EFFECT OF PRESSURE ON ELECTRICAL RESISTIVITY AND LATTICE PARAMETERS OF $CeRh_2Si_2$*

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We report the pressure dependence of lattice parameter at room temperature up to 13 GPa and the electrical resistivity of $CeRh_2Si_2$ in the temperature range from 2.5 K to 300 K up to 8 GPa. The compression curve of unit-cell volume is well fitted to Murnaghan equation of state. The resistivity below 10 K is described as $\rho(T) = \rho_0 + AT^2$, where ρ_0 is the residual resistivity and A the constant. $A(P)$ shows a peak around the critical pressure $P_C \sim 1.0$ GPa. The Grüneisen parameter of the Kondo temperature T_K is estimated above P_C and compared with those of the heavy fermion compounds.

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1. Introduction

$CeRh_2Si_2$, which crystallizes in the $ThCr_2Si_2$ type tetragonal structure, is an antiferromagnet with two transition temperatures at $T_{N1} = 36$ K and $T_{N2} = 24$ K [1,2]. The superconductivity appears at 400 mK above 0.9 GPa, near the critical pressure ($P_C \sim 1.0$ GPa) required to suppress antiferromagnetic ordering [3]. In the present work, we report the electrical resistivity of a single crystalline $CeRh_2Si_2$ under pressure in detail and discuss the electronic properties near the quantum critical point induced by pressure.

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2. Experimental

Sample preparation and characterization of the single crystal in the present experiment was described in Ref. [4]. The electrical resistance was measured for the current along a-axis by using a cubic anvil-type high-pressure cell up to 8 GPa. A mixture of Fluorinerts of FC70 and FC77 in ratio 1:1 was used as a pressure transmitting medium.

The pressure dependence of lattice parameters was determined by X ray (MoKα) powder diffraction with Guinier-type focusing camera and highly sensitive film. Hydrostatic pressure was generated by tungsten-carbide Bridgman anvils and Be sheet as a gasket. Details of the pressure apparatus have been reported previously [5,6].

3. Results

3.1. X ray diffraction

Fig. 1 shows the pressure dependences of the relative lattice parameters $a/a_0, c/c_0$ of the tetragonal cell and the relative volume V/V_0, respectively, where $a_0(= 4.070\,\text{Å})$, $c_0(= 10.156\,\text{Å})$ and $V_0(= c_0 a_0^2)$ are the values of a, c and V at ambient pressure. It is revealed that the tetragonal structure is stable at room temperature up to 13 GPa. Both a/a_0 and c/c_0 decrease smoothly with increasing pressure without any discontinuous change. Linear compressibilities of a- and c- axis are 2.2×10^{-3} GPa^{-1} and 3.0×10^{-3} GPa^{-1}.

We attempted a least-squares fit of the data V to the first-order Murnaghan's equation of state, $P = (B_0/B_0')[(V_0/V)^{B_0'} - 1]$, where B_0 denotes the bulk modulus at ambient pressure and B_0' is its pressure derivative. These are estimated to be 139 GPa and 2.2.

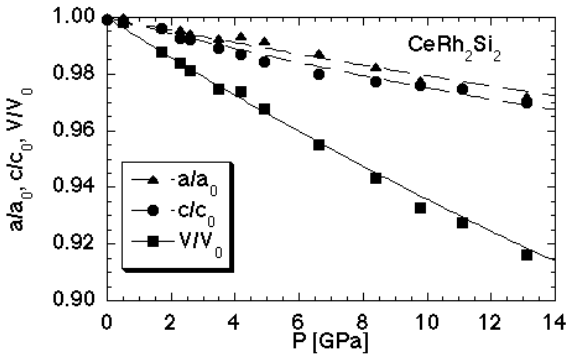

Fig. 1. Pressure dependence of a/a_0, c/c_0, and V/V_0 of $CeRh_2Si_2$. The solid line for the pressure dependence of V/V_0 shows the result of Murnaghan's fitting. The dashed lines for a/a_0 and c/c_0 are guides to eye.

3.2. Resistivity

Fig. 2 shows the T^2 dependence of the electrical resistivity. The resistivity is described as $\rho\ (T) = \rho_0 + AT^2$ at low temperature in a wide pressure range up to 8 GPa, where ρ_0 is the residual resistivity and A is the constant. $A(P)$ shows a peak around $P_C \sim 1.0$ GPa, which has been discussed previously [7,8], indicating that the large spin fluctuation gives rise to the pressure-induced quantum phase transition. The residual resistivity also shows anomalous pressure dependence.

