Transport properties of the heavy-fermion superconductor Ce_2CoIn_8

2003 J. Phys.: Condens. Matter 15 S2175

(http://iopscience.iop.org/0953-8984/15/28/346)

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **15** (2003) S2175–S2178 PII: S0953-8984(03)62919-X

Transport properties of the heavy-fermion superconductor Ce_2CoIn_8

Genfu Chen[1], **Shigeo Ohara**[1], **Masato Hedo**[2], **Yoshiya Uwatoko**[2] **and Isao Sakamoto**[1]

[1] Department of Electrical and Computer Engineering, Nagoya Institute of Technology, Nagoya 466-8555, Japan
[2] The Institute for Solid State Physics, The University of Tokyo, Kashiwa 277-8581, Japan

E-mail: sakamoto@elcom.nitech.ac.jp

Received 12 November 2002
Published 4 July 2003
Online at stacks.iop.org/JPhysCM/15/S2175

Abstract
We present experimental results on the magnetic susceptibility, electrical resistivity and Hall coefficient for the normal state of Ce_2CoIn_8 in the temperature range 2–300 K. These results confirmed the heavy-fermion behaviour of Ce_2CoIn_8. The resistivity shows a linear temperature dependence in the low-temperature range, which develops remarkably with increasing pressure. This suggests that Ce_2CoIn_8 is near the quantum critical point.

1. Introduction

In the past two decades, heavy-fermion superconductors have constituted a subject of intensive research. Recently, Hegger *et al* reported a new pressure-induced heavy-fermion superconductor, $CeRhIn_5$ [1], which crystallizes with a tetragonal $HoCoGa_5$ structure [2, 3]. $CeRhIn_5$, ordering antiferromagnetically below $T_N = 3.8$ K, exhibits superconductivity under pressure $P > 1.6$ GPa. The isostructural compounds $CeTIn_5$ with T = Co and Ir have been found to exhibit heavy-fermion superconductivity at 2.3 and 0.4 K, respectively, at ambient pressure [4, 5]. On the other hand, the compounds Ce_2TIn_8 (T = Co, Rh and Ir) crystallize in a Ho_2CoGa_8 structure [2, 3] with one more layer of $CeIn_3$ along the *c*-axis than $CeTIn_5$. Ce_2RhIn_8 orders antiferromagnetically at $T_N = 2.8$ K and exhibits superconductivity at $T_c = 2.0$ K under applied pressure [6]. Ce_2IrIn_8 remains in a paramagnetic state down to 50 mK at ambient pressure [7]. Recently, we have succeeded in growing a single crystal of Ce_2CoIn_8 and found that the electronic specific heat coefficient is about 500 mJ K^{-2}/mol Ce and that Ce_2CoIn_8 becomes superconducting below 0.4 K [8]. In this paper, we report experimental results on the magnetic and transport properties of Ce_2CoIn_8 in the normal state. We also grew the nonmagnetic reference compound Y_2CoIn_8.

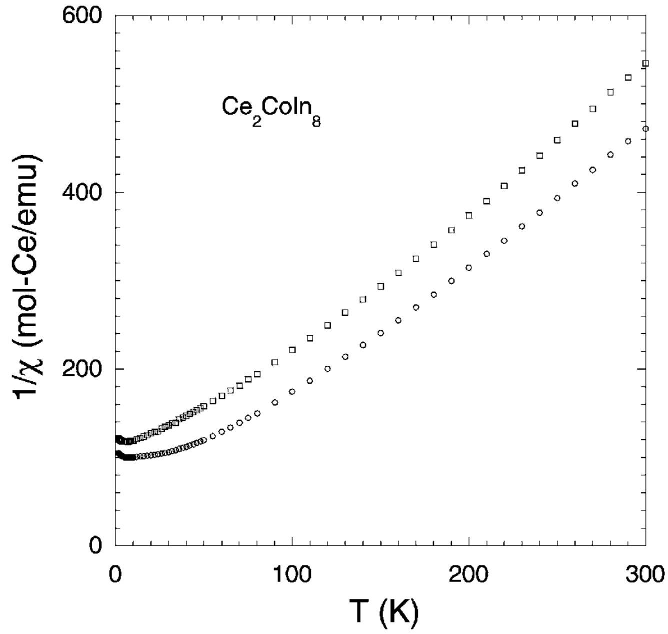

Figure 1. The inverse susceptibility $1/\chi$ of Ce_2CoIn_8 measured from 2 to 300 K in a magnetic field H of 0.5 T parallel (circles) or perpendicular (squares) to the c-axis.

