Title
Magnetic ordering in URh2Ge2: A resistivity investigation at ambient and elevated pressures

Journal
Physics Letters A, 110(9)

ISSN
0375-9601

Authors
Thompson, JD
Fisk, Z
Gupta, LC

Publication Date
1985-08-01

DOI
10.1016/0375-9601(85)90558-4

MAGNETIC ORDERING IN URh_2Ge_2: A RESISTIVITY INVESTIGATION AT AMBIENT AND ELEVATED PRESSURES

J.D. THOMPSON [a], Z. FISK [a] and L.C. GUPTA [a,b]

[a] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[b] *Tata Institute of Fundamental Research, Colaba, Bombay 400 005, India*

Received 9 April 1985; accepted for publication 15 June 1985

Magnetic ordering at 2.0 K is inferred from resistivity measurements on URh_2Ge_2. The transition temperature is not sensitive to applied pressure, suggesting stability of the magnetic moment of uranium in this material.

Neutron diffraction measurements of polycrystalline samples showed [1] that UPd_2Si_2, UPd_2Ge_2 and URh_2Si_2, all belonging to the tetragonal $ThCr_2Si_2$-type structure (space group I4/mmm), undergo an antiferromagnetic phase transition at 150, 140 and 137 K respectively. This is consistent with results of magnetic susceptibility measurements by Zygmunt [2] where the occurrence of an antiferromagnetic phase transition in these materials was first suggested. In the case of URh_2Ge_2, however, neutron diffraction and magnetic susceptibility results did not agree. According to the susceptibility measurements, URh_2Ge_2 also undergoes an antiferromagnetic phase transition at 8 K; whereas the neutron measurements did not reveal any magnetic phase transition down to 4.2 K. The motivation for us to undertake resistivity measurements on URh_2Ge_2 was to investigate the occurrence of a possible magnetic phase transition below 4.2 K and to examine the anomaly, if any, in the resistivity of this material in the neighbourhood of 8 K. In the following we present evidence suggestive of a magnetic phase transition in URh_2Ge_2 at 2.0 K.

Polycrystalline samples of URh_2Ge_2 were prepared by arc melting stoichiometric quantities of the elements. The buttons were flipped over a number of times to ensure good homogeneity of the material. The ac resistivity $\rho(T)$ was measured using a standard four-probe and lock-in detection technique. We have also studied the pressure effects on the resistive behaviour up to 16 kbar. The high pressure cell employed in these measurements has been described elsewhere [3]. The pressure was monitored using superconducting lead as a manometer.

Fig. 1 shows the temperature variation of the resistivity at ambient pressure. The inset of the figure shows an enlarged view of the resistivity as a function of temperature below 20 K. It is very clear that the resistivity exhibits a precipitous fall at 2.0 K. We attribute this behaviour to a magnetic phase transition in URh_2Ge_2 below 2.0 K. No unusual behaviour in the resistivity is observed in the neighbourhood of 8 K which rules out a magnetic phase transition at this temperature. Thus our results are in conformity with the neutron measurements where no magnetic transition was observed in this range of temperature. The shape of the anomaly which the resistivity exhibits at 2.0 K is very much similar to that observed in $CePd_2Si_2$ [4] around 10 K (T_N). In $CePd_2Si_2$, the temperature derivative of the resistivity at the antiferromagnetic transition temperature is positive from which it was inferred that the new Brillouin zone resulting from antiferromagnetic ordering does not intersect those portions of the Fermi surface that are important for electronic conduction. We believe that a similar situation obtains in URh_2Ge_2.

The resistivity measurements were performed with pressure as a variable parameter ($P \leqslant 16.6$ kbar). The results for two pressures $P = 5.2$ and 16.6 kbar below 20 K are shown as an inset to fig. 1. The temperature at which the peak in $\rho(T)$ (see inset to fig. 1) occurs,

