HIGH FIELD SPECIFIC HEAT OF SINGLE-CRYSTALLINE $U(Pt_{0.95}Pd_{0.05})_3$

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The hexagonal compound $U(Pt_{0.95}Pd_{0.05})_3$ shows both long-range antiferromagnetic order and high c/T -values at low temperature that are characteristic for heavy-fermion behaviour. Magnetic fields (of 12 T along the b-axis and 13 T along the a-axis) can suppress the ordering completely, but the large heavy-fermion contribution is still present at high fields.

1. INTRODUCTION

In the series $U(Pt_{1-x}Pd_x)_3$ superconductivity and long-range antiferromagnetic order occur besides spinfluctuation and Kondo phenomena (1). When substituting Pd for Pt in UPt_3 , the superconductivity is suppressed and a state of long-range antiferromagnetic order (LRAF) is created (2). The antiferromagnetic order, of the spin-density wave type, is most pronounced in the 5 at% Pd-compound, that has a Néel temperature of 5.9 K. In the specific heat ($c(T)$) this ordering is reflected as a sharp peak superimposed on a large heavy-fermion background. Neutron scattering experiments (3) on single-crystalline $U(Pt_{0.95}Pd_{0.05})_3$ show that the ordered moments ($\sim 0.6\mu_B/U$ -atom) are aligned along the b-axis. Specific heat measurements (4) in an applied field ($B \leq 5$ T) have shown a rather strong in-plane anisotropy: $T_N(B)$ decreases faster for $B//b$ than for $B//a$.

As noted before (1,2) it is remarkable that the heavy-fermion behaviour is preserved as the LRAF order sets in. This suggests that only a part of the itinerant character of the f-electrons is lost and that in the ordered state strong fluctuations, probably of the Kondo type, persist (T_K decreases with increasing Pd contents for $x \leq 0.10$ (5)). Measurements of $c(T)$ of pure UPt_3 in field show that c/T increases with B and has a maximum at 20 T where the metamagnetic transition occurs (6). However, in a field of 24.5 T, c/T is still larger than in 0 T. This shows that when the intersite correlations have collapsed at 20 T other fluctuations (possibly of the Kondo type) persist.

In this contribution we investigate the suppression of the long-range order in $U(Pt_{0.95}Pd_{0.05})_3$ in very large magnetic fields (B up to 20 T). We also investigate the heavy fermion part of $c(T)$ as function of field.

FIGURE 1
Specific heat of $U(Pt_{0.95}Pd_{0.05})_3$ with a) $B//a$ and b) $B//b$, field values are indicated.

2. EXPERIMENTAL

The specific heat measurements were performed on a single-crystalline sample of a cubic shape ($5 \times 5 \times 5$ mm³), cut out by spark erosion of a crystal grown by the Czochralski method in a tri-arc furnace. The high field

specific heat measurements were carried out at the High Field Magnet Laboratory of the University of Nijmegen, using the 20 T Bitter-type of coil. The experiments were performed in an adiabatic way with a sapphire sample holder equipped with a ruthenium-oxide thermometer and a nickel-chromium film as a heater (6).

FIGURE 2

Phase diagram of $U(Pt_{0.95}Pd_{0.05})_3$, originating from the specific heat measurements, for the a-axis (+), the b-axis (●) and the c-axis (broken line).

3. RESULTS AND DISCUSSION

In Fig. 1a and b the results ($B \leq 13$ T) are presented for $B//a$ and $B//b$ respectively. $T_N(B)$ is reported in Fig. 2 together with the low field data of Ref. (4). The phase boundaries separate a region of long-range antiferromagnetic order from a region with short range antiferromagnetic fluctuations. The results obtained here agree very well with those obtained from magnetisation measurements. Fields directed along the hexagonal axis are known not to suppress T_N (4), this was confirmed by a field sweep up to 13 T at 5 K, in which no magnetocaloric effect was observed. Extrapolating $T_N(B)$ towards 0 K we obtain a total suppression of the LRAF ordered state at 13 T and 12 T for $B//a$ and $B//b$ respectively. A similar anisotropy for suppressing the LRAF could be deduced from magnetisation measurements where anomalies in $M(B)$ at 1.3 K occur at 12.6 T and 11.8 T respectively (7).

A remarkable feature of the field measurements is seen in the shape of the ordering peaks. With the field along the b-axis the peak sharpens with increasing field up to 8 T, and loses its sharpness there above. This feature is absent for $B//a$. At present we cannot offer an explanation for this sharpening. On the other hand, the external field tends to break up the antiferromagnetic coupling thus causing the dominant overall suppression of T_N .

From the low-T part of our data it is clear that γ ($= \lim_{T \rightarrow 0} c(T)$) remains large over the whole field range. Data at 20 T reveal a c/T of 450 $mJmol^{-1}K^{-2}$ at 2.25 K (8), which is still larger than the value for UPT_3 in 0 T. Thus the heavy-fermion behaviour is preserved in $U(Pt_{0.95}Pd_{0.05})_3$ at our maximum field.

Despite the difficulty to separate out the contribution of the LRAF order to $c(T)$, we infer from our high-field data an initial increase of γ , as observed in pure UPT_3 . This suggests that the scenario for UPT_3 (6) also applies to the remaining contribution of $U(Pt_{0.95}Pd_{0.05})_3$, i.e. the presence of competing magnetic interactions that can be separated into a Kondo on-site type of interaction and an inter-site interaction. It would be interesting to investigate at which field γ passes through a maximum by extending our temperature range towards lower temperatures. Presumably this occurs near ~ 12 T (7) compared to 20 T in UPT_3 . The coexistence of three types of interactions demonstrates the complex nature of the electron-electron processes in $U(Pt_{0.95}Pd_{0.05})_3$.

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