



Resistivity of non-Fermi liquid U_2Pt_2In under pressure

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Abstract

Non-Fermi liquid behaviour in single-crystalline U_2Pt_2In has been studied by means of resistivity experiments ($I\parallel c$) under hydrostatic pressure ($P < 1.5$ GPa). At ambient pressure the resistivity $\rho(T)$ follows a power law $\rho \sim T^\alpha$ with $\alpha \sim 0.5$. Upon applying pressure α increases. For $P > 1$ GPa a minimum develops in $\rho(T)$. A study of the field dependence of the minimum confirms its magnetic origin. The ratio c/a is proposed as the effective control parameter, rather than the unit cell volume. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: U_2Pt_2In ; Non-Fermi liquid; Pressure effects

The intermetallic compound U_2Pt_2In (tetragonal Zr_3Al_2 -type structure) is one of the few stoichiometric compounds known to exhibit non-Fermi liquid (NFL) properties [1] at ambient pressure, as evidenced by a pronounced $c/T \sim -\ln T$ contribution to the specific heat below ~ 6 K [2] and a low-temperature electrical resistivity described by a power law $\rho \sim T^\alpha$ with $\alpha \sim 1$ for $I\parallel a$ and $\alpha \sim 0.5$ for $I\parallel c$ [3]. A broad maximum at $T_{\max} = 8$ K in the magnetization measured for $B\parallel c$ [3] and a rapid increase below T_{\max} of the line width of a dynamic component in the zero-field μ SR spectra [2] indicate the presence of short-range magnetic correlations. μ SR experiments confirm the absence of (weak) magnetic order. Although the residual resistivity of U_2Pt_2In is quite high ($\rho_0 \sim 100 \mu\Omega$ cm), X-ray [3] and neutron diffraction [4] experiments carried out on single-crystalline samples rule out the possibility of significant crystallographic disorder (namely intersite exchange). The location of U_2Pt_2In at the border line of magnetic and non-magnetic compounds in a Doniach-type of diagram for the U_2T_2X family [5] suggests the proximity to a quantum critical point as the origin of the non-Fermi liquid behaviour in this compound.

Recently, polycrystalline samples of $(U_{1-x}Th_x)_2Pt_2In$ were prepared for $x \leq 0.1$ [6] and studied by magnetization and μ SR, which showed that Th doping stabilizes the magnetic state in U_2Pt_2In [7]. Assuming that the main role of Th doping is an expansion of the unit cell, applying hydrostatic pressure gives the opportunity to study the effects of a unit cell volume reduction and an eventual recovery of the Fermi liquid state.

Resistivity measurements in the temperature range 0.3–300 K, under pressures up to 1.5 GPa and magnetic fields up to 8 T, were carried out in bar-shaped single crystals of U_2Pt_2In using a standard four-probe method. A CuBe piston cylinder-type clamp cell was used with Fluorinert as pressure transmitting medium. The pressure values were corrected for an empirical efficiency of 80%.

The zero-pressure resistivity curve for $I\parallel c$ follows a power law of the type $\rho \sim T^\alpha$ with $\alpha \sim 0.5$ in the temperature range $0.3 \leq T \leq 2.3$ K [3]. Upon increasing the pressure, α gradually increases for $P < 1$ GPa (Fig. 1). However, as the pressure is increased further, a minimum in the resistivity develops, which shifts to higher temperatures and becomes more pronounced at high pressures: $T_{\min} \sim 1.2$ K at $P = 1.20$ GPa and $T_{\min} \sim 2.1$ K at 1.45 GPa.

In order to investigate whether the observed minimum has a magnetic origin, measurements of $\rho(T)$ under magnetic field ($B\parallel I$) were performed at $P = 1.45$ Pa (Fig. 2).

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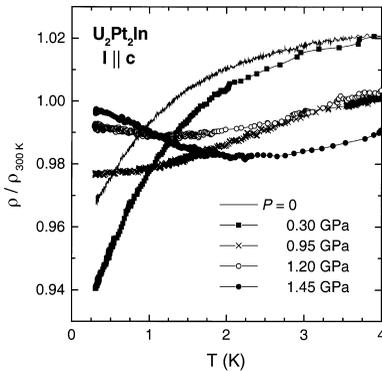


Fig. 1. Temperature dependence of the electrical resistivity (normalized to the respective room-temperature values) at several pressures for $I \parallel c$ in single-crystalline U_2Pt_2In .