2. Experimental details

Single crystals of Ce_2CoIn_8 and Y_2CoIn_8 were grown from In flux as described elsewhere [8]. Arc-melted Ce_2Co and Y_2Co ingots were used. The crystals grown were characterized by x-ray diffraction using Cu Kα radiation. The lattice parameters obtained for both compounds agree with the reported values [2]. The magnetization was measured by using a SQUID. The resistivity and Hall effect were measured using a standard four-point (or five-point) dc method. Pressure was applied by utilizing a clamp-type piston (WC)–cylinder (Cu–Be) pressure cell with an oil (Daphne 7373) as the transmitting fluid.

3. Results and discussion

Figure 1 shows the inverse susceptibility $1/\chi$ of Ce_2CoIn_8 measured from 2 to 300 K in a magnetic field H of 0.5 T parallel and perpendicular to the c-axis. The magnetic susceptibility shows an anisotropy, with χ larger for $H \parallel c$-axis. Above 200 K, the susceptibility follows the Curie–Weiss law and yields the Weiss temperature 3 K (−14 K) and effective moment $\mu_{eff} = 2.3\ \mu_B$ (2.2 μ_B) for $H \parallel c$-axis (a-axis). The value of μ_{eff} is slightly smaller than that for free Ce^{3+} ions (2.54 μ_B). The deviation from the Curie–Weiss behaviour below 150 K may be attributed to a crystalline-electric-field (CEF) effect. The susceptibility exhibits a weak maximum at about 7 K for both directions, but no anomaly is observed in ρ at this temperature. Note that such a maximum in the susceptibility was also observed for $CeRhIn_5$ [1].

The temperature dependence of the magnetic resistivity ρ_m of Ce_2CoIn_8 at various pressures is shown in figure 2. ρ_m was obtained by subtracting the resistivity of Y_2CoIn_8 from that of Ce_2CoIn_8, $\rho_m = \rho(Ce_2CoIn_8) - \rho(Y_2CoIn_8)$. With increasing pressure, the curve for $\rho_m(T)$ shifts toward higher temperatures, which is a typical behaviour for Ce-based

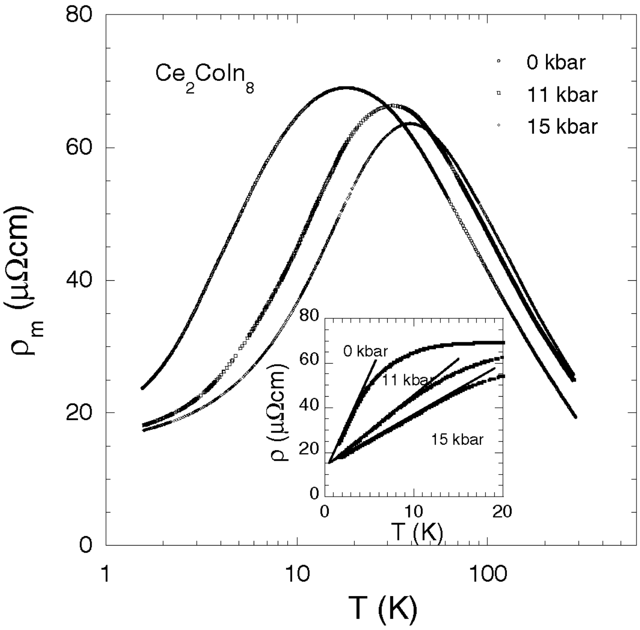

Figure 2. The temperature dependence of the magnetic resistivity $\rho_m(T)$ for Ce_2CoIn_8 measured at different pressures. The inset shows the temperature dependence of the resistivity at low temperatures.

heavy-fermion compounds [9]. The inset shows ρ versus T at low temperatures. In the lowest temperature range, the resistivity shows a linear temperature dependence and this can be described by $\rho = \rho_0 + AT$. The values of ρ_0 and A are found to decrease with increasing pressure. This behaviour, a characteristic of non-Fermi-liquid states, is also observed for the normal state of $CeCoIn_5$ above T_c [10]. Thus we infer that the electronic state of Ce_2CoIn_8 is in the vicinity of the quantum critical point even at ambient pressure.

Figure 3 shows the temperature dependence of the Hall coefficient R_H for Ce_2CoIn_8 and Y_2CoIn_8 measured with the magnetic field ($H = 1.0$ T) parallel to the c-axis. R_H for Ce_2CoIn_8 shows a maximum near $T_m = 40$ K and then decreases sharply with decreasing temperature, while Y_2CoIn_8 has a weak temperature dependence. According to [11], the Hall coefficient for a heavy-fermion material for $T \geqslant T_m$ can be described by the expression

$$R_H = R_0 + \gamma \rho_m \tilde{\chi} \tag{1}$$

where R_0 is the ordinary Hall constant, $\tilde{\chi}$ is the reduced susceptibility ($\tilde{\chi} = \chi/C$, where C is the Curie constant) and γ is a constant. The second term, the anomalous Hall coefficient, arises from skew scattering of conduction electrons by Ce ions. We plotted R_H versus $\rho_m \tilde{\chi}$ in the inset, for the temperature range 60–300 K. The linear dependence, shown by the solid line, gives $R_0 = -4.2 \times 10^{-10}$ m^3/C and $\gamma = 0.028$ K T^{-1}. Note that the γ-value is close to those of Ce_2Rh (or Ir)In_8 ($\gamma = 0.025$ K T^{-1}) [12]. For the lowest-temperature range, it is found that R_H for Ce_2CoIn_8 shows a ρ_m^2-dependence below 10 K.

