. 1. Susceptibility $\chi$ ($= M/H$ at $H = 0.1$T) versus $T$ for a- and c-axis.

and annealed in an evacuated ($10^{-6}$ torr) quartz tube at 1000 C for a week. The sample was checked for impurity phases using electron-probe micro-analyzer (EPMA) and powder x-ray diffraction, and found to contain less than 1% impurity phases. Magnetization measurements were made with SQUID magnetometer (MPMS-7, Quantum Design) for temperature between 1.8 and 300 K in magnetic fields up to 7 T. Electrical resistivity measurements were performed between 0.3 and 300 K using a four-lead technique.

## 3. Result and discussion

Susceptibility $\chi$ ($= M/H$ at $H = 0.1$T) versus temperature $T$ data for a- and c-axes of the single crystal $CeRu_3B_2$ between 1.8 and 300 K are shown in Fig. 1. The susceptibilities of both a- and c-axes are almost constant in the temperature range and the large anisotropy, $\chi_c/\chi_a \sim 6$, is observed. The estimated susceptibility value of polycrystalline sample, $\chi_{poly} = 2/3\chi_a + 1/3\chi_c \sim 2.7 \times 10^{-3}$(emu/mol), is about 10 times larger than the previous data [4]. This is possibly due to the preferred orientation effect.

The anisotropic behavior is also observed in the resistivity $\rho(T)$. Fig. 2 shows $\rho(T)$ of a- and c-axes beween 0.3 and 300 K. The residual resistivity ratio (RRR) is similar to the previous data (RRR $\sim 3$), but the absolute value of the residual resistivity $\rho_0$ is smaller than a half of the previous data [3]. The low temperature $\rho(T)$ data for each axis were compared to the equation $\rho(T) = \rho_0 + AT^2$. We obtain $\rho_0 = 25.8(\mu\Omega\cdot$ cm), $A = 1.84 \times 10^{-3}(\mu\Omega\cdot$ cm/K$^2$), $A/\gamma^2 = 7.5 \times 10^{-6}$ for a-axis and $\rho_0 = 9.01(\mu\Omega\cdot$ cm), $A = 5.87 \times 10^{-4}(\mu\Omega\cdot$ cm/K$^2$) , $A/\gamma^2 = 2.4 \times 10^{-6}$ for c-axis, where we use the value $\gamma = 15.6$ (mJ/mol $\cdot$ K$^2$) [2].

Figure 3 shows the details of $\rho(T)$ around $T_c$. The resistivity measured along c-axis $\rho_c(T)$ sharply drop to zero at $T = 0.98$K. But $\rho_a(T)$ starts to decreases from 1.2 K and gradualy decrease to zero. We estimate the volume fraction of superconducting phase by ac susceptibility measurement and the value is 98 % at 0.95 K which suggests that $CeRu_3B_2$ is a bulk superconductor. From these data, it is evident that the onset of $T_c$ is different along the a- and c-axes. At present this is not understood. One needs heat capacity measurements to confirm this observation. Such measurements are in progress.

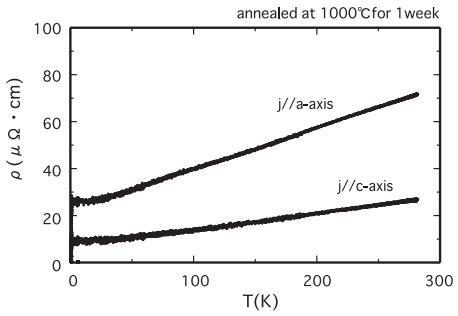


Fig. 2. Resistivity $\rho$ versus $T$ for a- and c-axis.

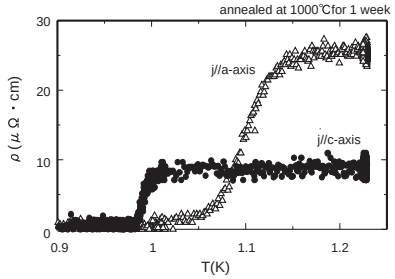


Fig. 3. Low temperature details of $\rho$.

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