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2003 J. Phys.: Condens. Matter 15 S2015

(http://iopscience.iop.org/0953-8984/15/28/317)

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **15** (2003) S2015–S2018 PII: S0953-8984(03)62841-9

Magnetic properties of U_2RhGa_8 and U_2FeGa_8

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Received 12 November 2002
Published 4 July 2003
Online at stacks.iop.org/JPhysCM/15/S2015

Abstract

We have grown single crystals of U_2FeGa_8 and U_2RhGa_8 with the tetragonal structure by the self-flux method. Both compounds are Pauli paramagnets and possess relatively large γ-values of 52 and 43 mJ K^{-2}/mol U, respectively.

1. Introduction

Recently, quasi-two-dimensional rare-earth and uranium compounds have attracted much attention in relation to superconductivity [1]. $CeCoIn_5$ and $CeIrIn_5$ with the tetragonal structure are heavy-fermion superconductors with transition temperatures of 2.3 and 0.4 K, respectively. On the other hand, $UTGa_5$ (T: transition metal) also crystallizes in the same tetragonal structure, and uniaxially distorted layers of UGa_3 and TGa_2 are stacked sequentially along the [001] direction (c-axis), as shown in figure 1(c) [2]. These compounds exhibit a wide variety of physical properties including Pauli paramagnetism ($UFeGa_5$) [3], semimetallicity ($UCoGa_5$ and $URhGa_5$) [4], and antiferromagnetism ($UNiGa_5$ and $UPtGa_5$) [5]. Itinerant magnetic characteristics of these compounds are inferred from their almost temperature-independent paramagnetic susceptibility, like that of the typical itinerant antiferromagnet UGa_3.

U_2TGa_8 has a structural similarity with $UTGa_5$: the tetragonal structure consists of the stacked TGa_2 and $2UGa_3$ layers, as shown in figure 1(b). Magnetic and thermal properties were previously investigated for a Pauli paramagnet, U_2RuGa_8 [6]. We have tried to grow the other U_2TGa_8 compounds, and succeeded in growing single crystals of U_2FeGa_8 and U_2RhGa_8. Electrical, magnetic, and thermal properties of the two compounds are investigated.

2. Experimental details

Single crystals of U_2RhGa_8 and U_2FeGa_8 were grown by the so-called Ga-self-flux method. Starting materials of 99.97% pure U, 99.99% (4N) Rh or 4N Fe, and 5N Ga in the atomic ratio of 2:1:30 were put into an alumina crucible and sealed in a quartz tube with an Ar atmosphere, where pressure was adjusted to 1 atm at 1050 °C. The tetragonal Ho_2CoGa_8 structure was

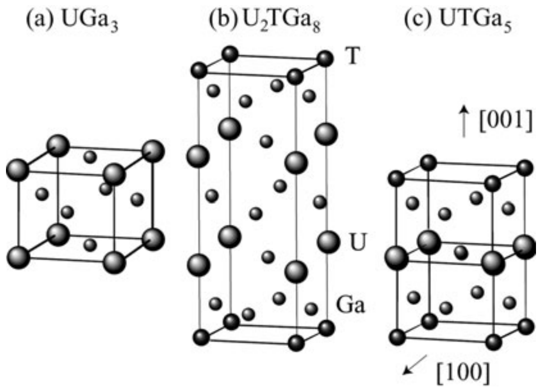

Figure 1. Crystal structures of (a) UGa_3, (b) U_2TGa_8, and (c) $UTGa_5$.

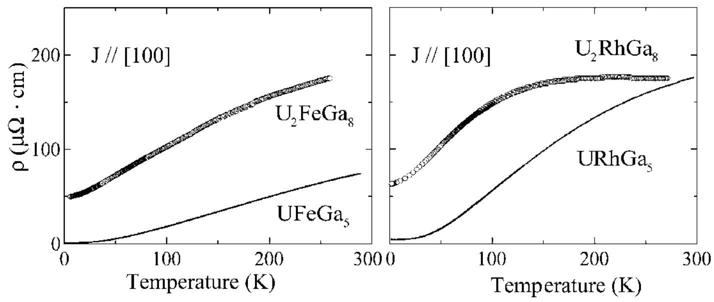

Figure 2. Temperature dependences of the electrical resistivities of U_2FeGa_8 and U_2RhGa_8, together with those for $UFeGa_5$ and $URhGa_5$.

confirmed by the x-ray powder diffraction method, and the crystal orientation was determined by the usual Laue method. The lattice parameters a and c were determined as 4.256 and 10.98 Å for U_2FeGa_8, and 4.297 and 11.08 Å for U_2RhGa_8, respectively.

