MAGNETIC AND TRANSPORT PROPERTIES OF $(Y_xCe_{1-x})_7Rh_3$*

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Magnetic and transport properties of $(Y_xCe_{1-x})_7Rh_3$ have been studied by measuring magnetization, magnetic susceptibility and electrical resistivity. Ce_7Rh_3 is a metal ferromagnet and Y_7Rh_3 is a semimetallic Pauli paramagnet. In $(Y_xCe_{1-x})_7Rh_3$, ferromagnetic phase disappears at about $x = 0.4$. Intermediate valence state can exist in high Y concentration range above $x = 0.5$. In this range, electrical properties can be realized by the Kondo scattering in semimetallic band structure.

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1. Introduction

The rare earth intermetallic compounds R_7Rh_3 (R: rare earth metal) crystallize in the Th_7Fe_3 type hexagonal structure in which R occupies three non-equivalent sites [1, 2]. Among these compounds, Ce_7Rh_3 is a heavy fermion metal compound having $\gamma = 0.85$ J/mol K^2 and becomes ferromagnet below $T_C = 6.8$ K [3]. On the other hand, Y_7Rh_3 is a Pauli paramagnet with semimetallic band structure [4]. Considering the difference of the electrical property in these two compounds, the change of magnetic and transport properties in Ce compound, when conductive carrier changes, can be observed in pseudo-binary system between Ce_7Rh_3 and Y_7Rh_3. At this point of view, $(Y_xCe_{1-x})_7Rh_3$ has been studied. In this report, we present the experimental results of magnetic and transport properties in $(Y_xCe_{1-x})_7Rh_3$ system.

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2. Experimental

Polycrystalline ingots of $(Y_xCe_{1-x})_7Rh_3$ were prepared by arc-melting the constituent elements of 99.9 % Ce, Y and 99.96 % Rh under high purity argon atmosphere. Obtained samples were found to be single phase with the Th_7Fe_3 type hexagonal structure by X ray diffraction analysis. Magnetization and magnetic susceptibility were measured by a vibrating sample magnetometer and a SQUID magnetometer. AC magnetic susceptibility measurement was carried out using the Hartshorn bridge circuit. Electrical resistivity was measured by conventional dc four terminal method.

3. Results and discussion

Fig. 1 shows the magnetic susceptibility χ (a) and reciprocal susceptibility χ^{-1} (b) for several x in $(Y_xCe_{1-x})_7Rh_3$ as a function of temperature. From $x = 0$ to 0.90, Curie–Weiss like behavior was observed in high temper-

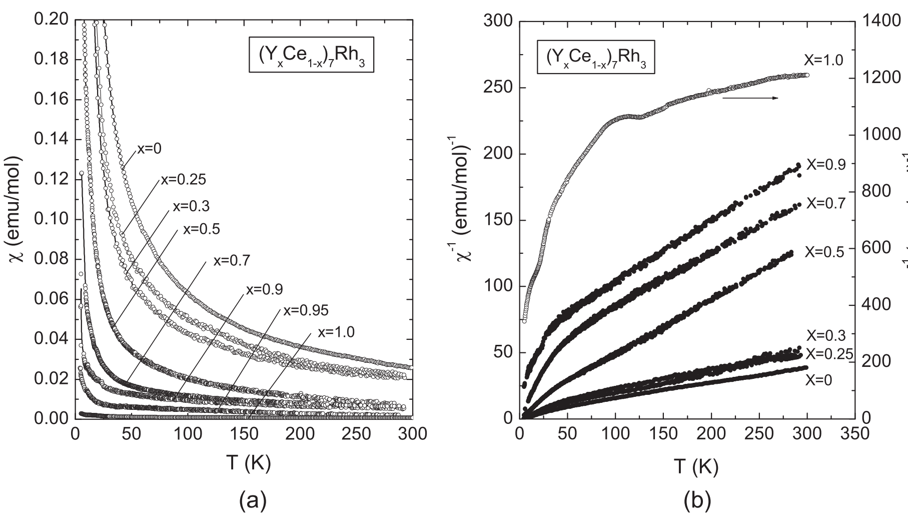

Fig. 1. Magnetic susceptibility (a) and reciprocal susceptibility (b) for several x in $(Y_xCe_{1-x})_7Rh_3$ as a function of temperature

ature; χ is almost temperature independent in Y_7Rh_3. Effective magnetic moment μ_{eff} obtained from χ^{-1}–T curves are $2.3\mu_B$/Ce for $x = 0$, 2.05 μ_B/Ce for $x = 0.25$ and 0.3. In this concentration range, magnetization curves at 4.2 K show ferromagnetic behavior. Thus magnetic moment of Ce is originated by Ce^{3+} ions with the effect of CEF. Ferromagnetic state disappears at about $x = 0.4$ from the result of ac magnetic susceptibility as shown in Fig. 2(b). The inset in Fig. 2(a) shows the x–T phase diagram. Above $x = 0.4$, effective magnetic moment decreases ($\mu_{\text{eff}} = 1.1\mu_B$/Ce for

