LA-UR-02-7296

Approved for public release; distribution is unlimited.

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

Author(s): F. Honda, A. Alsmadi, V. Sechovsk, J. Kamarak, H. Nakotte, A. H. Lacerda, M. Mihalik

Submitted to: 40th European High-Pressure Research Group
High Pressure Research-2003

Los Alamos
NATIONAL LABORATORY

Effect of pressure on the electrical resistivity and magnetism in UPdSn

F. Honda[a], A. Alsmadi[b], V. Sechovsk_[a], J. Kamarád[c], H. Nakotte[b], A.H. Lacerda[d] and M. Mihálik[c]

[a] Department of Electronic Structures, Charles University, 121 16 Prague 2, The Czech Republic

[b] State University of New Mexico, Las Cruces, NM88003, USA

[c] Institute of Physics, Academy of Sciences CR, 181 21 Prague 8, The Czech Republic

[d] National High Magnetic Field Laboratory, LANL, MS E 536 Los Alamos, NM87545, USA

[e] Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, Kosice, Slovakia

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↔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;

Address for correspondence:

F. Honda, KFES MFF UK, Ke Karlovu 5, 12116 Prague 2, The Czech Republic

phone: +420 2 21911353, fax: +420 2 21911351, e-mail: honda@apollo.karlov.mff.cuni.cz

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_1) [1,2]. The magnetic moments of U are aligned in the *bc*-plane in AF-1 phase and below T_1, 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 build 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_1. As can be seen in the inset, T_N increases (T_1 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.

ACKNOWLEDGEMENT

This work is a part of the research program MSM113200002 that is financed by the Ministry of Education of the Czech Republic and is partially supported by the Grant Agency of Czech Republic (grant # D202/01/D045) and by NSF (grant number: DMR-0094241). The work at the NHMFL Los Alamos was performed under the auspices of the NSF (INT-9722777), the US Department of Energy and the State of Florida.

REFERENCES

[1] H. Nakotte, R.A. Robinson, A. Purwanto, Z. Tun, K. Proke_, E. Brück, F.R. de Boer, Antiferromagnetism and domain effects in UPdSn, *Phys. Rev. B*, **58**, 9269 (1998).

[2] V. Sechovsk_ and L. Havela, *Handbook of Magnetic Materials*, [North Holland, Amsterdam, 1998], Vol. **11**, p. 1 and references therein.

[3] F.R. de Boer, E. Brück, H. Nakotte, A.V. Andreev, V. Sechovsk_, L. Havela, P. Nozar, C.J.M. Denissen, K.H.J. Buschow, B. Vaziri, M. Meissner, H. Maletta, P.V. Rogl, Magnetic, electrical, and specific-heat properties of UPdSn and UAuSn, *Physica B*, **176**, 275 (1992).

[4] M. Kurisu, H. Kawanaka, T. Takabatake, H. Fujii, Pressure-dependence of the electrical-resistivity and T_N of the ternary uranium antiferromagnets UNiSn, UPdIn and UPdSn, *J.Phys.Soc.Jpn.*, **60**, 3792 (1991).

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.