The electrical resistivity measurement was carried out by the usual four-probe DC method. The magnetic susceptibility was measured by a commercial SQUID magnetometer. The specific heat measurement was done by the quasi-adiabatic heat-pulse method.

3. Experimental results and analyses

First, we show in figure 2 the electrical resistivities ρ of U_2FeGa_8 and U_2RhGa_8 for the current J along [100], as well as those of $UFeGa_5$ and $URhGa_5$, shown by solid curves. U_2FeGa_8 and U_2RhGa_8 possess large residual resistivities, which might be due to stacking faults of the crystal structure elongated along [001]. There is no indication of a phase transition down to 1.5 K.

Figure 3 shows the temperature dependence of the magnetic susceptibility for the magnetic field H along [001]. The almost temperature-independent susceptibility can be attributed to Pauli paramagnetic susceptibility, like that of $UFeGa_5$ and $URhGa_5$, shown by thin curves.

Finally, figure 4 shows the T^2-dependence of the specific heat in the form of C/T. We can estimate the γ-value as 52 and 43 mJ K^{-2}/mol U for U_2FeGa_8 and U_2RhGa_8, respectively. These values are summarized in table 1.

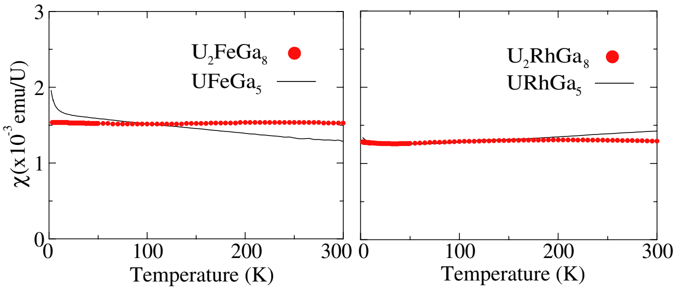

Figure 3. Temperature dependences of the magnetic susceptibilities for the field along [001] in U_2FeGa_8 and U_2RhGa_8, together with those for $UFeGa_5$ and $URhGa_5$.
(This figure is in colour only in the electronic version)

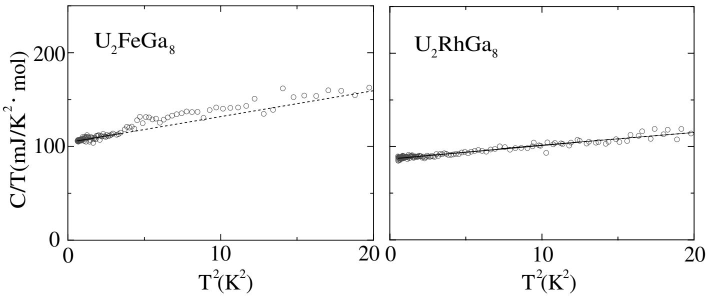

Figure 4. The T^2-dependence of the specific heat in the form of C/T, for U_2RhGa_8 and U_2FeGa_8.

Table 1. γ-values for U_2RhGa_8 and U_2FeGa_8.

	γ (mJ K^{-2}/mol U)	
$UFeGa_5$	40	Uncompensated metal
U_2FeGa_8	52	Compensated metal
$URhGa_5$	5	Semimetal
U_2RhGa_8	43	Uncompensated metal

From the number of valence electrons, U_2FeGa_8 is a compensated metal with an equal volume of electron and hole Fermi surfaces, while U_2RhGa_8 is an uncompensated metal. As for $UFeGa_5$ and $URhGa_5$, we have confirmed by dHvA experiment that $UFeGa_5$ is an uncompensated metal with a relatively large corrugated cylindrical Fermi surface and a lattice-like one [3], while $URhGa_5$ is a semimetal with small closed Fermi surfaces, resulting in a small γ-value of 5.5 mJ K^{-2} mol^{-1} [4]. The large γ-value suggests that U_2FeGa_8 has large electron and hole Fermi surfaces in contrast with the semimetallic $URhGa_5$.

In conclusion, we succeeded in growing single crystals of the Pauli paramagnets U_2FeGa_8 and U_2RhGa_8 with γ-values of 52 and 43 mJ K^{-2}/mol U, respectively.

Acknowledgment

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

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