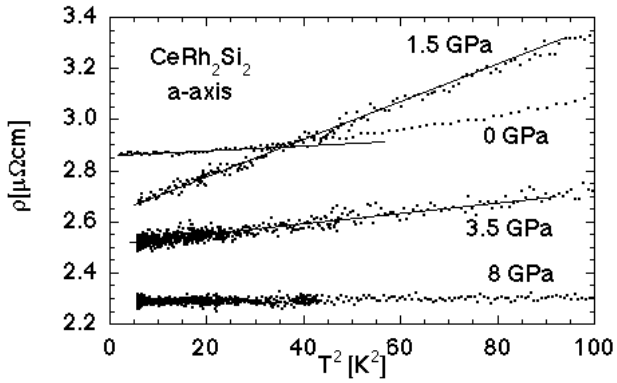

Fig. 2. T^2 dependence of the electrical resistivity along the a-axis of $CeRh_2Si_2$.

4. Discussion

According to the theory of Yoshimori [9], Kondo temperature T_K is proportional to $A^{-1/2}$. Then the Grüneisen parameter Γ of T_K is written,

$$\Gamma = -\left.\frac{\partial \ln T_K}{\partial \ln V}\right|_{V=V_0} = \frac{1}{2}\left.\frac{\partial \ln A}{\partial \ln V}\right|_{V=V_0} = \frac{1}{2}\frac{\Delta(\ln A)}{\frac{\Delta V}{V_0}}\,.$$

In Fig. 3, the values of A are plotted in logarithmic scale as a function of $\Delta V/V_0$. The linear relationship is found in the plot as is shown by solid lines above 1.5 GPa ($\Delta V/V_0 > 0.011$). From the result, the value of Γ is estimated to be 42 for $CeRh_2Si_2$, which is extremely large and comparable with those of heavy fermion compounds 59 and 65 for $CeInCu_2$ and $CeCu_6$, respectively [10]. Below 1.5 GPa, on the other hand, the observed values deviate significantly from the linear relation, suggesting that the electronic state is very unstable near the quantum critical point at P_C.

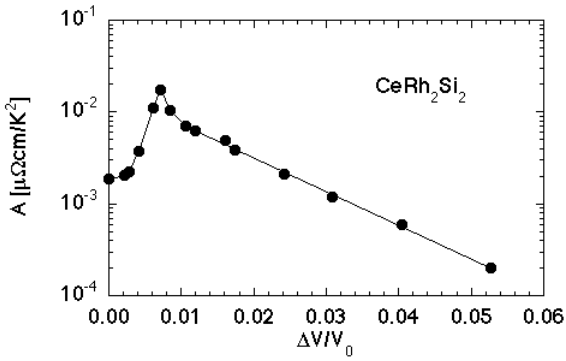

Fig. 3. The values of A as a function of volume change $\Delta V/V_0$ for $CeRh_2Si_2$, where A is the coefficient of T^2 of $\rho - T$ curve along a-axis.

5. Summary

From the measurements of the electrical resistivity and lattice parameters of $CeRh_2Si_2$ at high pressure, the volume dependence of Kondo temperature T_K was discussed, in which an anomaly is observed near the quantum critical point at $P_C \sim 1.0$ GPa. The Grüneisen parameter of T_K is estimated to be 42 above 1.5 GPa. The magnitude is comparable with that of heavy fermion compounds.

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REFERENCES

[1] S. Kawarazaki, M. Sato, Y. Miyako, N. Chigusa, K. Watanabe, N. Metoki, Y. Koike, M. Nishi, *Phys. Rev.* **B61**, 4167 (2000).

[2] F. Honda, N. Matsuda, T. Kagayama, G. Oomi, E.V. Sampathkumaran, *Magn. Soc. Jpn.* **23**, 474 (1999).

[3] R. Movshovich, T. Graf, D. Madrus, J.D. Tompson, J.L. Smith, Z. Fisk, *Phys. Rev.* **B53**, 8241 (1996).

[4] M. Ohashi, F. Honda, T. Eto, S. Kaji, I. Minamitake, G.Oomi, S. Koiwai, Y. Uwatoko, *Physica B* **312**, 443 (2002).

[5] F. Honda *et al.* , Proceedings of 18th AIRAPT (2001, Beijing), to be published.

[6] T. Kagayama, G. Oomi, *J. Magn. Magn. Mater.* **140**, 1227 (1995).

[7] M. Ohashi, G. Oomi, S. Koiwai, Y. Uwatoko, *Trans. Magn. Soc. Jpn.* **2**, 90 (2002).

[8] M. Ohashi, G. Oomi, S. Koiwai, Y. Uwatoko, *J. Phys. Soc. Jpn., Suppl.* **71**, 362 (2002).

[9] A. Yoshimori, H. Kasai, *J. Magn. Magn. Mater.* **475**, 31 (1983).

[10] T. Kagayama, G. Oomi, *J. Phys. Soc. Jpn., Suppl.* **B65**, 42 (1996).