Title: Effect of Pressure on the Electrical Resistivity and Magnetism in UPdSn

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Effect of pressure on the electrical resistivity and magnetism in UPdSn

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Running title: Effect of pressure on the magnetism of UPdSn

Abstract

The electrical resistivity of a UPdSn single crystal exerted to various hydrostatic pressures was measured as a function of temperature and magnetic field. Clear anomalies in the temperature dependence of resistivity along the c-axis mark the magnetic phase transitions between paramagnetic and antiferromagnetic (AF) state at \( T_N \) and the AF1\( \leftrightarrow \)AF2 transition at \( T_1 \). Large negative magnetoresistance effects have been observed not only in the AF state as a result of the metamagnetic transition to canted structure at \( B_c \), but also at temperatures far above \( T_N \). The latter result is attributed to the existence of AF correlations or short range AF orderings in the paramagnetic range. The value of \( T_N \) increases with increasing applied pressure, whereas \( T_1 \) simultaneously decreases. It is also found that \( B_c \) decreases with increasing pressure. As a consequence, the stability range of the AF-1 phase expands with applied pressure partially on account of the ground-state AF-2 phase.

Keywords: UPdSn, electrical resistivity, magnetoresistance, single crystal, high pressure;

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1. INTRODUCTION

UPdSn orders antiferromagnetically (AF-1) below $T_N = 37$ K and undergoes an magnetic order-order phase transition to the ground state AF-2 phase at 25 K ($= T_i$) [1,2]. The magnetic moments of U are aligned in the $bc$-plane in AF-1 phase and below $T_i$, they turn out of the $bc$-plane by about 45° in forming the AF-2 phase. In magnetic fields $B (> B_c)$ applied within the $ab$-plane the AF-2 phase is transformed towards a canted antiferromagnetic state (CAF) with a non-negligible spontaneous moment [1]. The magnetic phase transitions in UPdSn are accompanied by considerable electrical resistivity anomalies [3]. In order to elucidate the stability of those magnetic phases under pressure, we measured the electrical resistivity as a function of temperature, $\rho(T)$, and magnetic field, while applying various hydrostatic pressures up to 0.95 GPa.

2. EXPERIMENTAL PROCEDURE

The UPdSn single crystal has been grown by Czochralski method in a tri-arc furnace. The electrical resistivity for current along the $c$-axis was measured by means of a standard four-probe method using an AC resistance bridge. We used a conventional clamp type piston-cylinder device with mineral oil as a transmitting medium. This pressure cell was designed and built for the 20-T superconducting magnet at the Pulse Field Facility, NHMFL, LANL. Using this setup we have measured the electrical resistance of UPdSn in magnetic fields up to 18 T applied within the $ab$-plane and in hydrostatic pressures up to 0.95 GPa (value at room temperature).

3. RESULTS AND DISCUSSION

Fig.1 shows the $\rho(T)$ curves measured at a pressure of 0.95 GPa for several values of magnetic field. The pressure development of $\rho(T)$ measured in zero field is shown in the inset. The two clear anomalies on the $\rho(T)$ curves determined from their temperature derivatives, $d\rho/dT$, which are indicated by arrows in zero-field data, are attributed to the magnetic phase transitions at $T_N$ and $T_i$. As can be seen in the inset, $T_N$ increases ($T_i$ decreases) with increasing pressure with a rate of 1.9 K/GPa (-1.9 K/GPa), i.e. the stability range of the AF-1
phase expands with pressure. The positive pressure effect on $T_N$ (which is consistent with a previously published result [4]) can be connected with existence of large stable U magnetic moments, which corroborates the scenario of UPdSn physics considering the $5f$-electron states close to localization [2]. Because in the localized system, the exchange integrals become enhanced with reducing inter-atomic distances between magnetic ions while the magnetic moments are conserved, characteristic temperature increases with increasing pressure. It is also found that the $T_1$-related resistivity anomaly becomes gradually broadened with increasing pressure.

Also when applying magnetic field the $T_1$-related resistivity anomaly is suppressed rapidly, which indicates only one field-induced CAF phase at temperatures up to $T_N$. The $T_N$-related anomaly is shifted with field of 18 T to a somewhat higher temperature, which reflects the gradually increasing spontaneous-moment component in the CAF phase. The resistivity values at this anomaly become strongly suppressed with field. The considerable field-induced reduction of resistivity decays with increasing temperature above $T_N$, nevertheless it can be traced up to 150 K.

Fig.2 presents the effect of pressure on the magnetoresistance (MR), where magnetoresistance $\Delta \rho/\rho$ [%] is defined as $(\rho(B)-\rho(0))/\rho(0)$. The figures (a) and (b) show the MR curves at 3.5 K under various pressures and those measured on UPdSn exerted to a hydrostatic pressure of 0.95 GPa at various temperatures, respectively. Below $T_1$, both the dramatic decrease of electrical resistivity and the hysteresis accompany the AF-2 $\leftrightarrow$ CAF magnetic phase transition. It is found that the onset field of this transition, $B_c$, decreases and the hysteresis becomes larger with increasing pressure. This behavior can be connected with magnetoelastic phenomena of this compound. From the thermodynamical point of view, the volume of the CAF phase is considered to be smaller than that of AF-2, since $dB_c/dp < 0$. Due to the external force (pressure), the latent heat at the transition increases, making larger hysteresis loops. It is also found that the magnetoresistance ratio after the transition in 0.7 GPa is twice bigger than that in 0.3 GPa. It can be assumed that this considerable change in magnetoresistance reflects the change of canting angle of the magnetic moments (or magnetic structure).

The change of slope of the 30-K MR curve around 3 T, shown in Fig.2(b), can be attributed to the onset of transition from the AF-1 phase to the CAF phase. Pronounced negative magnetoresistance phenomena were also found at temperatures above $T_N$. Although decaying with increasing temperature, a considerable negative MR effect (~10%) is still seen
This result together with temperature dependence of the electrical resistivity data in Fig. 1 can be conceived with a scenario considering a strongly enhanced conduction-electron scattering on AF correlations or short-range AF ordered U moments, which persist in the paramagnetic range at temperatures far above $T_N$, but can be suppressed in sufficiently large magnetic fields. It is suggested that the AF correlation is not so sensitive to the inter-atomic distances, because the effect of pressure on the MR in paramagnetic region is negligible in this pressure range. To prove the relevance of this scenario, microscopic experiments, especially neutron scattering under pressure and electrical resistivity measurements under higher pressure are desirable.

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REFERENCES

FIGURE CAPTIONS

FIGURE 1  The temperature dependence of electrical resistivity of UPdSn at a pressure of 0.95 GPa in various magnetic fields. Inset shows the pressure-induced development of $\rho(T)$ in zero magnetic field.

FIGURE 2  (a) MR at 3.5 K under high pressure; (b) MR curves measured at selected temperatures under pressure 0.95 GPa.
Fig. 1 (F. Honda et al., EPRG 2002)
Fig. 2 (F. Honda et al., EHPRG 2002)