ELSEVIER

Physica B 284–288 (2000) 1281–1282

PHYSICA B

www.elsevier.com/locate/physb

Search for a quantum phase transition in $U(Pt_{1-x}Pd_x)_3$

M.J. Graf[a,*], R.J. Keizer[b], A. de Visser[b], S.T. Hannahs[c]

[a]*Department of Physics, Boston College, Chestnut Hill, MA 02459, USA*
[b]*Van der Waals-Zeeman Inst., Univ. of Amsterdam, 1018XE Amsterdam, The Netherlands*
[c]*National High Magnetic Field Lab., Florida State University, Tallahassee, FL 32310, USA*

Abstract

Pd in $U(Pt_{1-x}Pd_x)_3$ suppresses the superconducting T_c to 0 K at $x_c \simeq 0.007$ and induces a conventional AFM state for $x \geqslant x_c$. The resistivity below 1 K for $x \leqslant 0.02$ shows a deviation from Fermi liquid behavior described by $\rho(T) = \rho_0 + AT^{\alpha}$; α varies from 2 for $x = 0$ to 1.6 for $x \simeq x_c$. This suggests that a quantum phase transition (QPT) exists near x_c. Transport for a sample with $x = 0.004 < x_c$ has a pressure-independent exponent $\alpha = 1.77$, suggesting that if a QPT exists it may be associated with the magnetic transition. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Heavy fermion; Quantum phase transition; Unconventional superconductivity; UPt_3

Pd-substitution is a powerful technique for studying superconductivity, magnetism, and their interplay in UPt_3. It is the only known way to increase the splitting of the double superconducting transition [1]. This increase has been correlated with an increase in the ordered moment associated with anomalous small-moment antiferromagnetism (SMAF) [2]. Also, it has been shown that Pd-substitution both suppresses the superconducting T_c to 0 K at $x_c \simeq 0.007$ [3] and induces conventional large-moment antiferromagnetism (LMAF) for $x > x_c$ [4]; the phase diagram for $x \leqslant 0.02$, from resistivity [3] and μSR measurements [5,6], is shown in Fig. 1. It is strongly suggestive of a competition between superconductivity (SC) and static magnetic ordering (LMAF), as expected for a spin-fluctuation-based pairing mechanism.

Apart from the nature of, and distinction between, the SMAF and LMAF phases, the phase diagram in Fig. 1 raises interesting questions. A quantum phase transition (QPT) may occur if the phase lines indeed go to $T = 0$ K near $x = 0.007$. The QPT could be of magnetic origin, as observed in other heavy fermion systems (see Ref. [7]), or possibly be associated with superconductivity [8,9]. Here we present initial studies of these possibilities.

First, we examine the temperature-dependent resistivity of $U(Pt_{1-x}Pd_x)_3$ for $x \leqslant 0.02$ and for $T \leqslant 1$ K for a variety of polycrystal and single-crystal samples. Pure UPt_3 has a Fermi liquid-like low-T resistivity with a quadratic T-dependence. As Pd is substituted in for Pt, we observe a clear deviation from quadratic behavior. The quadratic term is thought to arise from spin-fluctuation scattering, and the resistivity can be written $\rho(T) = \rho_0 + A(T/T_{sf})^2$, where T_{sf} is the spin-fluctuation temperature (roughly 18 K in pure UPt_3 [10]). This holds only when $T \ll T_{sf}$. The observed deviation could be explained within a Fermi liquid picture if T_{sf} was reduced by well over a factor of two for Pd concentrations of $x = 0.005$; this is inconsistent with thermodynamic measurements.

The data is best described by $\rho(T) = \rho_0 + AT^{\alpha}$, with α varying from 2 for $x = 0$ to 1.6 for $x \simeq x_c$; from limited data above $x = 0.01$ it appears that α either stays constant, or increases weakly, for $x > x_c$ (see Fig. 2). This suggests that a quantum phase transition (QPT) exists near x_c, associated with either T_c or the Néel temperature T_N approaching 0 K. The value 1.6 is near the predicted value of 1.5 for 3D critical fluctuations with dynamic exponent $z = 2$ [11].

Transport data for a polycrystalline sample with $x = 0.004 < x_c$ is shown in Fig. 3 for ambient pressure ($T_c = 0.25$ K) and 10 kbar. Data for the suppression of T_c will be presented elsewhere, but T_c approaches 0 K at

* Corresponding author. Fax: + 1-617-552-8478.
E-mail address: grafm@bc.edu (M.J. Graf)

0921-4526/00/$ - see front matter © 2000 Elsevier Science B.V. All rights reserved.
PII: S0921-4526(99)02553-3

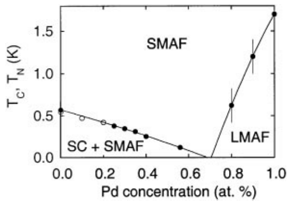

Fig. 1. $U(Pt_{1-x}Pd_x)_3$ phase diagram, $x \leqslant 0.02$ (open and solid symbols for single and polycrystals, respectively).

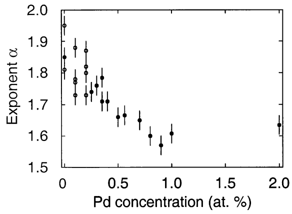

Fig. 2. Power-law exponent versus Pd concentration.

10 kbar. While the coefficient of the temperature-dependent resistivity is reduced, the exponent $\alpha = 1.77$ is pressure independent, suggesting that if a QPT exists it may be associated with the magnetic transition. We are currently studying the pressure-dependent transport of samples with $x \geqslant x_c$ to determine the change in α as the LMAF T_N approaches 0 K.

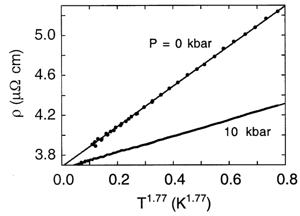

Fig. 3. Pressure dependence of the resistivity, $x = 0.004$.

Acknowledgements

Work was supported by Research Corporation (RA0246), NATO (CG960116) and by the Dutch funding agency FOM; the NHMFL is sponsored by the NSF and the State of Florida.

References

[1] T. Vorenkamp et al., Phys. Rev. B 48 (1993) 678.
[2] R.J. Keizer et al., Phys. Rev. B 60 (1999) 10527.
[3] M.J. Graf et al., Physica B 259–261 (1999) 666.
[4] A. de Visser et al., Physica B 230–232 (1997) 49.
[5] R.J. Keizer et al., J. Phys.: Condens. Matter 11 (1999) 8591.
[6] A. de Visser, M.J. Graf et al., in preparation.
[7] P. Coleman, Physica B 261 (1999) 353, and references therein.
[8] R. Ramazashvili, Phys. Rev. B 56 (1997) 5518.
[9] R. Ramazashvili, P. Coleman, Phys. Rev. Lett. 79 (1997) 3752.
[10] J.O. Willis et al., Phys. Rev. B 31 (1985) 1654.
[11] A.J. Millis, Phys. Rev. B 48 (1993) 7183.