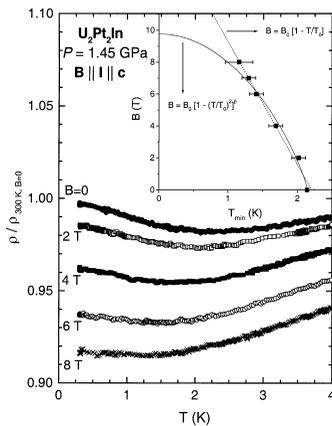


Fig. 2. Normalized $\rho(T)$ at $P = 1.45$ GPa for several magnetic fields applied parallel to the current direction ($B \parallel I \parallel c$). Inset: field dependence of T_{\min} (the lines are fits to the data).

T_{\min} decreases smoothly with the strength of the applied magnetic field: $T_{\min} \sim 1.7$ K for $B = 4$ T and $T_{\min} \sim 1.2$ K for 8 T. Also the minimum becomes less pronounced with field, and is almost suppressed at 8 T. Due to the limited range of temperatures and fields available and the relative uncertainty in determining T_{\min} (especially for the higher fields where the minimum is very shallow), it is not possible at the moment to clearly trace the evolution of T_{\min} with B . The inset of Fig. 2 shows that the data can be equally fitted with a linear dependence ($B = B_0(1 - T/T_0)$) with $B_0 = 17.0 \pm 1.1$ T and $T_0 = 2.20 \pm 0.05$ K or a typical antiferromagnetic-like field dependence of the ordering temperature: $B = B_0[1 - (T/T_0)^2]^\beta$ with $B_0 = 9.8 \pm 1.1$ T, $T_0 = 2.14 \pm 0.03$ K and $\beta = 0.82 \pm 0.17$. The field effect on the resistivity curves strongly suggests that T_{\min} has a magnetic

origin. Whether T_{\min} is associated with magnetic ordering remains undecided at the moment.

The structure in $\rho(T)$ at $P = 1.45$ GPa resembles in part that of an antiferromagnetic phase transition of the spin-density wave type, as observed e.g. in the heavy-fermion antiferromagnets URu_2Si_2 ($T_N = 14$ K) [8] and $U(Pt_{0.95}Pd_{0.05})_3$ ($T_N = 5.8$ K) [9]. In these compounds $\rho(T)$ rises below T_N because of the opening of the energy gap. At about $0.9T_N$, $\rho(T)$ develops a local maximum, below which the resistivity drops because of the ordered structure. The data in Fig. 1 show that this local maximum is not observed at temperatures $> 0.15T_N$, which might be related to the large residual resistance values of our samples.

The emergence of a magnetic component to $\rho(T)$ upon applying pressure is quite surprising. Applying pressure on a compound at the magnetic instability normally leads to an increase of the control parameter J and brings the compound in the non-ordering Fermi-liquid regime. A possible explanation for this unusual behaviour might be offered by assuming that the control parameter J is not governed by the volume, but by the c/a ratio of the tetragonal unit cell. This is supported by the comparison of the unit cell volumes and c/a ratios of U_2Pt_2In and the antiferromagnets U_2Pd_2In ($T_N = 37$ K) and U_2Pt_2Sn ($T_N = 15$ K) [10]. Whereas the unit cell volume of U_2Pt_2In is smaller than that of U_2Pd_2In and larger than that of U_2Pt_2Sn , the c/a ratio is always smaller (for simplicity we have not taken into account the doubling of the crystal structure along the c -axis in single-crystalline U_2Pt_2In) [11]. Thus the appearance of magnetic ordering under pressure might be the result of a c/a ratio increase. This in turn requires the compressibility to be anisotropic. X-ray diffraction experiments to determine the lattice parameters of U_2Pt_2In under pressure and of $(U,Th)_2Pt_2In$ are underway to investigate this hypothesis.

In summary, we have measured the resistivity of single-crystalline U_2Pt_2In under moderate pressures and conclude that U_2Pt_2In is easily driven away from its non-Fermi-liquid state, as expected for compounds at a quantum critical point.

Acknowledgements

P.E. acknowledges the European Commission for a Marie Curie Fellowship within the TMR programme.

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