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Magnetoresistance in CePtSn under high hydrostatic pressures

M. Míšek*, J. Prokleška, P. Javorský, V. Sechovský

Charles University, Faculty of Mathematics and Physics, Department of Condensed Matter Physics, Ke Karlovu 5,
121 16 Prague, Czech Republic

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ABSTRACT

We report the evolution of magnetic-history dependent antiferromagnetic phases in CePtSn. We concentrate on the magnetoresistance in magnetic fields up to 14 T applied along the crystallographic *b*-axis, measured on a CePtSn single crystal subjected to hydrostatic pressure ($p \leq 2.2$ GPa) generated in a double-layered CuBe/NiCrAl piston cylinder cell. We observe a gradual increase of the critical field B_c^{LF} of the low field (LF) transition up to ∼1.2 GPa where only one transition is observed at ∼11.5 T. For pressures above 1.2 GPa we observe two transitions again and B_c^{LF} decreases with further increasing pressure to reach $B_c^{LF} \sim 7.5$ T at 2.5 GPa. The position of the high field (HF) transition remains almost unaffected by applied pressure. A scenario considering the spin-slip AF structure in CePtSn is briefly discussed.

1. Introduction

CePtSn belongs to the group of Ce*TX* (*T*—transition element, *X*—p-element) compounds crystallizing in the orthorhombic TiNiSi-type structure (*Pnma* space group). Similar to some Ce*TX* homologues a strong anisotropy of magnetic and other electronic properties is observed in magnetic fields [1].

In zero magnetic field CePtSn undergoes two magnetic phase transitions, one connected with the onset of antiferromagnetic (AF) ordering at $T_N \sim 7.5$ K and the other is a transition between two incommensurate AF phases at $T_t \sim 5$ K [2]. In order to explain the discrepancies between the observation of incommensurate magnetic ordering in the neutron diffraction and the indication for local commensurate ordering from muon spin relaxation experiments, a spin-slip model was proposed [3].

The most interesting and unusual behavior of this compound is observed for the magnetic field applied parallel to the *b*-axis along which the AF structure propagates incommensurably with the crystal lattice and the spin-slips are created. At ambient pressure and low temperatures ($T < 3$ K), two field-induced (AF to AF) transitions are observed for $B_c^{LF} \sim 3.5$ T and $B_c^{HF} \sim 11$ T, respectively [1]. Both the transitions are accompanied by pronounced magnetoresistivity steps (−30% and +10%, respectively), however, only with minor features visible on the magnetization curve. Originally, the low field transition was reported as irreversible and the zero field cooled (ZFC) state restored via heating the sample well above ∼3 K [2]. This phenomenon was explained as a suppression of one of the magnetic phases coexisting at low temperatures. The 11-T transition is reversible, accompanied by observable hysteresis. Recently [4], a more complex behavior was observed on transport and elastic properties, indicating partial restoration of the ZFC state by magnetic field cycling.

In this paper we will discuss the evolution of this history dependent phenomenon studied by electrical resistivity under high hydrostatic pressures up to 2.2 GPa on the single crystal sample.

2. Results

The electrical resistivity measurements were performed with a Quantum Design 14-T Physical Properties Measurement System (PPMS) using a standard four-point method at temperatures down to 2 K and fields up to 14 T. For generating high hydrostatic pressures we used a double-layered CuBe/NiCrAl piston–cylinder cell with Daphne oil as a hydrostatic pressure-transmitting medium. Pressure was determined by the resistivity change of manganin pressure sensor at room temperature and by Pb superconducting (SC) manometer at low temperatures, the hydrostaticity was

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* Corresponding author.
E-mail address: martinmisek@hotmail.com (M. Míšek).

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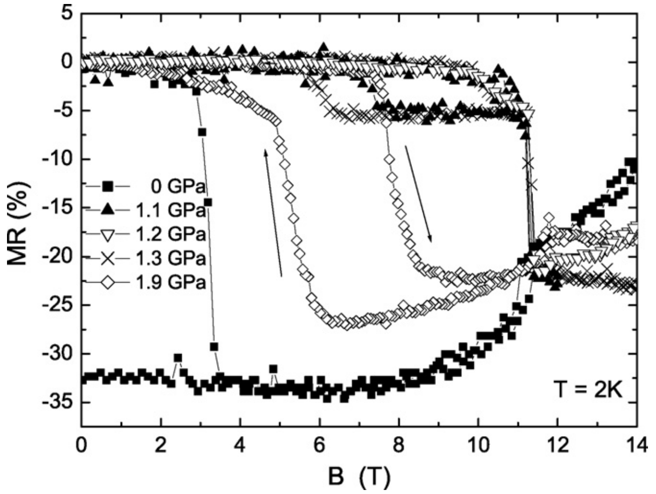

Fig. 1. Field dependence of the electrical resistivity at $T = 2$ K for selected pressures, measured for field applied along the *b*-axis in longitudinal geometry.

check by the examining the width of the Pb SC transition. For clarity, all pressures in this article are related to low temperatures.

Our efforts concentrated on the magnetic history dependent phase and related magnetic phase transitions. With applying hydrostatic pressure (see Fig. 1) the LF transition is shifted to higher fields at a rather high rate (~6.0 T/GPa). The LF transition becomes reversible at any applied hydrostatic pressure, however, it shows a large hysteresis. The position of the HF transition remains intact by applied pressure in our experiment.

