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.](image1)

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 consider-ably 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].

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× 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. 2. Magnetization curves of NdPtSn with field applied along the three principal directions at $T = 2$ K and 4.5 K.](image2)

![Fig. 3. Tentative magnetic phase diagram of NdPtSn as proposed from magnetization data.](image3)

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