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The high-pressure effect of an electronic state in uranium compounds: $UPtGa_5$ and UN

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Abstract
We studied the electronic states of two antiferromagnets, $UPtGa_5$ and UN, by measuring the electrical resistivity under pressure. When pressure P is applied, the Néel temperature T_N decreases, becoming zero at $P_c = 8.0$ GPa for $UPtGa_5$ and $P_c = 3.5$ GPa for UN.

1. Introduction

Application of pressure is a useful experimental method for controlling the magnetic interaction and hybridization between the f electrons and conduction electrons in uranium and cerium compounds, where the RKKY interaction and the Kondo effect compete with each other [1]. As pressure is applied to these compounds with magnetic order, the magnetic ordering temperature decreases, becoming zero at the quantum critical pressure P_c, because the Kondo effect overcomes the RKKY interaction. Around this critical region, the non-Fermi liquid nature and/or superconductivity appear. In the present study, we studied two antiferromagnets, $UPtGa_5$ and UN, by measuring the electrical resistivity under pressure. The present results indicate a strong pressure effect for magnetic ordering of two antiferromagnets.

2. Experimental results and analyses

$UPtGa_5$ with the tetragonal structure orders antiferromagnetically below 26 K ($=T_N$). From neutron diffraction experiments, magnetic moments of uranium ions are found to be aligned ferromagnetically in the (001) plane, directed along the [001] direction [2]. The ordered moment is 0.24 μ_B/U and the electronic specific heat coefficient γ is reported as 57 mJ K^{-2} mol^{-1}. Figure 1 shows a temperature dependence of the electrical resistivity at ambient pressure and under various pressures.

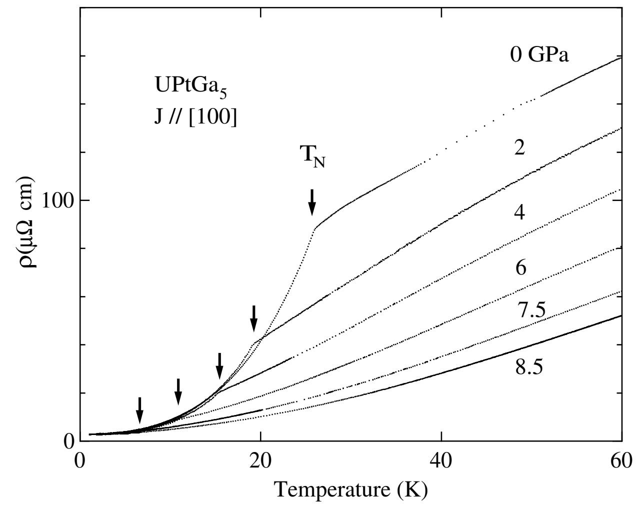

Figure 1. The temperature dependence of the electrical resistivity ρ under pressure for $UPtGa_5$.

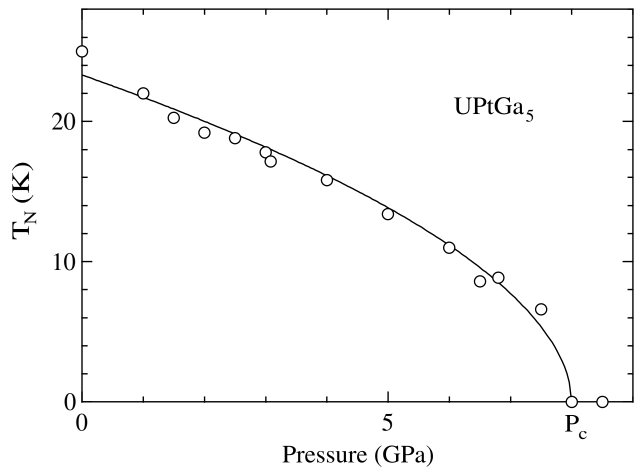

Figure 2. The pressure dependence of T_N for $UPtGa_5$.

Here pressure was applied by using a cubic anvil apparatus [3]. At ambient pressure, the resistivity decreases steeply below T_N. With increasing pressure, the Néel temperature decreases smoothly as shown by arrows in figure 1. We show in figure 2 the pressure dependence of the Néel temperature, where a solid curve for $T_N(P) = T_N(P = 0)(1 - \frac{P}{P_c})^n$ with $T_N(P = 0) = 23$ K and $n = 0.53$ provides a guide. The critical pressure P_c is estimated as 8 GPa. Here we note that the low-temperature resistivity follows a Fermi liquid relation: $\rho = \rho_0 + AT^2$, below 5 K. The values of A and ρ_0 are approximately unchanging against pressure.

UN with the cubic NaCl-type structure also orders antiferromagnetically below $T_N = 53$ K, with the type-I antiferromagnetic structure [4]. Its ordered moment is 0.75 μ_B/U and the electronic specific heat coefficient γ is 50 mJ K^{-2} mol^{-1}.