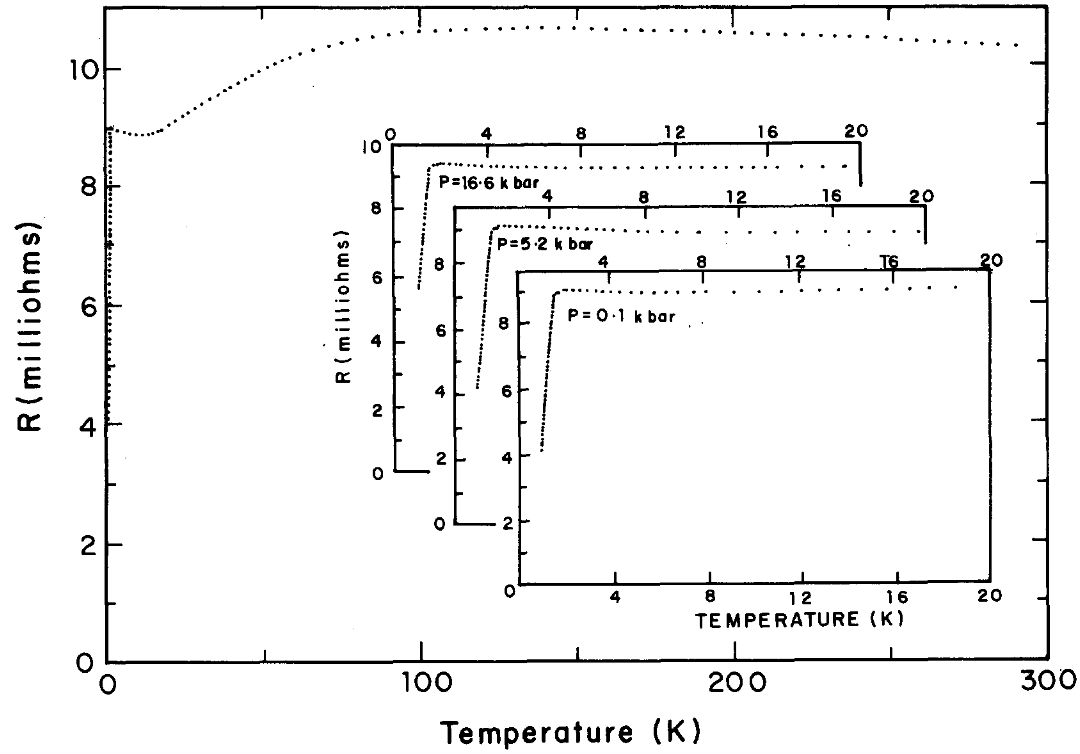

Fig. 1. Resistive behaviour of URh_2Ge_2. The precipitous fall of $\rho(T)$ at 2.0 K signals magnetic ordering in the system. The inset shows resistivity below 20 K at 5.2 and 16.2 kbar.

remains essentially unchanged and the resistance of the sample exhibits only a small increase (~5%) over the entire range of temperature above T_N. The insensitivity of the resistivity to pressure suggests that the uranium moment is stable and no strong mixed valency effects exist in the material. This must be contrasted with the situation in $CePd_2Si_2$ where T_N (~10 K at ambient pressure) is depressed markedly with pressure [4]. This behaviour is consistent with the existence of an incipient moment instability in this material which had been suggested earlier on the basis of the observation of Kondo side-bands in the resisitvity and a high spin fluctuation temperature in the magnetic susceptibility [5].

Though the crystallographic structure of URh_2Ge_2 (space group P4/mmm) is different [1] from that of UPd_2Ge_2, UPd_2Si_2 and URh_2Si_2, the uranium sublattice is identical in all these cases. In view of this, it is remarkable that URh_2Ge_2 exhibits such a low ordering temperature (2 K, this work). As mentioned above, these materials exhibit magnetic ordering at temperatures which are nearly the same and are not very sensitive to the nature of the nonmagnetic elements. One important feature of the structure of URh_2Ge_2 is that the nonmagnetic elements are randomly distributed among various crystallographic sites. We feel that the disorder among the nonmagnetic atoms in URh_2Ge_2 damps the RKKY oscillations and may be responsible for the low ordering temperature. Further, it is conceivable that besides RKKY coupling, a super exchange interaction, mediated through the paths involving nonmagnetic atoms, may also play an important role in the effective magnetic interaction between uranium atoms. This would be particularly true between uranium atoms at the corner and the body centre of the unit cell, which are separated by about 5.8 Å rendering direct overlap of the 5f orbitals rather weak. Due to the disorder among the nonmagnetic atoms, the sign and magnitude of this interaction also may fluctuate.

It should be of interest to examine whether or not the nonmagnetic atoms in URh_2Ge_2 undergo crystallographic ordering at 2.0 K.

It should be pointed out that superconductivity has recently been reported in URu_2Si_2 ($T_s = 0.8$ K) [6]. In this material, the high temperature magnetic moment per uranium atom is 1.43 μ_B. There are only two other known superconducting U-based materials, namely UPt_3 [7] and UBe_{13} [8], with U–U spacing $\Delta U > 4$ Å. That URu_2Si_2 should exhibit superconductivity is rather interesting vis-a-vis the magnetic behaviour of the materials URh_2Ge_2, URh_2Si_2, UPd_2Si_2 and UPd_2Ge_2 in which case also ΔU is about 4 Å.

To summarise, magnetic ordering at 2.0 K has been inferred from our resistivity measurements on URh_2Ge_2. This temperature is very low compared to the ordering temperatures of related U-based materials, viz., URh_2Si_2, UPd_2Si_2 and UPd_2Ge_2 which we believe, is due to the disorder of the Rh–Ge atoms in the lattice. The insensitivity of the resistivity with pressure suggests that the uranium moment is stable.

Work at Los Alamos was performed under the auspices of the U.S. Department of Energy.

References

[1] H. Ptasiewic Bak, J. Leciejewicz and A. Zygmunt, J. Phys. F35 (1981) 1225.
[2] A. Zygmunt, quoted in ref. [1].
[3] J.D. Thompson, Rev. Sci. Instrum. 55 (1984) 231.
[4] R.D. Parks, J.D. Thompson and S. Horn (1985), unpublished.
[5] V. Murgai, S. Raaen, L.C. Gupta and R.D. Parks, in: Valence fluctuations, eds. P. Wachter and H. Boppart (North-Holland, Amsterdam, 1982) p. 537.
[6] W. Schlabitz, J. Baumann, J. Diesing, W. Krause, G. Neumann, C.D. Bredl and V. Rauchschwalbe, presented at Intern. Conf. on Valence fluctuations (Cologne, Aug. 1984).
[7] R.H. Ott, H. Rudigier, Z. Fisk and J.L. Smith, Phys. Rev. Lett. 50 (1983) 1595.
[8] G.R. Stewart, Z. Fisk, J.O. Willis and J.L. Smith, Phys. Rev. Lett. 52 (1984) 679.