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MAGNETIC PROPERTIES OF CePtSn UNDER PRESSURE*

B. Janoušová[a], V. Sechovský[a], Yu.V. Sushko[b]
and T. Komatsubara[c]

[a]Dept. of Electronic Structures, Charles University
121 16 Prague 2, Czech Republic
[b]Dept. of Physics and Astronomy, Univ. of Kentucky
Lexington, KY 40506-0055, USA
[c]Dept. of Physics, Graduate School of Science, Tohoku Univ.
Sendai 980-8578, Japan

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We report on magnetic susceptibility measurements on a CePtSn single crystal under hydrostatic pressures up to 0.82 GPa. Application of hydrostatic pressure on CePtSn leaves both the Néel temperature T_{N} and the AF1–AF2 transition temperature T_{M} nearly intact. This is rather unexpected because the volume contraction was believed to be the main reason for the transformation from the antiferromagnetic Kondo metal with $T_{\mathrm{N}} = 7.5$ CePtSn to a non-magnetic Kondo semi-metal CeNiSn G.M. Kalvius *et al.*, *Physica B* **289–290**, 256 (2000). The only pressure effect observed is a 25% reduction of low-temperature magnetization by the pressure of 0.82 GPa. A possible scenario for physics of CePtSn is discussed accounting for the observed pressure effects.

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1. Introduction

Within the CeTX series, CePtSn and CeNiSn are those of the most interesting compounds. CeNiSn is a Kondo semi-metal with a very low carrier density [2]. Peculiar physical properties of CeNiSn are explained in terms of a narrow gap (∼ 5 meV) in the density of states near the Fermi level and a spin gap in the spectrum of coherent antiferromagnetic (AF) excitations at low temperatures [3]. CePtSn is a highly anisotropic Kondo metal that exhibits three magnetic phase transitions at 7.5, 5.0 and 2.5 K [4–6]. All the three magnetic phases are AF with the magnetic propagation vector close to 1/2 b*.

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Physics of CePtSn can be strongly influenced by substitution of Ni for Pt [7]. The unit cell volume decreases monotonically with Ni doping, which is tentatively attributed to a gradual enhancement of the hybridization of Ce-4f electron states with conduction electron states. As a consequence, the magnetic properties of Ce(Pt,Ni)Sn are altered. The loss of magnetism in the $\mathrm{CePt}_{1-x}\mathrm{Ni}_x\mathrm{Sn}$ series around $\mathrm{x}_{\mathrm{cr}} \sim 0.7$ corresponds to a volume reduction by approximately 1.5%.

This was beleived to be due to the enhanced Kondo effect with respect to the RKKY interaction, as corroborated by photoemission studies [8].

The unit cell volume contraction can be achieved also by applying hydrostatic pressure. Such an experiment has one big advantage over the chemical pressure — it avoids changes of electronic structure and structural disorder.

2. Experimental

A single crystal of CePtSn was grown under Ar atmosphere by Czochralski method employing a tri-arc furnace from melt of Ce (4 N), Pt (3 N) and Sn (5 N). The crystal quality was checked by X-rays and thermal-neutron diffraction. Microprobe analysis did not reveal any significant off-stoichiometry. Approximately 8 mm^3 rectangular-shaped sample was cut with faces parallel to the three principal crystallographic directions.

The DC magnetization (susceptibility) measurements over the temperature range 2–300 K, in a magnetic field 0–5.5 T (applied along the crystallographic a and b-axes) and in hydrostatic pressures up to 0.82 GPa were carried out with the commercial SQUID magnetometer (Quantum Design). The application of high pressures was enabled by employing a specially designed 180 mm long Cu-Be pressure cell, linked via a Cu-Be capillary (3 mm o.d./0.3 mm i.d.) to a compressor.

3. Results

Fig. 1 shows the temperature dependence of susceptibility in the range 1.8–8 K in $B = 0.01$ T $\parallel$ a-axis. The temperature of the sharp peak corresponding to T_{N} (in this case = 6.8 K) stays visibly unaffected by applied pressure. The same holds for $T_{\mathrm{M}} \sim 5.0$ K which is manifest by a change of slope on the susceptibility curve. The only considerable pressure effect is a remarkable (25%) reduction of the magnetization at T_{N} in the pressure of 0.82 GPa. Similar effects were observed for $B = 5.5$ T where the two magnetic phase transitions lie closer to each other ($T_{\mathrm{N}} = 6.5$ K and $T_{\mathrm{M}} = 5.2$ K). Also here, the transition temperatures don't differ from the ambient pressure values.

