SUPERCONDUCTIVITY IN $CeRh_2Si_2$ UNDER PRESSURE*

S. Araki†, M. Nakashima, R. Settai

Graduate School of Science, Osaka University, Toyonaka, Osaka, 560-0043 Japan

T.C. Kobayashi

Research Center for Materials Science at Extreme Conditions, Osaka University
Toyonaka, Osaka 560-8531, Japan

and Y. Ōnuki

Graduate School of Science, Osaka University, Toyonaka, Osaka, 560-0043 Japan
Advanced Science Research Center, JAERI, Tokai, Ibaraki 319-1195, Japan

(Received July 10, 2002)

We have studied the pressure-induced superconductivity in an antiferromagnet $CeRh_2Si_2$ by measuring the electrical resistivity for a high-quality single crystal. The superconducting resistivity drop was observed around $P_c \simeq 1.06$ GPa, at which the Néel temperature becomes zero, namely in a pressure region from 0.97 to 1.20 GPa. The zero resistivity appears below 0.4 K between 1.03 to 1.08 GPa. The resistivity at low temperatures follows the Fermi liquid AT^2 relation in the whole pressure region, even at P_c. The A value becomes a maximum around P_c.

PACS numbers: 71.27.+a, 74.62.Fj, 74.70.Tx

In some antiferromagnetic cerium compounds, the Néel temperature T_N decreases with increasing pressure and vanishes at P_c. The superconductivity around P_c has been reported in a few compounds such as $CePd_2Si_2$ and $CeIn_3$ [1].

$CeRh_2Si_2$ is one of the pressure-induced superconductor [2], which crystallizes in the tetragonal $ThCr_2Si_2$-type structure. $CeRh_2Si_2$ is an antiferromagnet with $T_N = 36$ K at ambient pressure. T_N decreases monotonously

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

† Present address: Advanced Science Research Center, Japan Atomic Energy Research Institute, Tokai, Ibaraki 319-1195, Japan.

with increasing pressure and vanishes at $P_c \simeq 1.06\,$GPa. Superconductivity with $T_{sc} = 0.35\,$K was found by Movshovich *et al.* [2] for a polycrystalline sample, in which superconductivity appears in a relatively wide pressure range from 0.6 to 1.6 GPa around P_c.

We searched for superconductivity in a single crystal with the residual resistivity ratio RRR $\simeq$ 30, but no evidence of superconductivity was observed. On the other hand, the superconducting resistivity drop was observed below T_{sc} for a polycrystalline sample with RRR = 62 in the pressure range from 0.7 to 2.9 GPa [3]. The T_{sc} value was unchanged in this pressure range, but the degree of the resistivity drop had a maximum around P_C. Recently, we have succeeded in growing a high-quality single crystal with RRR = 100. The superconducting resistivity drop in the sample was observed at 1.1 GPa, where $T_{sc} = 0.38\,$K but the resistivity remains a finite value even at 35 mK [4]. We continued the investigation of superconductivity for the high-quality single crystalline sample.

Single crystals of $CeRh_2Si_2$ were grown by the Czochralski pulling method in a tetra-arc furnace. Starting materials were 4N (99.99% pure)-Ce, 4N-Rh and 5N-Si. The electrical resistivity was measured by a four-probe ac resistance bridge (Linear Research, LR-700) at low temperatures down to about 100 mK with a dilution refrigerator. The current was directed along the [001] direction. Pressures were applied by utilizing a BeCu piston-cylinder cell with a 1:1 mixture of commercial Daphne oil (7373) and kerosene as a pressure-transmitting medium.

The low-temperature electrical resistivity under pressures follows the Fermi liquid relation $\rho = \rho_0 + AT^2$. Fig. 1 shows the pressure dependence of the A and ρ_0 values. With applying pressures, A value increases and shows a maximum around 1.0 GPa. $\sqrt{A}$ (1 GPa)/$\sqrt{A}$ (0 GPa) = 3.8 is consistent with the ratio of the electronic specific heat coefficient γ (1 GPa)/γ (0 GPa) $\simeq$ 3.5 [5]. The residual resistivity ρ_0 has an anomaly around 1.0 GPa.

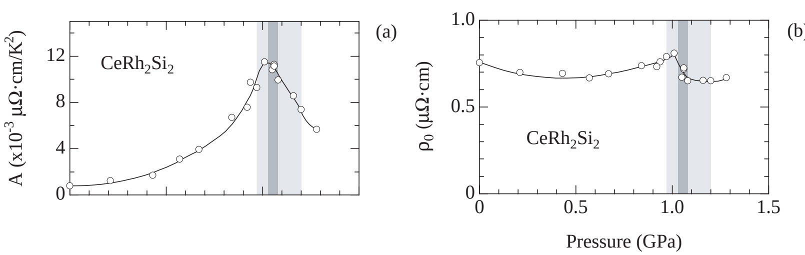

Fig. 1. Pressure dependence of A and ρ_0 values in $CeRh_2Si_2$.