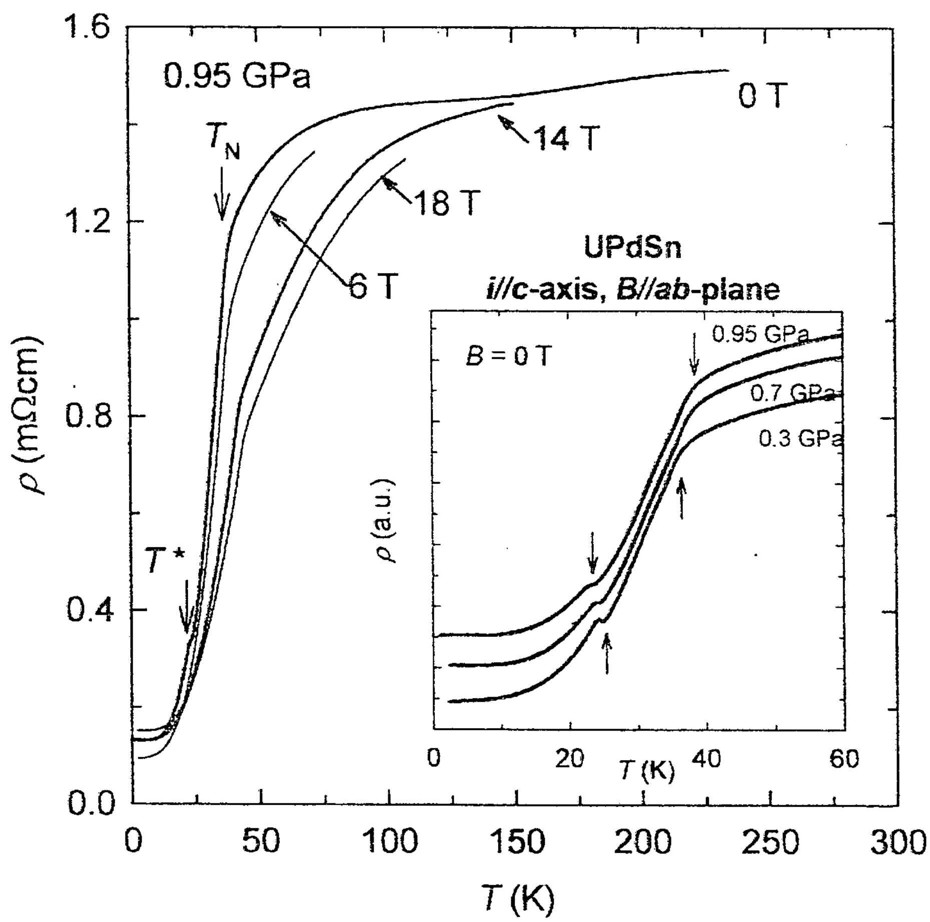

Fig.1 (F. Honda et al., EHPRG 2002)

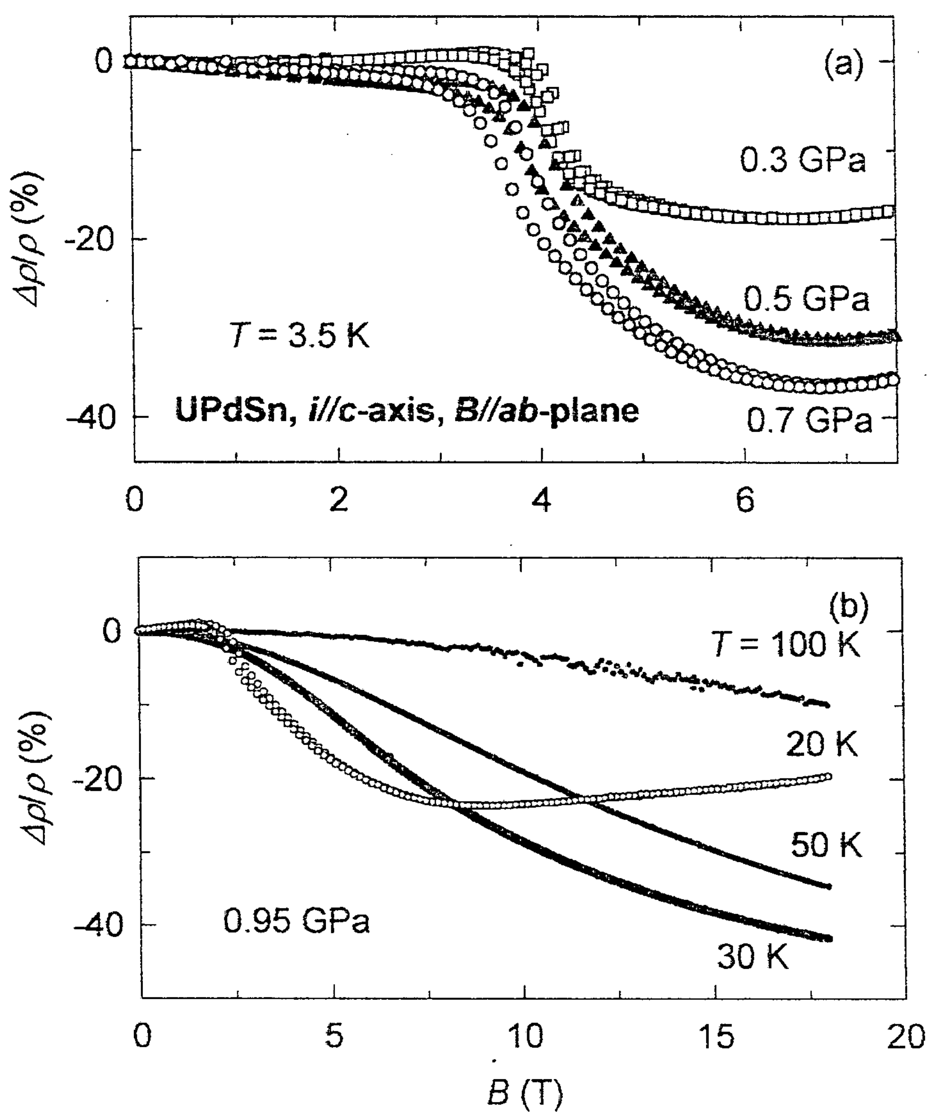

Fig.2 (F. Honda et al., EHPRG 2002)