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2003 J. Phys.: Condens. Matter 15 S2019

(http://iopscience.iop.org/0953-8984/15/28/318)

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **15** (2003) S2019–S2021 PII: S0953-8984(03)62654-8

Electrical resistivity of single-crystal $URhGe_2$ under high pressure

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Received 12 November 2002
Published 4 July 2003
Online at stacks.iop.org/JPhysCM/15/S2019

Abstract
We have measured the electrical resistivity under pressure for the orthorhombic ferromagnet $URhGe_2$. Its two ferromagnetic ordering temperatures $T_{C2} = 30$ K and $T_{C1} = 25$ K exhibit different pressure dependences. T_{C2} increases under pressure from 30 K at ambient pressure to 40 K at 6–8 GPa, while T_{C1} decreases with increasing pressure and seems to vanish at around 8 GPa. $URhGe_2$ is found to be ferromagnetic even at 8 GPa, and the values of A and ρ_0 in the electrical resistivity expression $\rho = \rho_0 + AT^2$ are unchanged against pressure.

Cerium and uranium compounds exhibit a variety of properties such as magnetic, charge, and quadrupolar orderings, heavy fermions, and unconventional superconductivity. Recently, a new aspect of these compounds with magnetic ordering has been discovered. When pressure P is applied to $CeIn_3$ [1], $CeRhIn_5$ [2], and UGe_2 [3], the ordering temperature T_{ord} decreases, and a quantum critical point corresponding to the extrapolation $T_{ord} \to 0$ K is reached at $P = P_c$. Surprisingly, superconductivity appears around P_c even in the ferromagnetic state of UGe_2 [3]. Furthermore, a ferromagnet, URhGe, with a Curie temperature $T_c = 9.5$ K and a saturated moment $\mu_s = 0.42\,\mu_B$/U becomes superconductive below 0.25 K [4]. Ferromagnetic moment-mediated superconductivity is most probably realized in UGe_2 and URhGe.

In order to clarify the superconducting properties of these ferromagnetic compounds, we searched for other similar uranium compounds. One of the candidates is $URhGe_2$ with orthorhombic crystal structure ($Immm$, $a = 4.294$ Å, $b = 15.98$ Å, and $c = 8.726$ Å) [5]. Our recent data for the single-crystalline sample indicated two anomalies, at $T_{C2} = 30$ K and $T_{C1} = 25$ K [6], which correspond to ferromagnetic orderings as determined from the magnetic susceptibility and specific heat measurements. The magnetic easy axis is the b-axis, with a

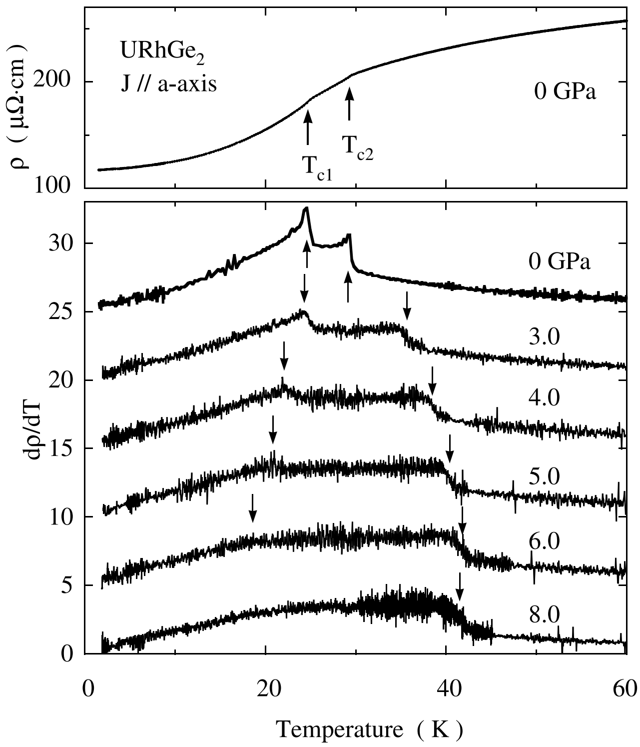

Figure 1. Temperature dependences of the electrical resistivity ρ at ambient pressure (top) and $d\rho/dT$ for different pressures (bottom) in $URhGe_2$. The vertical scales for $d\rho/dT$ are shifted by five units.

saturated moment of 0.76 μ_B/U, while the other axes are hard axes. The electronic specific heat coefficient $\gamma = 98$ mJ K^{-2} mol^{-1} is relatively large in the uranium compounds [6].

