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Specific heat measurements on $URuGa_5$ and U_2RuGa_8

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Abstract

Due to their large U–U separations, $URuGa_5$ and U_2RuGa_8 seemed to be interesting systems for possible heavy fermion behavior. In this article we report the specific heat data (1.4–18 K) and magnetic measurements. The determined values of the Sommerfield constant γ are 37 mJ U-mol^{-1} K^{-2} for $URuGa_5$ and 57 mJ U-mol^{-1} K^{-2} for U_2RuGa_8.

Keywords: Low temperature physics; Specific heat; Heavy fermion compounds

1. Introduction

Searching for new heavy fermion systems we investigated the two ternary uranium compounds $URuGa_5$ and U_2RuGa_8 which have the same tetragonal space group symmetry (P4/mmm). Grin et al. had investigated the structure of $URuGa_5$ (lattice parameters: $a = 0.4312$ nm, $c = 0.6800$ nm [1]) and U_2RuGa_8 ($a = 0.42929$ nm, $c = 1.10590$ nm [2]). The U–U distances of both samples were reported to be clearly beyond the Hill limit (4.31 and 4.22 Å respectively), although magnetic measurements in Refs. [1,2] show no sign of any magnetic ordering down to 80 K.

2. Preparation

Polycrystalline samples were prepared by arc melting in a Zr-gettered argon atmosphere. Starting components were U (99.95%), Ru (5 N), and Ga (5 N). The resulting products were wrapped in tantalum foil and sealed into an evacuated quartz glass tube. As described in Refs. [1] and [2] we annealed the samples at 600 °C for one week.

3. Results and discussion

The X-ray powder diffraction was performed at room temperature, using a Siemens D 5000 diffractometer in Bragg–Brentano geometry. Both samples crystallize in tetragonal structures (space group P4/mmm) which belong to the linear inhomogeneous structure series $RE_mT_mGa_{3m+2n}$ [1]. In U_2RuGa_8 we have detected a small second phase of pure uranium. The results of our X-ray measurements are shown in Table 1. The shortest U–U distance in U_2RuGa_8 occurs between two U-atoms along the c axis and therefore it is not equal to the value of the lattice parameter a. For a detailed discussion of the two structures see Refs. [1,5].

The specific heat was measured with a relaxation method, as described by Bachmann et al. [3], between 1.3 K and 18 K. Fig. 1 shows the result in the C/T vs. T^2 plot. From this we calculated the value for the electronic contribution to the specific heat with

$$C/T = \gamma + \beta T^2$$

We used the low temperature data between 1.3 K and 10 K for the fit. The results of our specific heat measurements are shown in Table 1.

The Debye temperature Θ_D was calculated from the phonon contribution of the specific heat, with

Table 1
Results of our measurements of $URuGa_5$ and U_2RuGa_8

Measurements	$URuGa_5$	U_2RuGa_8
a	0.4312 nm	0.4288 nm
c	0.6800 nm	1.1062 nm
U–U distance	0.431 nm	0.422 nm
γ (mJ U-mol^{-1} K^{-2})	37 ± 2.5	57 ± 3.3
θ_D (K)	319 ± 10	358 ± 10

