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Effect of high pressure and magnetic field on the electrical resistivity of YbAgCu₄

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Abstract

The electrical resistivity of YbAgCu₄ has been measured at pressures up to 100 kbar and at temperatures between 1 and 300 K. With increasing pressure, the resistivity maximum shifts to lower temperatures and the coherent regime disappears above about 60 kbar. At the highest pressures, a field of 8 T produces a large negative magnetoresistance, roughly equivalent to a negative pressure of 30 kbar. The behavior is consistent with a pressure-induced decrease in the Kondo temperature.

The compound YbAgCu₄ has a cubic-crystal structure and is one of the few Yb-based heavy-fermion compounds with a large linear coefficient of specific heat $\gamma = 245 \text{ mJ/mol K}^2$ [1]. At ambient pressure, this compound shows no phase transition down to 80 mK and has a relatively large T^2 -coefficient of resistivity ($A = 0.06 \mu\Omega \text{ cm/K}^2$) that persists up to 15 K [2]. Unlike Ce- and U-based heavy-fermion compounds in which pressure P depresses the heavy-mass state, as evidenced by decreases in γ and A , pressure enhances A in YbAgCu₄ for $P \leq 18.3$ kbar. This behavior has been interpreted as due to a decrease in the Kondo temperature (T_K) with increasing P and suggests that for sufficiently high P the Kondo scale would eventually become smaller than the RKKY scale and YbAgCu₄ should order magnetically at some elevated pressure [2]. Evidence for this trend has been reported for YbCuAl which has a γ at $P = 0$ comparable to that of YbAgCu₄ and which

appears to order magnetically for $P \geq 100$ kbar [3]. With the objective of observing magnetic ordering in YbAgCu₄, we have measured the resistivity $\rho(T)$ between 1.2 and 300 K and at $P \leq 100$ kbar.

The sample was prepared by melting a mixture of stoichiometric amounts of Yb, Ag, and Cu which were sealed in a tantalum tube. The melt was slowly cooled to room temperature, allowing the growth of polycrystalline YbAgCu₄. Electrical resistivity measurements were carried out using a standard four-probe configuration and a LR-400 AC resistance bridge. The pressure was generated in a Bridgman-type cell with steatite as the pressure transmitting medium and lead as a pressure manometer.

The electrical resistivity ρ as a function of T is plotted at various pressures in Fig. 1. Inspection of the low-temperature behavior in the inset shows that the T^2 -coefficient and the residual resistivity $\rho(1.2 \text{ K})$ increase with pressure while the temperature range over which $\rho \propto T^2$ is reduced with increasing pressure. For $P > 60$ kbar there is no evidence for a coherent regime ($\rho \propto T^2$) above 1.2 K. These observations are consistent with a strongly

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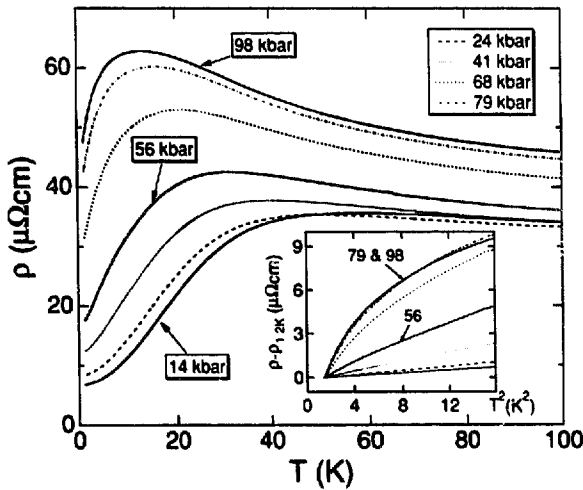


Fig. 1. Electrical resistivity ρ versus temperature T of YbAgCu_4 at various pressures between 14 and 98 kbar. Inset: [$\rho - \rho(1.2 \text{ K})$] as a function of T^2 at the same pressures.

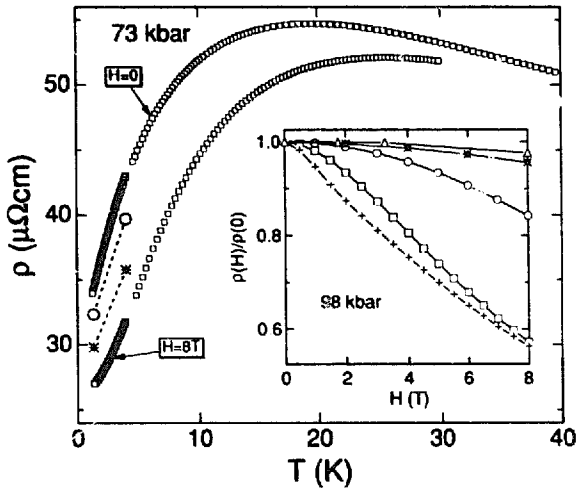


Fig. 2. Electrical resistivity ρ versus temperature T of YbAgCu_4 at 73 kbar in 0 and 8 T. Data points for intermediate fields of 4 T (circles) and 6 T (stars) are also shown. The broken lines are guides to the eye. Inset: Normalized magnetoresistance $\rho(H)/\rho(H = 0)$ as a function of the magnetic field H at 98 kbar and temperatures of 1.3 K (bottom curve), 4, 15, 33 and 41 K (upper curves).

volume-dependent reduction of the conduction electron-Yb localized 4f electron antiferromagnetic coupling constant J and are in agreement with Doniach's phase diagram [4]. Therefore, from the expression $T_K \propto \exp(-1/JN(E_F))$, where $N(E_F)$ is the density-of-

states at the Fermi energy, we expect a smaller Kondo temperature at higher pressures. The evolution of $\rho(1.2 \text{ K})$ and A then suggests that both are proportional to T_K^{-c} , with the exponent c of the order of 0.5 and 2-2.5, respectively, as argued by Flouquet et al. and Barbara et al. [5, 6]; i.e. for YbAgCu_4 the low- T transport is increasingly dominated by Kondo spin fluctuations at high pressure. If this is so, we would expect $\rho(\text{low-}T)$ to diminish with applied field since a magnetic field should suppress the spin fluctuations. Figure 2 shows that this is the case. For $P = 73 \text{ kbar}$ and high fields, we see that a $\rho \propto T^2$ behavior is recovered and $\rho(1.2 \text{ K})$ and the T^2 -coefficient decrease with increasing H . Comparing the resistivity curves of $P = 73 \text{ kbar}$ and $H = 8 \text{ T}$ with $P = 56 \text{ kbar}$ and $H = 0$ suggests that an 8 T field is roughly equivalent to a negative pressure of 15 kbar. At 98 kbar a magnetic field of 8 T modifies the resistivity curve even more significantly and corresponds to a negative pressure of more than 30 kbar. To our knowledge, this is the first example where P and H exhibit opposite (but consistent) effects on the low-temperature resistivity of a heavy-fermion compound. These results support strongly that $\rho(\text{low-}T)$ is dominated by Kondo-spin fluctuations. The inset of Fig. 2 shows the large negative magnetoresistance above and below T_K which confirms the important role of Kondo spin fluctuations in the scattering process at low temperature. No magnetic phase transition has been found above 1.2 K and pressures as high as 98 kbar (Fig. 1).

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