Magnetic Properties RNi_5Sn (R = Pr, Nd) Compounds

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(Received September 13, 2012)

X-ray diffraction and magnetic measurements of RNi_5Sn (R = Pr, Nd) compounds are reported. These compounds crystallize in the hexagonal $CeNi_5Sn$-type structure. Magnetic data indicate that both compounds are antiferromagnet with the Néel temperatures T_N equal to 24 K (R = Pr) and 8.8 K (R = Nd). The magnetic data below T_N suggest the complex magnetic order.

DOI: 10.12693/APhysPolA.123.145
PACS: 75.30.Cr, 75.30.Kz, 75.40.Gb, 75.50.Ee

1. Introduction

The rare-earth intermetallics are subject of the intense investigations for determining these magnetic properties. RNi_5Sn (R = La–Nd) compounds crystallize in the hexagonal crystal structure (space group $P6_3/mmc$) with the complex crystal structure [1]. The temperature dependence of the magnetic susceptibilities of RNi_5Sn, where R = La–Nd in the temperature range 80–400 K indicate that $LaNi_5Sn$ is the Pauli paramagnet while the other compounds follows the Curie–Weiss law [2].

In this work we report the DC and AC magnetic measurements for RNi_5Sn (R = Pr, Nd) in purpose to determine these magnetic properties in particularly at low temperatures.

2. Experiment

The samples were obtained by a standard arc-melting procedure and next annealed at 650 °C per 1 month. From X-ray powder diffraction patterns recorded at room temperature (PANanalytical X'Pert PRO diffractometer, Cu K_α radiation) determine the crystal structure. The diffraction data were analyzed using the Rietveld type program Fullprof [3]. DC magnetic measurements were carried out using a MPMS SQUID magnetometer in the temperature range between 2 and 300 K in magnetic field up to 50 kOe. Additional AC magnetic susceptibility measurements were performed in low magnetic field using Quantum Design PPMS platform. Both in-phase, χ' and out-of-phase, χ'', component of the $\chi_{AC} = \chi' + \chi''$ are measured at the function of the frequency and temperature.

3. Result

The X-ray diffraction data indicate that both compounds crystallize in hexagonal $CeNi_5Sn$-type structure (space group $P6_3/mmc$). In this structure the rare-earth atoms (Pr or Nd) occupy two different sublattices: R1 2c site: 1/3, 2/3, 1/4 and R2 2a site: 0, 0, 0. Ni atoms occupy four sublattices Ni1 2b site: 0, 0, 1/4, Ni2 2d site: 1/3, 2/3, 3/4, Ni3 4f site: 1/3, 2/3, z_1, Ni4 12k site: x, y, z_2 and Sn atoms 4f site: 1/3, 2/3, z_3. The determined crystal structure parameters are collected in Table I. These parameters agree well with the published previously data [1].

TABLE I

Crystal structure parameters of RNi_5Sn (R = Pr, Nd) compounds determined from the X-ray data at room temperature.

Compounds	$PrNi_5Sn$	$NdNi_5Sn$
a [Å]	4.925(1)	4.9208(9)
c [Å]	19.791(4)	19.7562(38)
V [Å^3]	415.72(25)	414.28(21)
Ni3 z_1	0.5425(6)	0.5426(6)
Ni4 x	0.8310(6)	0.8312(6)
y	0.6620(5)	0.6625(6)
z_2	0.1458(6)	0.1460(5)
Sn z_3	0.0873(5)	0.0875(5)
R_{Bragg} [%]	13.6	12.7
R_F [%]	12.6	11.6

The results of the magnetic measurements are presented in Figs. 1 and 2. Above 100 K the reciprocal magnetic susceptibilities obey the modified Curie–Weiss law $\chi(T) = \chi_0 + \frac{C}{T-\theta_p}$ where χ_0 is constant part of susceptibility, C — the Curie constant and θ_p — paramagnetic Curie temperature (see Fig. 1). The negative values of the paramagnetic Curie temperature indicate the antiferromagnetic interactions and the effective magnetic moments are near to the free R^{3+} ion values (see Table II). At low temperatures the maxima at 24 K (Pr) and 8.8 K (Nd) are observed. For $PrNi_5Sn$ the large increase of the magnetic susceptibility below 5 K is observed. In the case of $NdNi_5Sn$ the large difference between ZFC and

