Contrastive transport properties in Y_7Rh_3 and La_7Rh_3

Y. Nakamori [a,1], H. Fujii [a], T. Tsutaoka [b], T. Tokunaga [b], M. Ito [c], T. Suzuki [c] T. Fujita [c]

[a] *Faculty of Integrated Arts and Science, Hiroshima University, Higashi-Hiroshima 739-8521, Japan*
[b] *Faculty of Education, Hiroshima University, Higashi-Hiroshima 739-8524, Japan*
[c] *Graduate School of advanced Sciences of matter, Higashi-Hiroshima 739-8526, Japan*

Abstract

Transport, thermodynamic and magnetic properties in La_7Rh_3 and Y_7Rh_3 were examined. The results indicated that La_7Rh_3 was metallic and becomes superconducting below 2.5 K, while Y_7Rh_3 shows metallic behavior at low temperature, but semiconducting one at high temperature. In addition, the number of carrier in Y_7Rh_3 is less than that in La_7Rh_3, while the electron correlation of Y_7Rh_3 is stronger than that of La_7Rh_3. Thus the contrastive physical properties in R_7Rh_3 might be originated in both the difference of the number of carrier and strength electron correlation owing to change in the lattice constants.

Key words: transport, semimetal, rare-earth compound, nearly localized electron system

1. Introduction

R_7Rh_3 crystallizes in the Th_7Fe_3-type hexagonal structure with a number of rare-earth elements (R = Y, La to Nd, Sm, Gd to Er, and Lu) [1]. It have been clarified that the light-rare-earth compounds (R = Ce, Pr, Nd) show a ferromagnteic behavior and metallic transport properties [2][3], while Sm_7Rh_3 and the heavy-rare-earth compounds (R = Gd, Tb, Dy, Ho and Er) show an antiferromagnetic behavior and semimetallic transport properties like metallic at low temperature but semiconducting at high temperature [4][5]. To clarify the origin of such contrastive properties in R_7Rh_3, we studied physical properties of non-magnetic compound Y_7Rh_3 and La_7Rh_3, in which the lattice constants are almost the same as in heavy- and light-rare-earth compounds, respectively. In this paper, we present the results on transport, thermodynamic and magnetic properties of Y_7Rh_3 and La_7Rh_3. Detail of the sample preparation and the other experimental procedures are given in Ref. [6].

[1] Faculty of Integrated Arts and Science, Hiroshima University, Higashi-Hiroshima 739-8521, Japan E-mail: ynakamo@hiroshima-u.ac.jp

2. Results and Discussion

Fig. 1 shows the electrical resistivity ρ as a function of temperature for R_7Rh_3 with R = La and Y. The ρ of La_7Rh_3 shows metallic behavior with negative curvature at high temperature and the superconducting transition at $T_c = 2.5$ K, which is consistent in the results of Ref. [7]. On the other hand, the ρ of Y_7Rh_3 shows anomalous transport properties with a negative temperature coefficient of the ρ at high temperature, a broad maximum around 200 K and metallic conductivity at low temperature. These semiconductive behaviors of ρ at high temperature have also observed in the heavy-rare-earth R_7Rh_3 compounds as well [5].

As is shown in Fig. 2(a), the Hall coefficients R_H of La_7Rh_3 and Y_7Rh_3 are positive at whole temperature, indicating that the dominant carrier is hole. Assuming single carrier model, we can deduce that both the compounds are in a low-carrier system and the number of carriers at 4.2 K in Y_7Rh_3 (0.04/atom) is less than that in La_7Rh_3 (0.29/atom). Therefore, the origin of contrastive transport properties in La_7Rh_3 and Y_7Rh_3 might be due to the difference of number of carrier. As shown in Fig. 2(b), the Hall mobility μ_H at low temper-

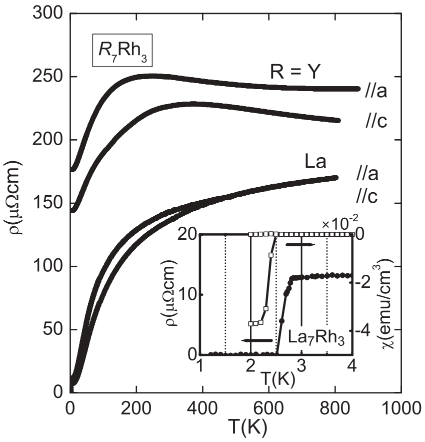

Fig. 1. Temperature dependence of the electrical resistivity ρ for La_7Rh_3 and Y_7Rh_3.