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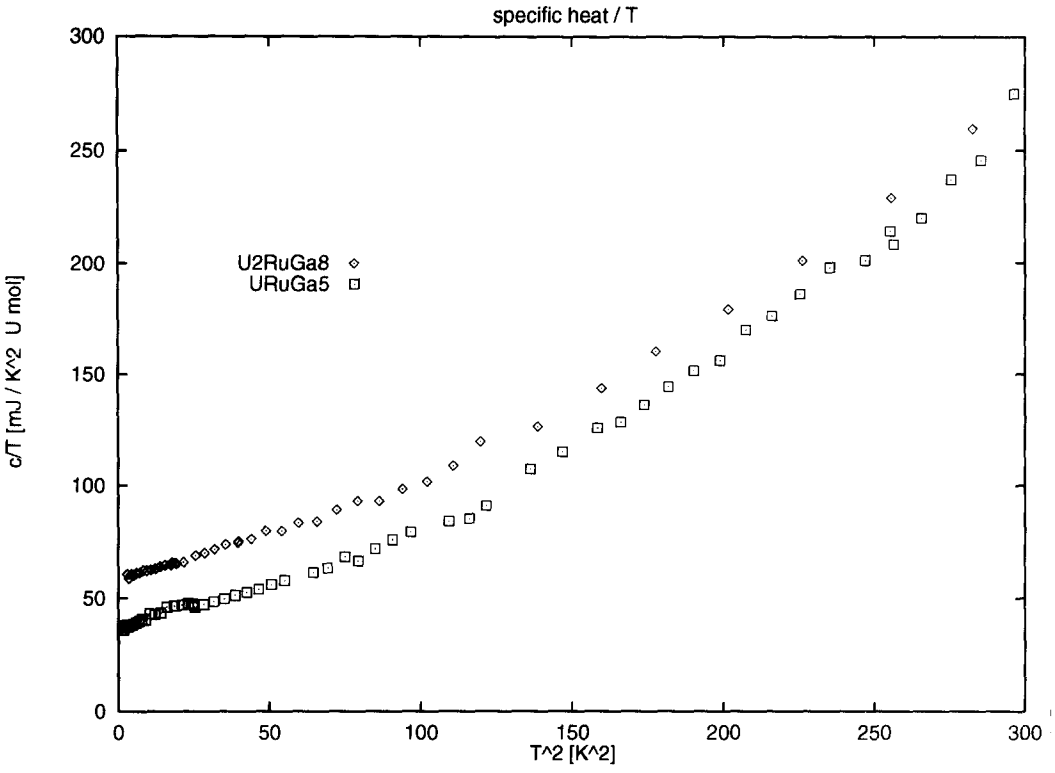

Fig. 1. Specific heat measurements on $URuGa_5$ and U_2RuGa_8 in the diagram C/T vs. T^2.

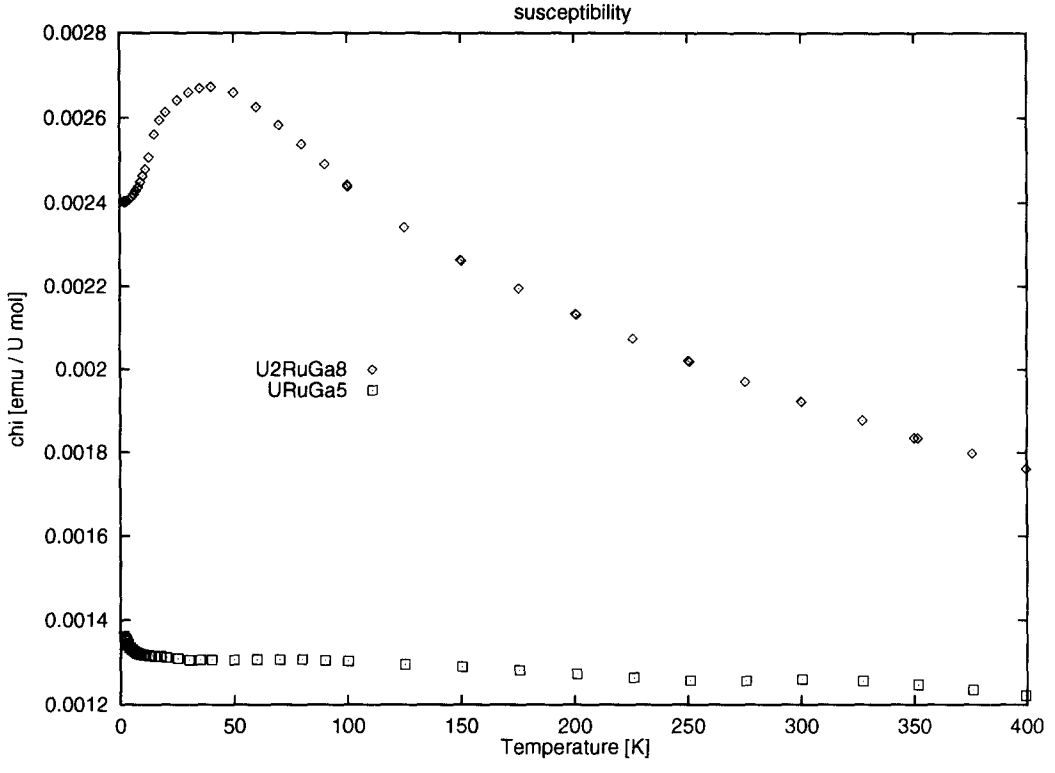

Fig. 2. Susceptibility χ vs. T of $URuGa_5$ and U_2RuGa_8.

$$\Theta_D = (1944*10^3 n/\beta)^{1/3}$$

where n is the number of atoms per formula unit ($n=7$, $n=11$).