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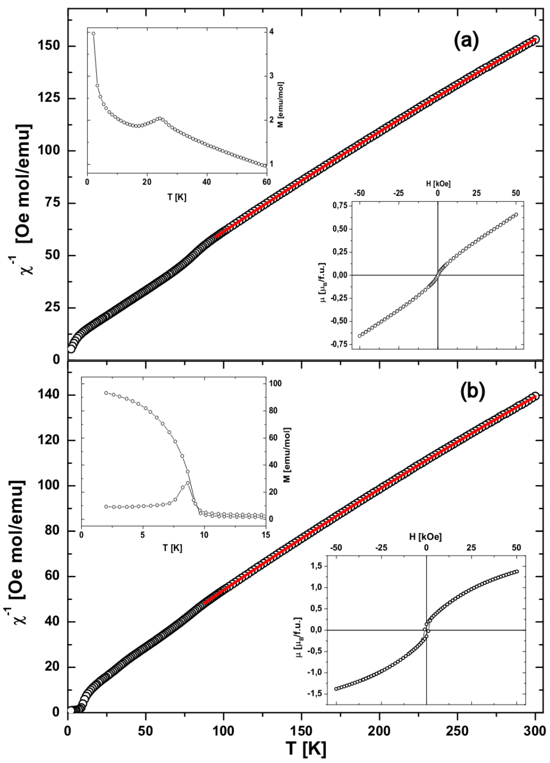

Fig. 1. Temperature dependence of the reciprocal magnetic susceptibilities of (a) $PrNi_5Sn$ and (b) $NdNi_5Sn$. The inset shows the magnetization versus external magnetic field at 2 K (top) and temperature dependence of the magnetization at low magnetic field. For $NdNi_5Sn$ the zero-field cooling (ZFC) and field cooling (FC) curves are shown.

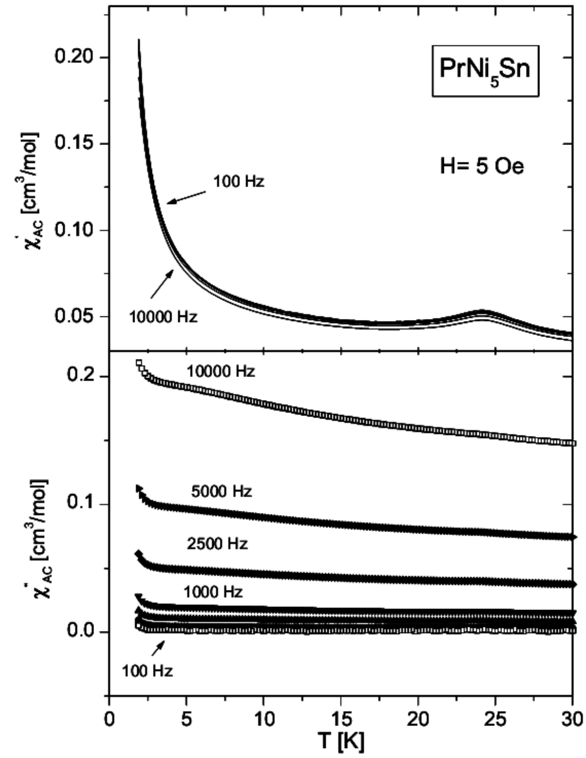

Fig. 2. Temperature dependence of the real χ' and imaginary χ'' part of the AC magnetic susceptibilities near the Néel temperature for $PrNi_5Sn$.