In summary, we have succeeded in growing a single crystal of Ce_2CoIn_8 and measured the magnetic and transport properties for the normal state. Ce_2CoIn_8 exhibits characteristics typical of heavy-fermion materials. We speculated that Ce_2CoIn_8 is near the quantum critical point even at ambient pressure.

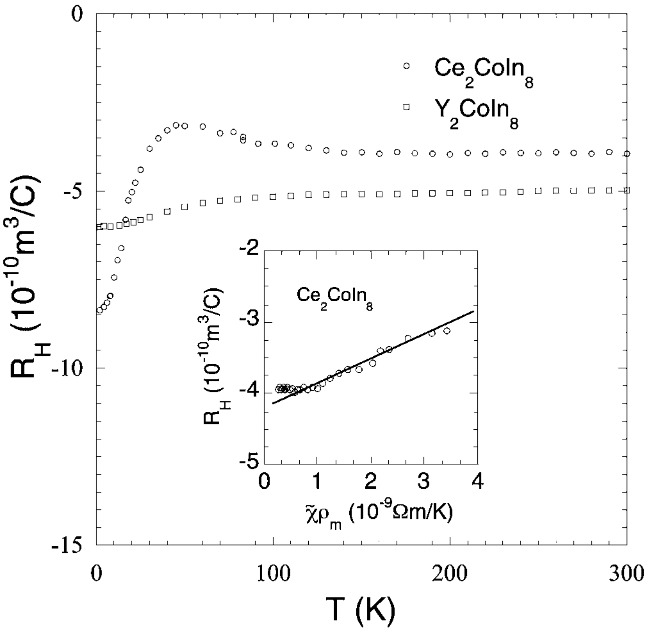

Figure 3. The temperature dependence of the measured Hall coefficient R_H for Ce_2CoIn_8 and Y_2CoIn_8. The inset shows a plot of R_H versus $\rho_m\tilde{\chi}$.

References

[1] Hegger H, Petrovic C, Moshopoulou E G, Hundley M F, Sarrao J L, Fisk Z and Thompson J D 2000 *Phys. Rev. Lett.* **84** 4986

[2] Kalychak Ya M, Zaremba V I, Baranyak V M, Bruskov V A and Zavalij P Yu 1979 *Izv. Acad. Nauk SSSR, Met.* **1** 209

[3] Moshopoulou E G, Fisk Z, Sarrao J L and Thompson J D 2001 *J. Solid State Chem.* **158** 25

[4] Petrovic C, Pagliuso P G, Hundley M F, Movshovich R, Sarrao J L, Thompson J D, Fisk Z and Monthoux P 2001 *J. Phys.: Condens. Matter* **13** L337

[5] Petrovic C, Movshovich R, Jaime M, Pagliuso P G, Hundley M F, Sarrao J L, Fisk Z and Thompson J D 2001 *Europhys. Lett.* **53** 354

[6] Nicklas M, Sidorov V A, Borges H A, Pagliuso P G, Petrovic C, Fisk Z, Sarrao J L and Thompson J D 2003 *Phys. Rev.* B **67** 020506(R)

[7] Thompson J D, Movshovich R, Fisk Z, Bouquet F, Curro N J, Fisher R A, Hammel P C, Hegger H, Hundley M F, Jaime M, Pagliuso P G, Petrovic C, Phillips N E and Sarrao J L 2001 *J. Magn. Magn. Mater.* **226–230** 5

[8] Chen G F, Ohara S, Hedo M, Uwatoko Y, Saito K, Sorai M and Sakamoto I 2002 *J. Phys. Soc. Japan* **71** 2836

[9] Kagayama T and Oomi G 1996 *J. Phys. Soc. Japan (Suppl.)* B **65** 5

[10] Sidorov V A, Nicklas M, Pagliuso P G, Sarrao J L, Bang Y, Balatsky A V and Thompson J D 2002 *Phys. Rev. Lett.* **89** 157004

[11] Fert A and Levy P M 1987 *Phys. Rev.* B **36** 1907

[12] Sakamoto I, Shomi Y and Ohara S 2003 *Physica* B at press