Magnetic-Field Effects on the Pseudogap in CeRhAs

Shunsuke Yoshii [a,1], Koichi Kindo [a], Tetsuya Sasakawa [b], Toshiaki Suemitsu [b]
Toshiro Takabatake [b]

[a] *KYOKUGEN, Osaka University, Toyonaka, Osaka 560-8531, Japan*
[b] *Department of Quantum Matter, ADSM, Hiroshima University, Higashi-Hiroshima 739-8530, Japan*

Abstract

The electrical resistivity and magnetization $M(H)$ of single crystal CeRhAs, which is the so-called Kondo insulator, have been measured in magnetic field up to 55T. At 1.3K, the slopes of $M(H \parallel b)$ and $M(H \parallel c)$ decrease at around 16T and 13T respectively, while $M(H \parallel a)$ increases monotonously. The longitudinal magnetoresistances along the b and c axes show characteristic structures partly associated with the anomaly of $M(H)$, while it along the a axis shows only a broad maximum. The transverse magnetoresistances for $I \parallel b$ follow H^{γ} ($\gamma = 1.5 \sim 1.7$). These observations suggest the existence of a narrow and anisotropic structure within the wide pseudogap.

Key words: CeRhAs; Kondo insulator; transport and magnetic properties; high magnetic field

The ternary compound CeRhAs with the ϵ-TiNiSi-type orthorhombic structure is classified into the Kondo insulators. The gap formation of this class of materials is considered to originate from the strong hybridization between conduction electrons and localized 4f electrons. In CeRhAs, the intermediate-valence state of the Ce 4f state and the formation of the energy gap at low temperatures were indicated by the electrical and magnetic measurements on polycrystalline sample[1]. Furthermore, photoemission spectroscopy study clearly revealed the development of a pseudogap with decreasing temperature below 210K with the magnitude of 50-60meV[2,3].Comparing with the result of photoemission from the isostructural CeRhSb with a small pseudogap, it was pointed out that the size of the gap observed in CeRhX series is well scaled with the Kondo temperature $T_{\rm K}$. These results suggest that the local Kondo coupling is essential for the gap formation in CeRhAs.

Recent studies on the single crystal have revealed structural phase transitions and anisotoropic properties[4]. In the strucure, Ce atoms form a zig-zag chain along the a axis of the orthorhombic structure. In addition, the modulations of the crystal structure have been observed along with the three successive phase transitions. From these results, an intimate correlation between the lattice modulation and the formation of gap becomes clear, and an reconsideration seems to be necessary to understand the mechanism of the gap formation or the novel behaviors of CeRhAs. In order to have an insight into the electronic structure of CeRhAs, we have investigated a magnetic field effect on the pseudogap state. In this paper, we report the measurements of the magnetization and the magnetoresistance of single crystal CeRhAs in the pulsed magnetic field up to 55T.

Figure 1 shows the magnetization curves $M(H)$ at 1.3K for the field along the three axes. While M_a increases almost linearly with H up to 55T, M_b and M_c change the slope at around 16T(H_b) and 13T(H_c), respectively, as indicated by arrows. The magnitude of M_a is smaller than M_b and M_c. This may be attributed to the anisotropic nature of the pseudogap suggested by the results of the electrical resistivity. No sign of a metamagnetic transition or an upward deviation from a straight line, and the very small value of

[1] Corresponding author. E-mail: yoshii@mag.rcem.osaka-uj.ac.jp

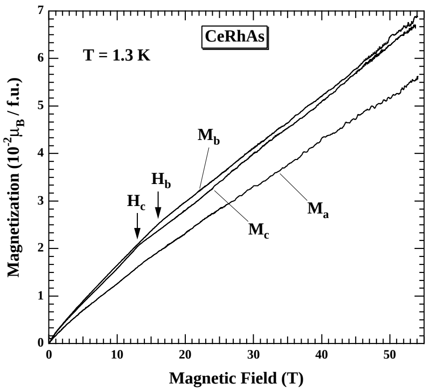

Fig. 1. Magnetization curves at 1.3K.

