

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

H.P.VAN DER MEULEN^a, J.J.M.FRANSE^a, A. DE VISSER^a, J.A.A.J.PERENBOOM^b and H.VAN KEMPEN^b

^aNatuurkundig Laboratorium, Universiteit van Amsterdam, Valckenierstraat 65,
 1018 XE Amsterdam, The Netherlands

^bHigh Field Magnet Laboratory, University of Nijmegen, Toernooiveld,
 6525 ED Nijmegen, The Netherlands

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/c 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.

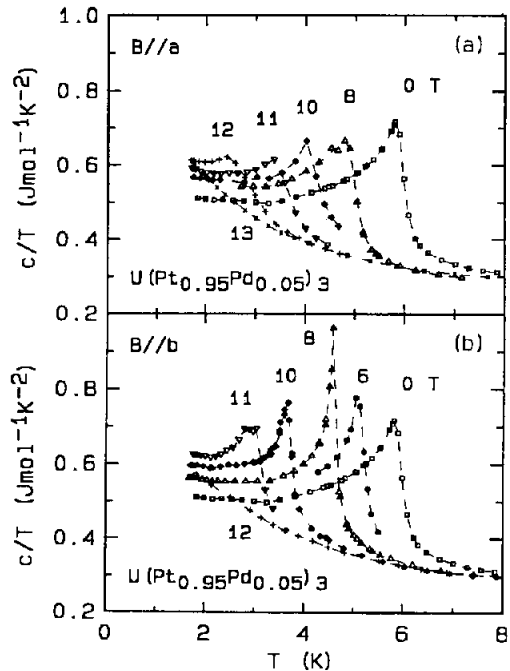


FIGURE 1
 Specific heat of $U(Pt_{0.95}Pd_{0.05})_3$ with a) $B//a$ and b) $B//b$, field values are indicated.

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).

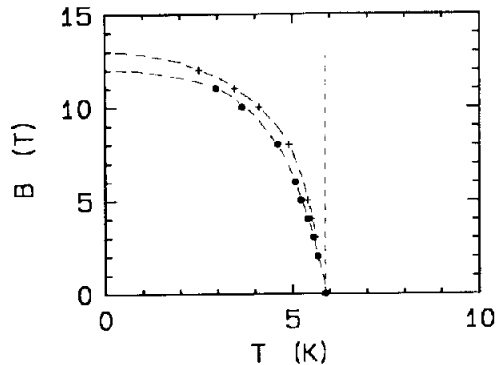


FIGURE 2

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 looses 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 $450 \text{ mJmol}^{-1}\text{K}^{-2}$ 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 $U(Pt_{0.95}Pd_{0.05})_3$.

ACKNOWLEDGEMENTS

This work was supported by the "Stichting Fundamenteel Onderzoek der Materie" (FOM) with financial support from the "Nederlandse Organisatie van Wetenschappelijk Onderzoek" (NWO). The work of A.d.V. has been made possible by a fellowship of the Royal Netherlands Academy of Arts and Sciences.

REFERENCES

- (1) A. de Visser, A. Menovsky and J.J.M. Franse, *Physica* 147 B, 81 (1987).
- (2) A. de Visser, J.C.P. Klaasse, M. van Sprang, J.J.M. Franse, A.A. Menovsky, T.T.M. Palstra and A.J. Dirkmaat, *Phys. Lett.* 113A (1986) 489.
- (3) P.H. Frings, B. Renker and C. Vettier, *J. Magn. Magn. Mat.* 63&64 (1987) 202.
- (4) M. van Sprang, R.A. Boer, A.A. Menovsky and J.J.M. Franse, *Jpn. J. Appl. Phys.* 26 (1987) 563; M. van Sprang, PhD thesis, University of Amsterdam (1989), unpublished.
- (5) J.J.M. Franse, H.P. van der Meulen and A. de Visser, this conference.
- (6) H.P. van der Meulen, Z. Tarnawski, J.J.M. Franse, A. de Visser, J.A.A.J. Perenboom, D. Althof and H. van Kempen, *Phys. Rev. B*, in print.
- (7) A. de Visser, M. van Sprang, A.A. Menovsky, J.J.M. Franse, *J. de Physique (Paris)* 49-C8, (1988) 761.
- (8) J.J.M. Franse, H.P. van der Meulen, A.A. Menovsky, A. de Visser, J.A.A.J. Perenboom and H. van Kempen, in *Proc. Yamada Conf. on Magn. Phase Trans.* (Osaka, April 13-16, 1990).