As the pressure is increasing the critical field of the LF transition is approaching the B_c^{HF} and the hysteresis is slightly suppressed (see Fig. 2). At ~1.2 GPa the two transitions merge B_c^{LF} and the magnetoresistance behavior is dramatically changed—only one step like transition is observed in fields up to 14 T accompanied by a negative magnetoresistance (see Fig. 3) but no observable hysteresis. This phase border remains unchanged with increasing pressure up to 1.6 GPa, when two transitions similar to the LF situation are restored (see Fig. 1), similar to the low pressure region (i.e. the low field transition with large hysteresis and high field transition without hysteresis). With further pressure increase the B_c^{LF} is decreasing reaching ~7.5 T at 2.2 GPa, whereas the B_c^{HF} remains intact and shows no hysteresis (see Fig. 2). Taking into account the characteristics of the transitions at B_c^{LF} and B_c^{HF} at high pressures (above 1.2 GPa) we assume that phase ordering scheme similar to that at ambient pressure, is restored. However, a notable difference is present—the MR step at B_c^{LF} transition is significantly smaller and full (i.e. 30%) drop is recovered for pressures above 2.0 GPa.

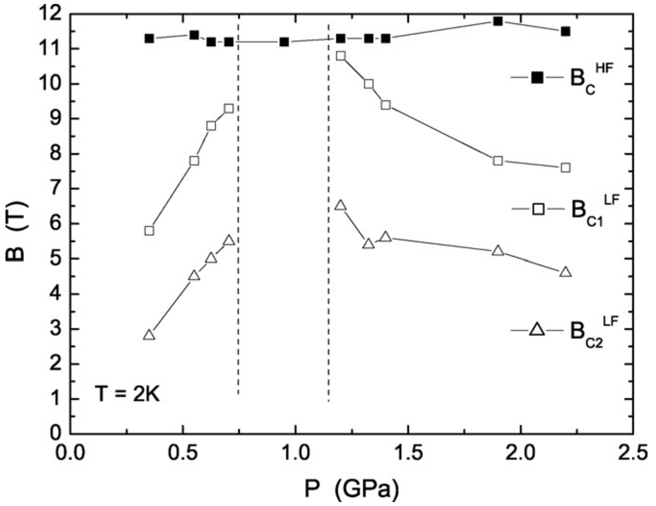

Fig. 2. Pressure dependence of critical fields as determined from the field dependencies at 2 K. B_{c1}^{LF} indicate the lower transition field observed with increasing field, B_{c2}^{LF} observed with decreasing field, respectively. Vertical lines indicate pressure region, where the LF transition was not observed.

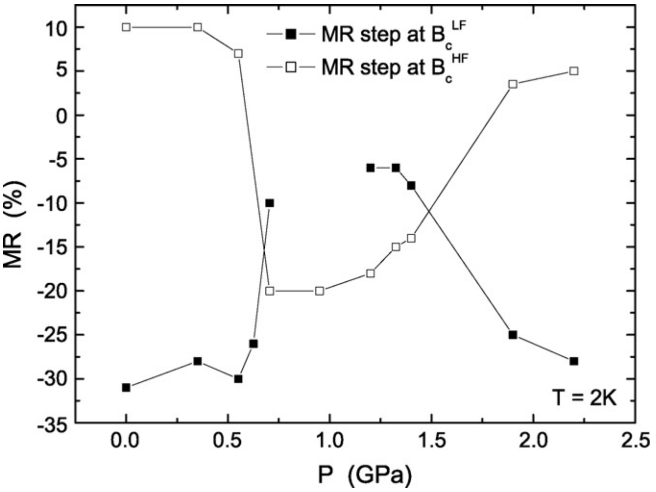

Fig. 3. Pressure dependence of changes accompanying the field induced transitions. MR steps at B_c^{LF} are deduced from B_{c1}^{LF}.

Concerning the magnetic ordering at zero field – as indicated in earlier study [5] the shift of the ordering temperatures with increasing pressure is confirmed and is in an agreement with our recent data – rather small and monotonous ($T_N \sim 8$ K and $T_t \sim 5$ K at 2.2 GPa, respectively). More interesting is the change of the character of the T_t related transition above 1.2 GPa, which is changed from rather featureless change of slope to clearly visible dip in the temperature dependence of the electrical resistivity. Taking into account the decrease between MR step accompanied the low field transition at these pressures and ambient pressure we may conclude that the ratio between AF phases building the ground state is significantly changed.

Definitely, our results show striking sensitivity of the magnetic history dependent phases to the applied hydrostatic pressures. It is clear, that the ground state of CePtSn is very close to the instability as already indicated by strong sensitivity to the stoichiometry and growing conditions. Speaking in the terms of the spin-slip model, the application of the pressure strongly influences the process of 'annealing' of magnetic structure imperfections by applied magnetic field, i.e. the spin stacking faults in different domains (characterized by different propagation vector in single crystal neutron diffraction) have different sensitivity to the applied magnetic fields, furthermore, this sensitivity can be very efficiently tuned by applied hydrostatic pressure. For the detailed discussion the further experiments are necessary, namely microscopic studies (determination of the magnetic moments directions and the evolution of population of different domains) under hydrostatic pressure and uniaxial stress along the *b*-axis.

Acknowledgements

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