Another magnetic phase transition is indicated in the low-pressure data. At ambient pressure the susceptibility exhibits a temperature hysteresis (from 2.4 K to 3.5 K). This transition has been previously revealed by neutron diffraction as a slight change of the magnetic propagation vector and enhancement of intensity of the corresponding magnetic peak. Both features show the same temperature hysteresis [9]. This transition is suppressed by applied hydrostatic pressure and disappears already at ~ 0.1 GPa.

The a-axis is an easy magnetization axis of CePtSn, which means that the biggest effect should be observed for $B \parallel a$-axis. This is also justified by the results for $B \parallel b$-axis which, again, show no change in transition temperature values but the magnetization is also reduced, in this case only by 2 % at 0.83 GPa.

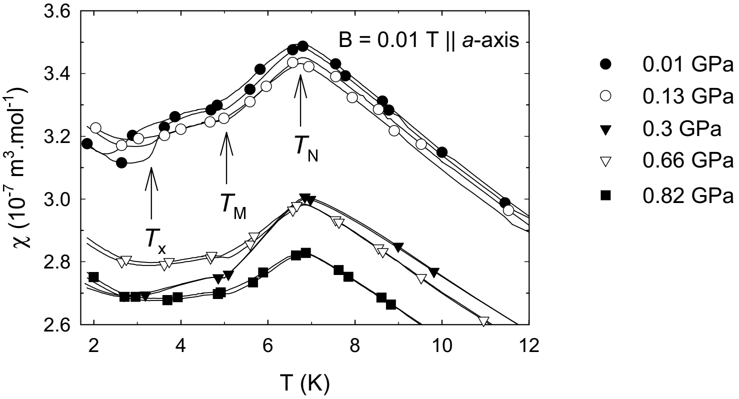

Fig. 1. Temperature dependence of susceptibility for $B = 0.01$ T applied along the a-axis. Data taken with step 0.1 K, for clarity only every 15th point is shown. Transition temperatures are pointed up by arrows.

4. Discussion

The observed value of $T_{\mathrm{N}} = 6.8$ K is by 0.7 K lower than the previously reported one [4–6] but is in good agreement with our recent neutron diffraction data performed on the same crystal [9]. The difference may be attributed to slight stoichiometry deviations of crystals used in different laboratories.

The magnetic-phase-transition temperatures (T_{N} and T_{M}) seem remaining intact in pressures up to 0.82 GPa. This was not expected from the analysis of results observed on compounds of the quasi-ternary series $\mathrm{CePt}_{1-x}\mathrm{Ni}_x\mathrm{Sn}$. If only the effect of the unit cell volume reduction was involved in the transformation between the AF ordering in CePtSn and the non-magnetic ground state in Ni-rich compounds one would observe an analogous evolution of magnetism in our pure experiments with CePtSn exerted to a hydrostatic pressure. Then, a sufficiently high pressure should lead to a decrease in T_{N} and, finally, to a complete disappearance of long-range magnetic order.

The observed decrease of magnetic moment in the highest applied pressure may be considered as a precursor of suppression of the long-range order at considerable higher pressures. Since compressibility values are not known for CePtSn no quantitative comparison with chemical pressure can be done at this stage of research.

Our results demonstrate the unit cell volume to be only one of principal parameters for physics of CePtSn and $\mathrm{CePt}_{1-x}\mathrm{Ni}_x\mathrm{Sn}$. The hybridization of the $4f$-electron states with the conduction electron states is not enhanced enough within our pressure experiment to allow the Kondo effect to overpower the RKKY interaction. Experiments extended to considerably higher pressures are strongly desirable to clarify the role of Kondo effect. Since the difference in lattice parameters of CePtSn and CeNiSn is highly anisotropic ($\Delta a/a = +2.05\%$, $\Delta b/b = -0.6\%$ and $\Delta c/c = -5.24\%$ — after [10]) it is possible that it is not the unit cell volume but much more likely the Ce-Ce interatomic distance which governs the hybridization strength. From this viewpoint also uniaxial pressure experiment can give further details.

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