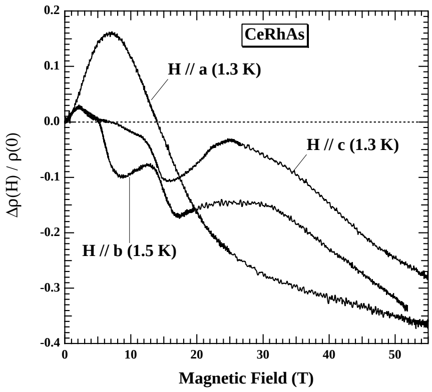

Fig. 2. Normalized longitudinal magnetoresistance.

M ($0.07\mu_{\rm B}$/f.u. for M_b at 55T) indicate that the non-magnetic state is still stable even at 55T.

The magnetoresistance(MR) exhibits anisotropic behaviors rather clearly. Figure 2 shows the results of the longitudinal MR measured at 1.3K-1.5K. Normalized results $\Delta\rho(H)/\rho(0)$ are plotted for comparison. Along the b and c axes, anomalous structures are observed in the field region of 12T-18T, which may be concerned with the changes of the slope of $M(H)$. In $\rho_b(H)$, another anomaly is observed at around 7T, although no corresponding anomaly was dected in $M(H)$. In contrast, $\rho_a(H)$ changes rather smoothly with a broad maximum at around 7T. In the high field region above 30T, the negative MR is enhanced with increasing field up to 55T for all the directions. This behavior may be interpreted as the result of an increase of carrier number, or closing of the pseudogap as was observed in CeNiSn[5]. However, non-saturating behavior and the fairly large value of $\rho(H)$ (40mΩcm for ρ_a and $\sim$10mΩcm for ρ_b,ρ_c at 55T) indicate that the magnetic field effect is not enough to destroy the gap. This may be due to the large Kondo temperature ($T_{\rm K}$=1200K) for CeRhAs compared to $T_{\rm K}$=50K for CeNiSn.

To study the origin of the characteristic structures observed in the longitudinal MR, we measured the transverse MR for $I \parallel b$. Irrespective of the field direction, it shows H^γ behavior in the low field region below 10T with γ value of 1.5$\sim$1.7. This result suggests the existence of a residual state at Fermi level. Then, the decrease of the transverse MR for $H >$30T can be explained by the increase of carrier density as mentioned above. Other possibility is a contamination of a small amount of impurities of CeAs. The observation of anisotropic behaviors in all the measurements may make this possibility to be small, because the cubic CeAs does not exhibit significant anisotropy in $\rho(H)$ and $M(H)$[6].

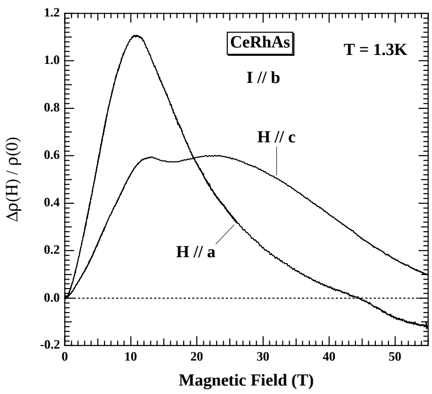

Fig. 3. Transverse magnetoresistance at 1.3K for $I \parallel b$ ($H \parallel a$ and $H \parallel c$).

Acknowledgements

This study was supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology.

References

[1] S.Yoshii, M.Kasaya, H.Takahashi, N.Mori, Physica B **223&224** (1996) 421.

[2] H.Kumigashira, T.Sato, T.Yokoya, T.Takahashi, S.Yoshii, M.Kasaya, Phys. Rev. Lett. **82** (1999) 1943.

[3] H.Kumigashira, T.Takahashi, S.Yoshii, M.Kasaya, Phys. Rev. Lett.**87** (2001) 67206.

[4] T.Sasakawa et al., Phys. Rev. B in press.

[5] K.Sugiyama, K.Kindo, G.Nakamoto, T.Takabatake, H.Fujii, J. Phys. Soc. Jpn. **67** (1997) 2455.

[6] K.Komorita et al., J. Magn. Magn. Mater. **104-107** (1992) 1241, S.Nimori et al. Physica B**186-188** (1993) 173, K.Sugiyama et al., J. Magn. Magn. Mater. **140-144** (1995) 1255.