We measured the resistivity of UN under pressure, as shown in figure 3. At ambient pressure, a small but sharp hump is observed at $T_N = 53$ K. On applying pressure, the hump

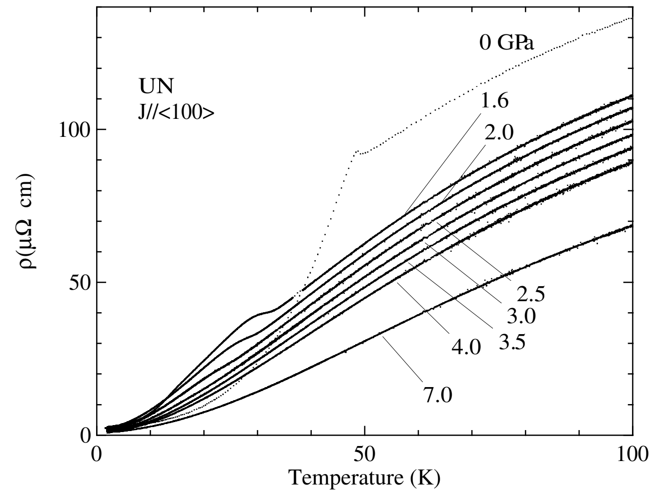

Figure 3. The temperature dependence of the electrical resistivity ρ under pressure for UN.

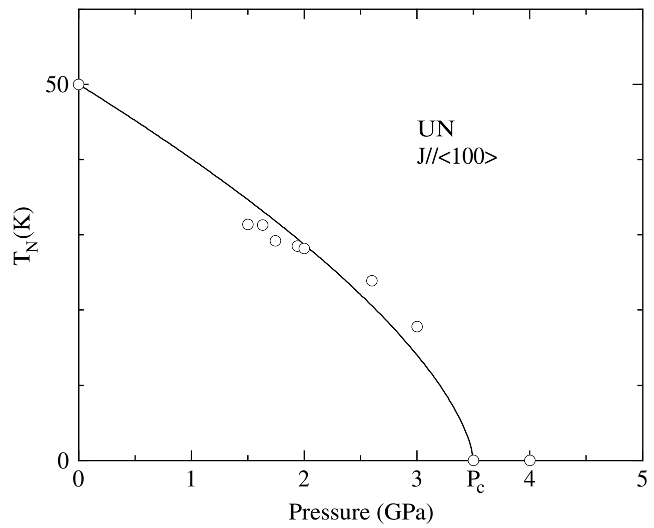

Figure 4. The pressure dependence of T_N for UN.

becomes broad but can be observed up to 3 GPa. Figure 4 shows the pressure dependence of the Néel temperature, where a solid curve for $T_N(P) = T_N(P = 0)(1-\frac{P}{P_c})^n$ with $T_N(P = 0) = 50$ and $n = 0.65$ K provides a guide. The critical pressure P_c is estimated as 3.5 GPa. The resistivity follows the Fermi liquid relation $\rho = \rho_0 + AT^2$ below 7 K. Figure 5 shows the pressure dependence of the A- and ρ_0-values. The A-value has a maximum at 2 GPa, while the ρ_0-value decreases steeply below about 2 GPa.

3. Summary

Pressure changes the electronic state from the antiferromagnetic state to the paramagnetic one for two antiferromagnets, UPtGa$_5$ and UN. We determined the critical pressure P_c as 8.0 GPa for UPtGa$_5$ and 3.5 GPa for UN.

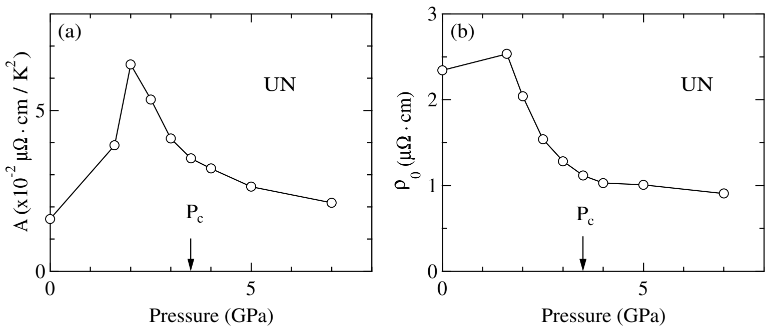

Figure 5. The pressure dependence of the A- and ρ_0-values of UN.

The low-temperature resistivity follows the Fermi liquid relation, but the relations of the A- and ρ_0-values versus pressure are not simple for either compound. The A- and ρ_0-values are unchanging against pressure for $UPtGa_5$, while both values show a change below P_c for UN. We note, however, that our previous measurement for a similar antiferromagnet, $UNiGa_5$, indicated that the A-value has a maximum at P_c but the ρ_0-value decreases monotonically with increasing pressure [5]. The electronic state at P_c is highly compound dependent.

Acknowledgments

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