The results for the temperature dependence of the magnetic susceptibility, measured on polycrystalline bulk samples in a field of 0.5 T with a Quantum Design SQUID are shown in Fig. 2. The susceptibility of

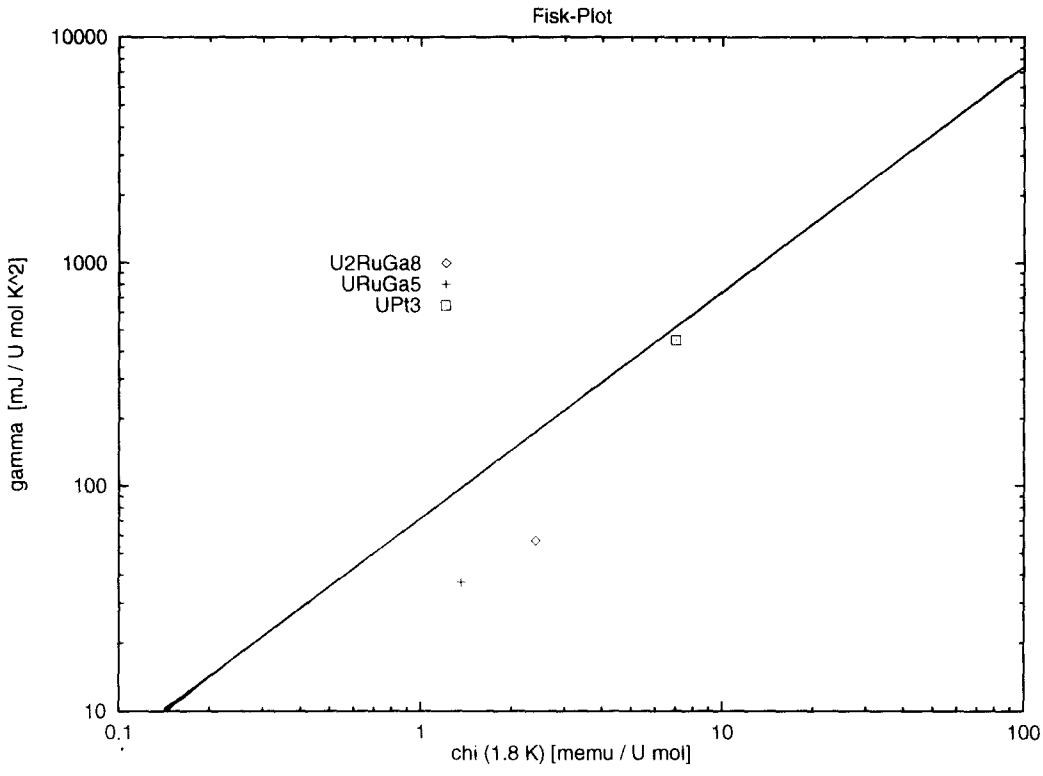

Fig. 3. Position of $URuGa_5$ and U_2RuGa_8 in the χ vs. γ plot. Solid line represents the free electron gas. (Data for UPt_3 taken from Ref. [4]).

U_2RuGa_8 shows a broad maximum around 40 K. In $URuGa_5$ the susceptibility is nearly constant over a wide temperature range, below 20 K there is an increase. We observe $\chi(1.8\ \text{K}) = 1.36 \times 10^{-3}$ emu U-mol^{-1} ($URuGa_5$) and $\chi(1.8\ \text{K}) \approx 2.4 \times 10^{-3}$ emu U-mol^{-1} (U_2RuGa_8). The magnetization measured at 2 K shows a linear behavior and no saturation up to 7 T. There is no Curie–Weiss behavior between 70 K and 400 K in both samples.

In conclusion, despite promising signs, like the large U–U distances and the absence of magnetic ordering down to 1.8 K, there is no heavy fermion behavior in either sample. Comparing our measurements with heavy fermion systems in the χ vs. γ plot (Fisk plot) our samples lie parallel to the Fermi liquid line (Fig. 3). The relative small values of χ, as well as the small Sommerfield constant γ give evidence of the presence of hybridization of the 5f electrons, i.e. rather broad bands. From the crystal structures we assume that the hybridization is between the 5f electrons and the Ga-atoms because the distances between the U- and Ga-atoms are shorter than the U–U and U–Ru distances (see Ref. [5]).

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