Search for a quantum phase transition in \( \text{U(Pt}_1-x\text{Pd}_x)_3 \)

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Abstract

Pd in \( \text{U(Pt}_1-x\text{Pd}_x)_3 \) suppresses the superconducting \( T_c \) to 0 K at \( x \geq x_c \). The resistivity below 1 K for \( x \leq 0.02 \) shows a deviation from Fermi liquid behavior described by \( \rho(T) = \rho_0 + AT^z \); \( z \) varies from 2 for \( x = 0 \) to 1.6 for \( x \approx x_c \). 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 \( z = 1.77 \), suggesting that if a QPT exists it may be associated with the magnetic transition. © 2000 Elsevier Science B.V. All rights reserved.

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Pd-substitution is a powerful technique for studying superconductivity, magnetism, and their interplay in \( \text{U(Pt}_1 \) 0.007 and induces a conventional AFM state for \( x \geq x_c \). The resistivity below 1 K for \( x \leq 0.02 \) shows a deviation from Fermi liquid behavior described by \( \rho(T) = \rho_0 + AT^z \); \( z \) varies from 2 for \( x = 0 \) to 1.6 for \( x \approx x_c \). 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 \( z = 1.77 \), suggesting that if a QPT exists it may be associated with the magnetic transition. © 2000 Elsevier Science B.V. All rights reserved.

First, we examine the temperature-dependent resistivity of \( \text{U(Pt}_1-x\text{Pd}_x)_3 \) for \( x \leq 0.02 \) and for \( T \leq 1 \) K for a variety of polycrystal and single-crystal samples. Pure \( \text{U(Pt}_1 \) 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 \( \rho(T) = \rho_0 + A(T/T_d)^2 \), where \( T_d \) is the spin-fluctuation temperature (roughly 18 K in pure \( \text{U(Pt}_1 \)). This holds only when \( T < T_d \). The observed deviation could be explained within a Fermi liquid picture if \( T_d \) 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 \( \rho(T) = \rho_0 + AT^z \), with \( z \) varying from 2 for \( x = 0 \) to 1.6 for \( x > x_c \); from limited data above \( x = 0.01 \) it appears that \( z \) 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

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Fig. 1. U(Pt$_{1-x}$ Pd$_x$)$_3$ phase diagram, $x \leq 0.02$ (open and solid symbols for single and polycrystals, respectively).

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

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

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References