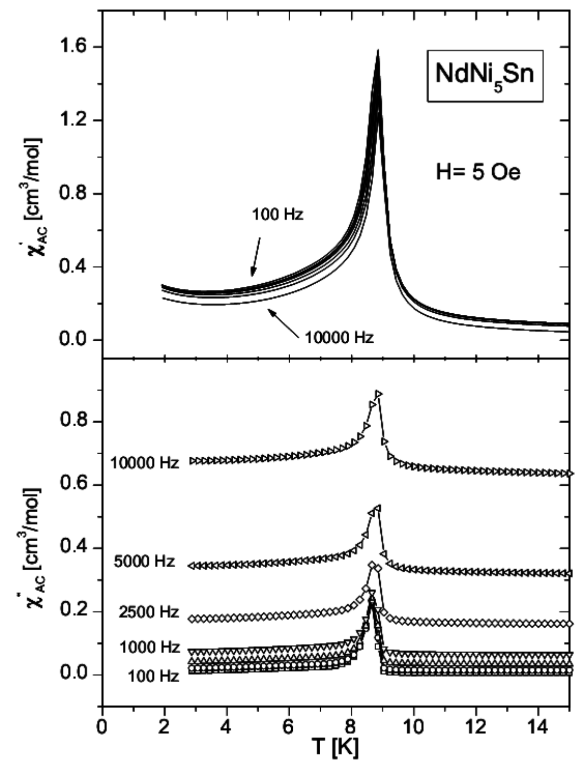

Fig. 3. As in Fig. 2, but for $NdNi_5Sn$.

FC curves while this difference for $PrNi_5Sn$ is not detected. For both samples the small ferromagnetic component connected with the impurity probably R_2Ni_7 phases below 60 K (Pr) and 80 K (Nd) are observed.

Temperature dependence of the ac susceptibilities gives maxima at T_N in χ' and χ'' for $NdNi_5Sn$ and only in χ' for $PrNi_5Sn$ (Fig. 2).

The magnetization curves for $PrNi_5Sn$ at 2 K indicate small impurity (see low temperatures data) and next linear dependence which suggest antiferromagnetic ordering (see lower inset in Fig. 1a). Similar dependence for $NdNi_5Sn$ (lower inset in Fig. 1b) suggest complex magnetic.

4. Summary

RNi_5Sn compounds have the complex crystal structure which contain fragments of $CeCu_5$ structure type and fragments of a hypothetical structure RX_7. The unit cell of RNi_5Sn contains two unit cells of the $CaCu_5$--type. This structure belongs to the hexagonal system (space group $P6/mmm$) in which Ca (R) atoms occupy 2a site: 0, 0, 0 where Cu two sites 2c: 1/3, 2/3, 0 and 3g: 1/2, 0, 1/2 [4]. Magnetic data indicate that $PrNi_5$ does not order up to very low temperatures [5] where $NdNi_5$ is ferromagnet with $T_c = 7$ K [6]. Doped Sn atoms change the crystal structure and the magnetic properties RNi_5Sn (R = Pr, Nd) compounds. Both compounds are antiferromagnets. The determined values of the Néel temperatures: 24 K for R = Pr and 8.8 K for R = Nd indicate that for these compounds the de Gennes scaling is not fulfilled which suggests the strong influence of the crystal electric field (CEF) [7]. The influence of the CEF on the magnetic properties is also observed in (Pr,Nd)Ni_5 compounds [5, 6]. The values of the effective magnetic moment suggest that the magnetic moment is localized only on the rare-earth atoms. Strong difference between ZFC and FC for $NdNi_5Sn$ confirm the complex magnetic order. The negative values of the paramagnetic Curie temperatures suggest that the antiferromagnetic interactions are dominant. In order to explain it, neutron diffraction experiments are planned.

TABLE II

Magnetic parameters of RNi_5Sn (R = Pr, Nd) compound T_N — Néel temperature, θ_p — paramagnetic Curie temperature, μ_{eff} — effective magnetic moment, μ — magnetic moment at 2 K, χ_0 — constant part of susceptibility.

R	T_N [K]	θ_p [K]	μ_{eff} [μ_B]		μ [μ_B]		χ_0 [mol/emu]	Ref.
			exp.	theor.	exp.	theor.		
Pr	24	−18.5	3.81	3.58	0.66	3.2	7.6×10^{-5}	this work
		−9	3.56					[2]
Nd	8.8	−10.4	3.91	3.62	1.4	3.27	9.2×10^{-6}	this work
		0	3.69					[2]

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