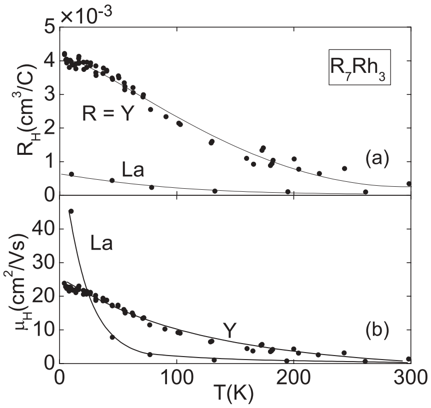

Fig. 2. (a)The Hall coefficient R_H and (b)The Hall mobitlity μ_H as a function of temperature.

ature of Y_7Rh_3 is suppressed more strongly than that of La_7Rh_3, suggesting that relatively strong electronic correlation exists in Y_7Rh_3.

A plot of specific heat divided by temperature C/T as a function of T^2 is shown in Fig. 3. By linear extrapolation of the C/T versus T^2 data to $T = 0$ K, we estimated the electronic specific heat coefficient $\gamma = 33.8$ mJ/molK^2 for La_7Rh_3 and 17.0 mJ/molK^2 for Y_7Rh_3, respectively. The large peak at 2.5 K for La_7Rh_3 owing to superconducting transition is observed. The derived $\Delta C/\gamma T_c$ value for La_7Rh_3 is 1.3, suggesting a conventional BCS superconductor. From the value of γ and number of carrier, we derived γ/γ_0, where γ_0 is specific heat coefficient for free electron, the values of which are 12.5 for La_7Rh_3 and 42.5 for Y_7Rh_3, suggesting that the electron correlation in Y_7Rh_3 is stronger than that in La_7Rh_3. Magnetic measurement indicated that the magnetic susceptibility χ of La_7Rh_3 shows Pauli paramagnetic behavior with broad maximum about 120 K, while the χ of Y_7Rh_3 shows a Curie paramagnetic-like behavior in addition to almost temperature independent χ_0, though the figure is not shown here. This also suggests that the electron correlation of Y_7Rh_3 is stronger than that of La_7Rh_3, and Y_7Rh_3 is nearly in a localized $4d$ electron system.

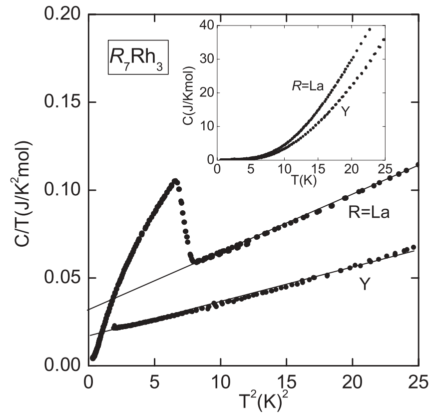

Fig. 3. Plot of the specific heat C/T as a function of T^2 for La_7Rh_3 and Y_7Rh_3. The inset shows the temperature dependence of C.

From the above results, it is concluded that the band structure in R_7Rh_3 changes metallic to semimetallic state with decreasing the lattice constants, although no band-structure calculations have been carried out on this system. Furthermore, it was clarified that the number of carriers decreases with decreasing the lattice constants and the strength of electron correlation show vice versa.

3. Summary

We have clarified that La_7Rh_3 with large lattice constant shows metallic transport properties, while Y_7Rh_3 with smaller lattice constant shows semimetallic transport properties, which are quite similar to other light- and heavy-rare-earth R_7Rh_3 compounds, respectively. The contrastive physical properties in R_7Rh_3 might be originated in both the difference of the number of carrier and strength of electron correlation owing to change of lattice constants.

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