Superconductivity appears around P_c, as shown in Fig. 2. An indication of superconductivity appears in the pressure region from 0.97 to 1.20 GPa, which is shown in Fig. 1 as a gray region. As shown in Fig. 2, the resistivity

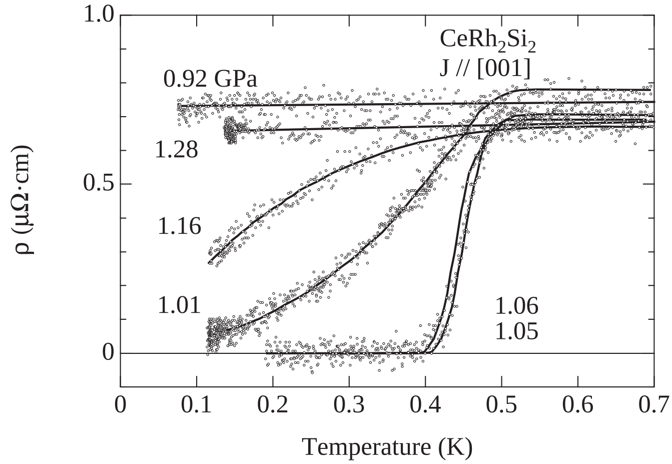

Fig. 2. Superconducting transition in the resistivity measurements in $CeRh_2Si_2$.

at $P = 1.01$ and 1.16 GPa decreases gradually with decreasing temperature below 0.5 K, but the zero resistivity is not attained. The zero resistivity is observed in an extremely narrow pressure region around P_c from 1.05 to 1.08 GPa, which is shown in Fig. 1 as a dense-gray region.

We also determined the upper critical field H_{c2} in superconductivity. Fig. 3(a) shows the temperature dependence of the electrical resistivity under magnetic fields along the [001] direction. The superconducting temperature T_{sc} for each field is defined as the temperature obtained from the extrapolation of the resistivity drop, as shown at $0\,T$ in Fig. 3(a). Fig. 3(b) shows the temperature dependence of H_{c2}. A solid line in Fig. 3(b) is a guide to eyes. The coherence length ξ is estimated as 340Å from $H_{c2}(0)$ $(= \Phi_0/2\pi\xi^2)$,

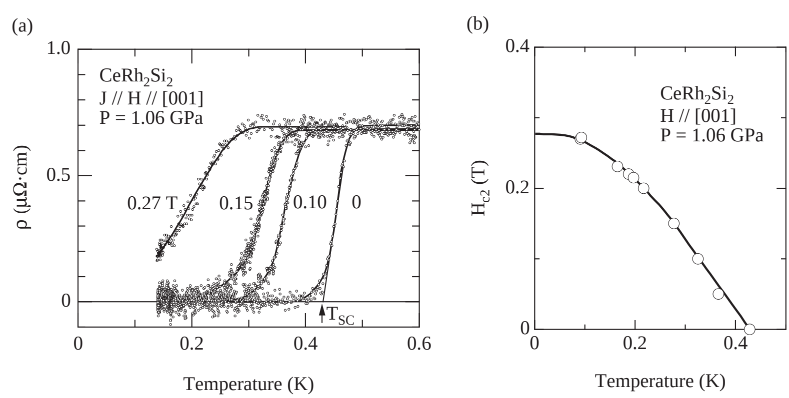

Fig. 3. (a) Low-temperature resistivity under magnetic fields and (b) temperature dependence of H_{c2} at 1.06 GPa in $CeRh_2Si_2$.

where Φ_0 is the quantum flux. We note that the mean free path for the present sample around 1.06 GPa is estimated from the de Haas–van Alphen experiment, being about 1000Å. This indicates that the present sample is close to a clean limit.

This work was financially supported by the Grant-in-Aid for COE Research (10CE2004) from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

REFERENCES

[1] N.D. Mathur, F.M. Grosche, S.R. Julian, I.R. Walker, D.M. Freye, R.K.W. Haselwimmer, G.G. Lonzarich, *Nature*, **394**, 39 (1998).

[2] R. Movshovich, T. Graf, D. Mandrus, J.D. Thompson, J.L. Smith, Z. Fisk, *Phys. Rev.* **B53**, 8241 (1996).

[3] T.C. Kobayashi, T. Muramatsu, M. Takimoto, K. Hanazono, K. Shimizu, K. Amaya, S. Araki, R. Settai, Y. Onuki, *Physica B* **281-282**, 7 (2000).

[4] S. Araki, R. Settai, T.C. Kobayashi, Y. Ōnuki, *J. Magn. Magn. Mater.* **226-230**, 81 (2001).

[5] T. Graf, J.D. Thompson, M.F. Hundley, R. Movshovich, Z. Fisk, D. Mandrus, R.A. Fisher, N.E. Phillips, *Phys. Rev. Lett.* **78**, 3769 (1997).