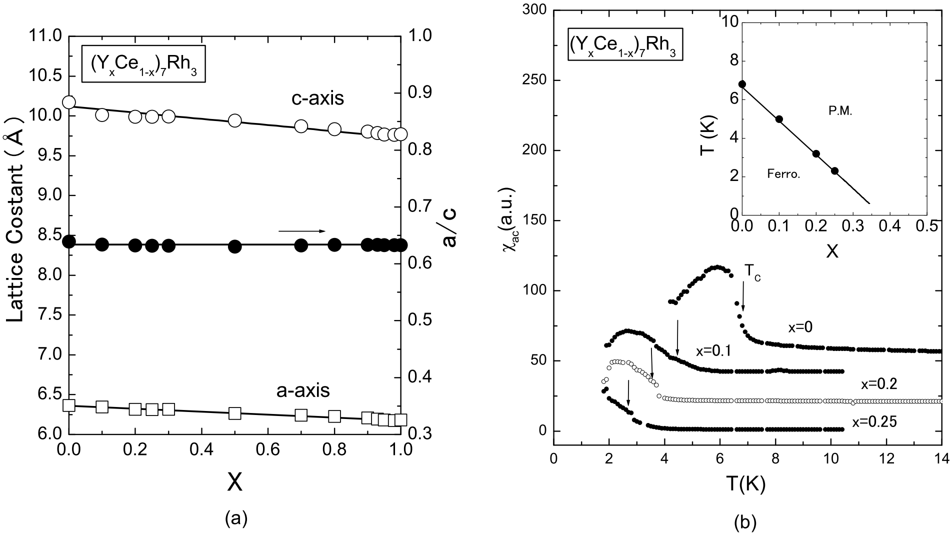

Fig. 2. Lattice constant (a) and temperature dependence of ac magnetic susceptibility (b) in $(Y_xCe_{1-x})_7Rh_3$. The inset (a) shows x–T phase diagram.

$x = 0.5$ and 0.99 μ_B/Ce for $x = 0.9$, respectively). These results indicate that the intermediate valence state may exist above $x = 0.5$. Trovarelli *et.al.*, suggested that in Ce_7Rh_3, each sublattce contributes to intermediate valence (Ce_{III}), Kondo effect (Ce_{II}) and magnetic ordering (Ce_I) due to the difference of Ce–Ce atomic distance [3]. In $(Y_xCe_{1-x})_7Rh_3$ system, there is no change in X ray diffraction pattern and lattice constant decreases continuously with increasing x as shown in Fig. 2(a). Lattice constant ratio is constant in entire concentration range. Thus, preferential substitution of Ce ions by Y does not appear. However, since interatomic distance between Ce ions decreases continuously with increasing x, RKKY interaction is suppressed and intermediate valence state between Ce^{3+} and Ce^{2+} can occur above $x = 0.5$.

Electrical resistivity ρ is shown in Fig. 3 as a function of temperature. At $x = 0$, resistivity decreases with decreasing temperature, exhibits minimum at about 23 K and an anomaly is observed at T_C. This indicates that the Kondo scattering is suppressed by RKKY interaction and ferromagnetic state is stabilized at low temperature. Resistivity increases with increasing x at room temperature and temperature coefficient of resistivity changes from positive to negative at about $x = 0.5$. Concerning the temperature variation of resistivity in Y_7Rh_3, negative temperature coefficient of resistivity at room temperature is attributed to the semimetallic band structure having narrow band gap and electron-hole pockets. Namely, thermal excitation of electrons due to narrow band gap brings about the semiconductive resistivity varia-

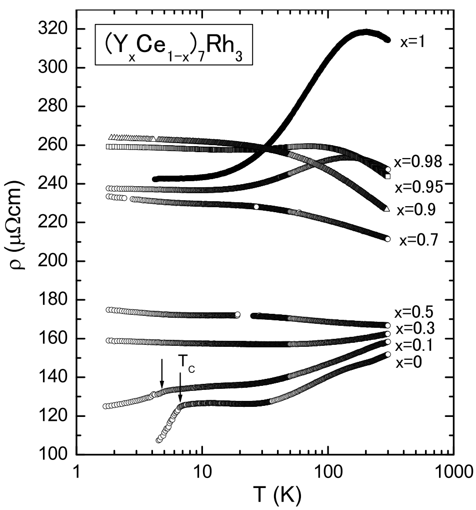

Fig. 3. Electrical resistivity for $(Y_xCe_{1-x})_7Rh_3$ as a function of temperature.

tion at high temperature. At low temperature, thermal excitation is reduced and metallic conduction is recovered by carriers in conduction band [4]. High resistivity value in Y_7Rh_3 indicates the low carrier semimetallic band structure. In $(Y_xCe_{1-x})_7Rh_3$, though the same temperature variation of ρ as Y_7Rh_3 is observed in $x = 0.98$, low temperature resistivity is pushed up with decreasing x and resistivity maximum disappears below $x = 0.9$. Considering the change of band structure in $(Y_xCe_{1-x})_7Rh_3$, low temperature resistivity increase may be attributed to the impurity Kondo effect. From these, in $(Y_xCe_{1-x})_7Rh_3$, electronic band structure changes from metallic to semimetallic at about $x = 0.5$ with increasing x, where ferromagnetic state vanishes. The change of magnetic properties can be originated by the decrease of minimum Ce–Ce interatomic distance and coexistence of intermediate valence and impurity Kondo state may exist in semimetallic band structure above $x = 0.5$. For further investigation, measurement of Hall effect is now in progress.

REFERENCES

[1] G.L .Olcese, *J. Less-Common Met.* **33**, 71 (1973).

[2] R.B. Roof Jr, A.C. Larson, D.T. Cromer, *Acta Crystallogr.* **14**, 1084 (1961).

[3] O. Trovarelli, J.G. Sereni, J.P. Kappler, *J. Low Temp. Phys.* **108**, 53 (1997).

[4] T. Tsutaoka, Y. Nakanori, T. Tokunaga, Y. Itoh, *J. Phys. Soc. Jpn.*, **70**, 199 (2001).