In the present study we have investigated the electrical resistivity under pressure for $URhGe_2$, and determined the P–T phase diagram, using a single-crystal sample grown by the Czochralski pulling method in a tetra-arc furnace (see [6] for details of the sample preparation).

Figure 1 (top) shows the temperature dependence of the electrical resistivity ρ at ambient pressure for the current J along the a-axis. The ordering temperatures denoted by T_{C1} and T_{C2} are due to ferromagnetic orderings. Figure 1 (bottom) displays the temperature dependence of $d\rho/dT$ for different pressures. The pressure was applied using a cubic anvil cell up to 8 GPa. The ordering temperatures T_{C1} and T_{C2} are clearly determined from the $d\rho/dT$ plot. The ordering temperatures T_{C2} increases monotonically with increasing pressure and saturates at 6 GPa, while T_{C1} decreases and seems to be fading out around 8 GPa.

Figure 2 shows the pressure dependences of T_{C1} and T_{C2}. These results indicate that $URhGe_2$ is still ferromagnetic even at 8 GPa, and a much higher pressure is needed to suppress the ferromagnetic state.

The low-temperature resistivity under pressure follows the T^2-dependence of $\rho = \rho_0 + AT^2$ below 6–7 K. We show in figure 3 the pressure dependences of the values of the coefficients A and ρ_0. The A- and ρ_0-values are approximately unchanged against pressure. A small maximum in the A-value is observed at 4 GPa, but this change is negligibly small. These results are expected because $URhGe_2$ is still ferromagnetic, and its ordering temperature remains well above the fitting upper limit.

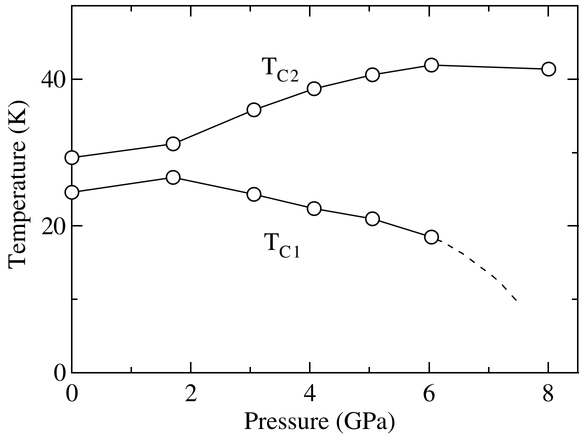

Figure 2. The T_{C1} and T_{C2} versus pressure phase diagram of $URhGe_2$.

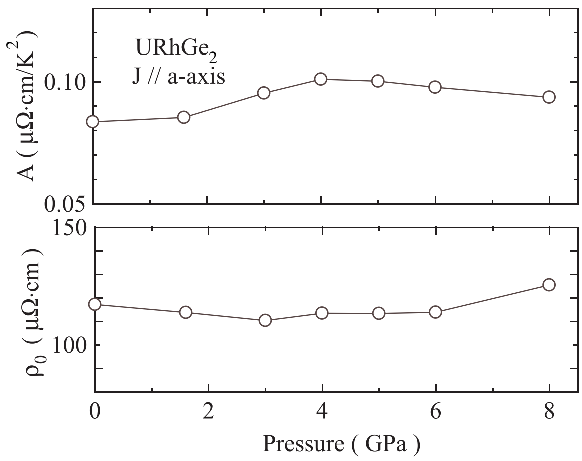

Figure 3. The pressure dependence of the coefficient A and the residual resistivity ρ_0 in $\rho(T) = \rho_0 + AT^2$ for $URhGe_2$.

In conclusion, we have studied the pressure dependence of the ferromagnetic ordering in $URhGe_2$ up to 8 GPa. This compound is still ferromagnetic even at 8 GPa.

Acknowledgment

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

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