Magnetic ordering in NdPtSn

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Abstract

NdPtSn, similar to other RPtSn compounds (R = light rare earth), crystallizes in the orthorhombic TiNiSi-type structure with the space group *Pnma*. We present first results of magnetic and specific-heat measurements on a NdPtSn single crystal at temperatures down to 0.5 K and in magnetic fields up to 9 T. The C_p vs. T dependence indicates two magnetic phase transitions, namely at 2.4 K (second-order) and at 1.9 K (first-order). The temperature dependence of susceptibility shows a maximum at 2.7 K. An S-shape develops on magnetization curves when decreasing temperature below 3 K. We conclude that NdPtSn exhibits an AF ordering below T_N = 2.4 K and undergoes an order-order transition of first-order type at T_M = 1.9 K to the ground state (also AF). A tentative magnetic phase diagram is also presented.

Key words: NdPtSn; antiferromagnetic ordering; magnetic phase transitions

1. Introduction

NdPtSn belongs to the isostructural family of RPtSn compounds (R = La ... Eu) which crystallize in the orthorhombic TiNiSi-type structure with the space group *Pnma*. The only report on NdPtSn claims absence of long-range magnetic order down to 1.5 K [1]. We have commenced a detailed study of NdPtSn to have an isostructural material with presumably stable 4f magnetic moments for a comparison with the Kondo antiferromagnet CePtSn [2].

2. Experimental

A single crystal of NdPtSn was grown under Ar atmosphere by a modified Czochralski method employing a tri-arc furnace. Powder made from a small part of the crystal was investigated by X-ray diffraction. Rietveld refinement of the diffraction pattern confirmed that the crystal is of a single phase with the space group *Pnma* and the lattice parameters a = 7.3689(2) Å, b = 4.5976(2) Å, c = 7.9955(2) Å. The specific heat (C_p) was measured between 0.4 and 300 K and magnetization (M) between 1.8 and 300 K in magnetic fields up to 9 T with the PPMS (Quantum Design).

3. Results and discussion

Contrary to the previous report we have found indications of 2 magnetic phase transitions. A sharp peak at 1.9 K in the C_p vs. T plot (Fig. 1) indicates a first-order magnetic phase transition and it is followed by a broader anomaly around 2.4 K (see Fig. 1). Similar, the temperature dependence of susceptibility $\chi(T)$ displays a cusp around 1.9 K and a maximum at 2.5 K, respectively. In a magnetic field, these anomalies are shifted to lower temperatures which suggests AF ordered state below 2.5 K. The magnetization curves $M(B)$ at 2 K shown in Fig. 2 manifest that the easy magnetization direction points along the c-axis. The magnetic moment at 9 T is, however, still considerably lower that the Nd^{3+} free-ion expectation value. The

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S-shape of the c-axis $M(B)$ curves indicates a metamagnetic transition around 1.5 T. The S-shape becomes smeared out with increasing temperature and vanishes above 3 K. These results corroborate the idea of the AF ordering in NdPtSn at low temperatures.

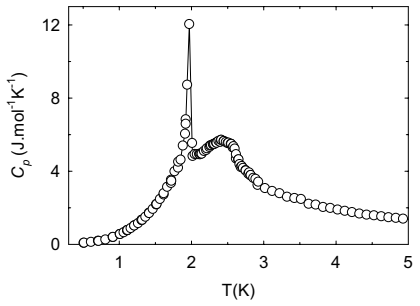

Fig. 1. Specific heat of NdPtSn at low temperatures.

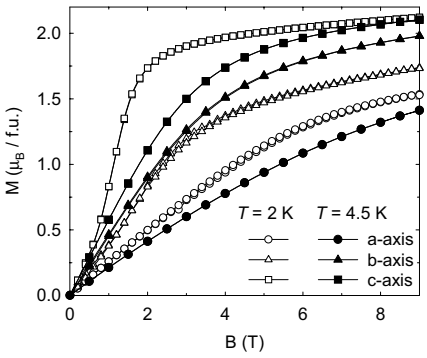

Fig. 2. Magnetization curves of NdPtSn with field applied along the three principal directions at $T = 2$ K and 4.5 K.

The susceptibility below 80 K deviates from the high-temperature Curie-Weiss (C.-W.) behaviour. This result is attributed to CEF interaction.

Our results obtained on the NdPtSn single crystal can be elucidated within the following scenario. Above 3 K NdPtSn is paramagnetic with C.-W. susceptibility behaviour above 80 K and CEF-caused deviation from the C.-W. law at lower temperatures. The observed maxima at 2.5 K on the temperature dependences of the susceptibility and specific heat are attributed to the onset of AF ordering at the Néel temperature. The C_p anomaly at $T_M = 1.9$ K is attributed to an order-order magnetic phase transition between the higher temperature AF1 and the ground-state AF2 phases. The first-order type transition may be a consequence of different order parameters of the AF1 and AF2 phases. When a magnetic field is applied along the c-axis (presumably the easy-magnetization direction) a metamagnetic transition from the AF ground state to the field-forced ferromagnetic-like aligned state occurs above 1.5 T. The moment at 9 T is still considerably lower than the Nd^{3+} free-ion expectation value. This deficiency may be due to CEF effects and/or a noncollinear ordering of Nd moments. A detailed analysis of CEF-related phenomena will be published elsewhere [3]. The tentative magnetic phase diagram in Fig. 3 was constructed on the base of magnetization data for a magnetic field applied along the a- and b-axes.

When comparing NdPtSn and CePtSn one aspect should be stressed on the first sight. The Nd ordered moment ($> 2.1\ \mu_B$) is not far from the Nd^{3+} free-ion value whereas the Ce moment is strongly reduced ($< 1\ \mu_B$). The Néel temperature of CePtSn, however, is $3\times$ lower than for NdPtSn. This virtual controversy may be understood in terms of a non-negligible $4f$(Ce)-conduction-electron hybridization, which causes a reduction of the $4f$ magnetic moment, but on the other hand promotes an exchange interaction, which may enhance the T_N-value.

To confirm our conclusions made from magnetic and specific-heat data and in order to determine details of magnetic structures in NdPtSn a neutron diffraction experiment is scheduled for the near future.

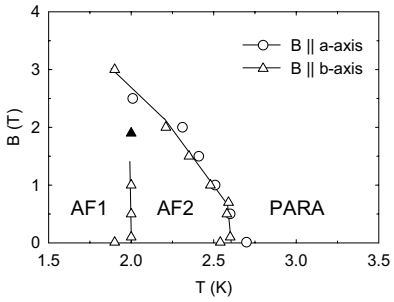

Fig. 3. Tentative magnetic phase diagram of NdPtSn as proposed from magnetization data.

Acknowledgements

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