Resistivity of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ under pressure

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Abstract

Resistivity measurement on single-crystalline $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ sample which shows a Spin density wave (SDW) transition at Néel temperature T_N=5.5K has been performed under hydrostatic pressure. A hump-type jump in resistivity due to the SDW transition shifts to lower temperature with increasing pressure, and finally disappears above P=0.5GPa. The ratio of gapped part of the Fermi-surface along the c-axis is estimated as ∼0.45 for P=0GPa and almost pressure independent.

Key words: Heavy fermion, pressure, $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$, Spin Desity Wave

The heavy-fermion system $Ce(Ru_{1-x}Rh_x)_2Si_2$ with the $ThCr_2Si_2$-type tetragonal structure shows an antiferromagnetic (AF) phase in the low Rh concentration range of 0.05≤x≤0.35 [1]. This AF phase has an incommensurable sinusoidal spin modulation along the tetragonal c-axis with wave vector $\boldsymbol{\tau}(0,0,k)$ with the maximum ordering temperature T_N=5.5K at x=0.15 [2]. For x=0.15, a hump-type jump in resistivity along the c-axis, a rapid decrease in susceptibility along the c-axis and a jump in specific heat were observed just below T_N [4]. These facts indicate the formation of a Spin-density-wave (SDW) with partial gapping of the Fermi-surface along the c-axis direction due to a uniaxial Fermi-surface nesting. The SDW depends sensitively on the band structure or electrical correlation, and thus observation of pressure effect for SDW phase is interesting. In order to clarify pressure effect for the SDW phase, we measured resistivity of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ under hydrostatic pressure.

Single-crystalline sample of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ were grown by Czochralski method in a tri-arc furnace and annealed at 800°C in vacuumed quartz tube for one week in argon atmosphere. The sample was cut by a spark cutter into a size of ∼1×0.5×4 mm^3. Resistivity was measured by using a standard DC four-probe technique in the temperature range of $0.5 \leq T \leq 50$K. The hydrostatic pressure was generated by using WC piston and CuBe cylinder pressure-cell, up to 0.5 GPa. A mixture of Fluorinert, FC70 and FC 77 was used as the pressure-transmitting medium.

Fig. 1 (a) shows the results of the resistivity measurements for $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ under hydrostatic pressure below T=10K with excitation current parallel to the c-axis. With decreasing temperature from 10K, resistivity decreases and shows a hump-type jump at around T_N=5.5K. This is consistent with previous results and has been associated with partial gapping of the Fermi-surface along the c-axis due to a uniaxial Fermi-surface nesting [4]. The hump-type anomaly shifts to lower temperature with increasing pressure and is no more observed for P=0.5GPa. This fact indicates that the gap opening is suppressed by hydrostatic pressure and finally disappeared at P∼0.5GPa. The temperature dependence of resistivity in the low temperature region for P=0.5GPa is proportional to T^2 and shows a Fermi liquid behavior. Fig. 2 displays the P-T phase diagram of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$, where

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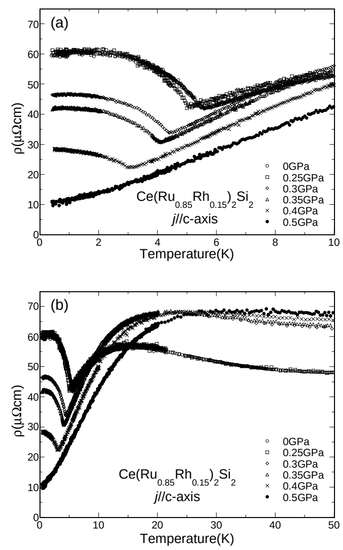

Fig. 1. Temperature dependence of the resistivity of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ under hydrostatic pressure with excitation current applied along the c-axis below 10K (a) or up to 50K (b).

the temperatures of the upturn in resistivity are estimated as T_N and plotted. T_N decreases gradually with increasing pressure for the low pressure region, then decreases rapidly around the $P_c \sim 0.5$GPa. This is consistent with the first result of resistivity under pressure by Sekine *et al.* as shown in Fig. 2 [5]. Pressure dependence of T_N has been reported also by Kawarazaki *et al.* from neutron diffraction measurement [3]. The present result shows stronger pressure dependence than their result, although the tendency is similar. Temperature dependence of resistivity in the range of $0 \leq T \leq 50$K is shown in Fig. 1 (b). For P=0GPa, with decreasing temperature from higher temperature, log T dependence of resistivity and a broad peak due to the Kondo effect are observed. Here, we estimated the temperature where the resistivity deviates from log T dependence as Kondo temperature $T_K \sim$20K. This is consistent with the value estimated form specific heat measurement. T_K increases with increasing pressure, and for P=0.5GPa, it is estimated as ∼35K. Following a former analysis for the conductivity in $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ in magnetic field, the total conductivity is written as $\sigma = \sigma_1 + \sigma_2$ if one assumes that the Fermi surface is divided independently into the magnetic region gapped by the nesting of the Fermi-surface and the ungapped region, where indices 1 and 2 refer to the ungapped and gapped regions, respectively. Then, the relative change in conductivity produced by the SDW gap opening is given by $(\sigma_p - \sigma_g)/\sigma_p = \sigma_{2p}/_p(1 - \sigma_{2g}/\sigma_{2p})$. Here, the subscripts g and p refer to the case when the magnetic region 2 is gaped or made paramagnetic by application of pressure P=0.5GPa. The contribution of the gapped magnetic part σ_{2g} is zero at T=0K. Thus, the relative change at T = 0K corresponds to the ratio of a gapped part of the Fermi-surface along the c-axis. Relative change of conductivity under pressure is estimated from the resistivity with the relation $(\sigma_p - \sigma_g)/\sigma_p = (\rho_g - \rho_p)/\rho_g$ as shown in Fig. 3. The ratio of the gapped part is estimated from the extrapolation of the relative resistivity change to 0K in Fig. 3 as ∼0.45 for P=0GPa and is consistent with the value estimated previously [4]. This ratio does not show variation under hydrostatic pressure over the experimental error. We already have reported that the SDW is also suppressed by magnetic field along the c-axis [4]. Here, T_N decreases with increasing field and no more observed above B_c = 3.5T. In that case, the ratio of the gapped part of the Fermi-surface along the c-axis decreases with increasing field in contrast with the result in magnetic field.

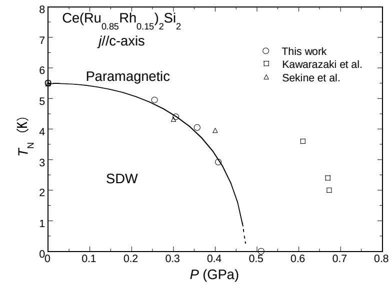

Fig. 2. P-T phase diagram of $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ under pressure. The open circle is the result of this work. The open square and open triangle are results obtained by Sekine *et al.*and Kawarazaki *et al.*, respectively. The solid line is a guide to eye.

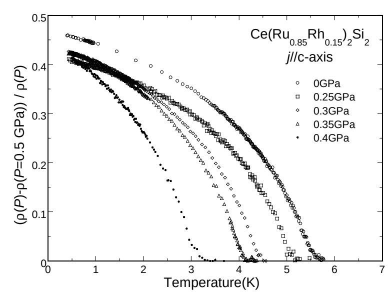

Fig. 3. The relative resistivity change parallel to the c-axis under various pressure.

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