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Magnetic, Transport and Thermal Properties of $NpNi_2Sn$

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In recent years uranium-based compounds with the composition UT_2M, where T stands for d-electron transition metal and M is a p-electron element, have attracted much attention because of large variety of their intriguing physical behavior, driven by hybridization between 5f-electronic states and s,p,d-states of neighboring atoms [1–7]. The compound UNi_2Sn is a cubic Heusler phase that exhibits a structural transition to an orthorhombic structure at $T = 220$ K, where both the magnetization and the electrical resistivity show large jumps and broad thermal hystereses [8,9]. Below the transition, clear indications of Kondo-like behavior were observed [8]. Motivated by these findings we have recently undertaken an exploratory study on the Np-based counterpart, i.e. $NpNi_2Sn$, which is reported here for the first time.

A polycrystalline sample of $NpNi_2Sn$ was synthesized by arc-melting stoichiometric amounts of the constituents under argon atmosphere. The as-cast button was checked by X-ray powder diffraction and shown to be single phase with an orthorhombic unit cell. The structure refinement yielded the space group *Pnma* and the lattice parameters: a = 9.6016(6) Å, b = 4.3576 (3) Å and c = 6.5922 (4) Å. Magnetic measurements were performed in the temperature range 2–300 K and in magnetic fields up to 7 T using Quantum Design SQUID magnetometer. Heat capacity and electrical resistivity studies were carried out over the temperature interval 2–300 K and in applied magnetic fields up to 9 T employing a Quantum Design PPMS platform.

Fig. 1 shows the temperature dependence of the reciprocal magnetic susceptibility of $NpNi_2Sn$. Above about 100 K, the $\chi^{-1}(T)$ curve can be approximated by a Curie–Weiss law with the effective magnetic moment $\mu_{eff} = 3.00\ \mu_B$ and the paramagnetic Curie temperature $\theta_p = -198$ K. The value of μ_{eff} is somewhat larger than that expected for free Np^{3+} ions (2.8 μ_B).

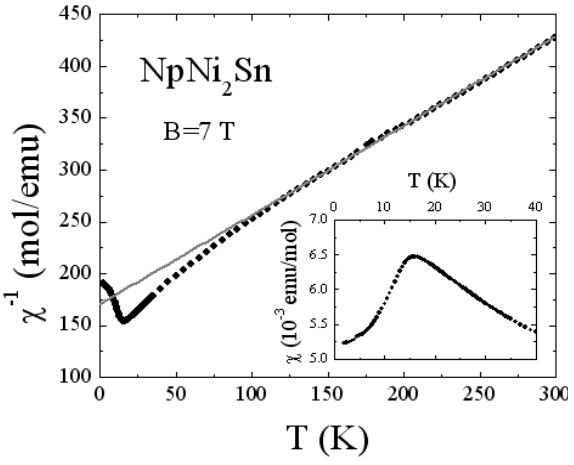

Fig. 1.

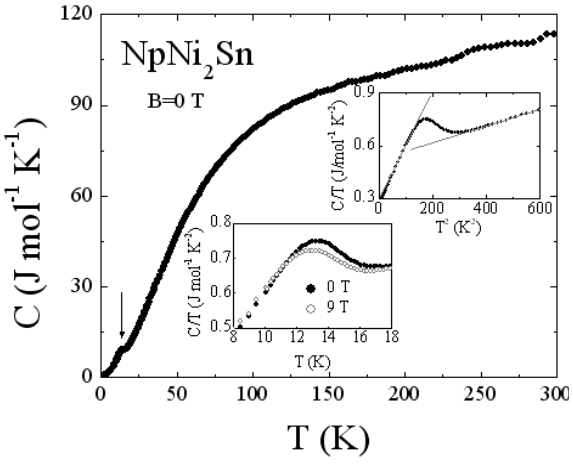

Fig. 2.

The large negative value of θ_p may hint at strong electronic correlations. As it is apparent from the inset to Fig. 1, the compound orders antiferromagnetically at the Néel temperature of 15 K. The magnetization measured in the ordered state is proportional to the magnetic field strength with no indication of any metamagnetic-like transformation up to 7 T (not shown).

The temperature variation of the specific heat of $NpNi_2Sn$ is displayed in Fig. 2. The magnetic phase transition at T_N = 15 K manifests itself as a small hump on the $C(T)$ curve. This anomaly is hardly affected by an applied magnetic field. As shown in the lower inset to Fig. 2, in a field of 9 T the maximum in $C(T)$ is slightly shifted to lower temperatures and gets faintly smaller in magnitude. The electronic contribution to the specific heat, derived as shown in the other inset to Fig. 2, is strongly enhanced. It amounts to 540 and 250 mJ/(mol K^2), when extrapolated to 0 K from the C/T data taken above and below T_N, respectively.

Fig. 3 presents the temperature dependence of the electrical resistivity of $NpNi_2Sn$ measured in zero magnetic field and in 9 T. The resistivity is about 130 μΩcm at 300 K and hardly changes its magnitude over the entire temperature range studied. In the paramagnetic state the resistivity exhibits a logarithmic temperature variation, characteristic of Kondo effect. The least squares fit of the formula $\rho(T) = \rho_0 + \rho_0^{\infty} - c_K \ln T$ to the experimental data yields the sum of the residual and spin-disorder resistivities $\rho_0 + \rho_0^{\infty} = 138$ μΩcm and the Kondo coefficient c_K = 1.4 μΩcm/K. The latter value is rather small. The antiferromagnetic transition at T_N manifests itself as an inflection point on the $\rho(T)$ curve and a distinct Suezaki–Mori-type feature in the dρ/dT vs. T variation (cf. the inset to Fig. 3). Upon applying magnetic field, these anomalies slightly shift towards lower temperatures. Deeply in the ordered state the resistivity is nearly independent of the magnetic field strength. In a field 9 T the transverse magnetoresistivity, $\Delta\rho/\rho = [\rho(B)-\rho(0)]/\rho(0)$, measured at 2 K is only –0.1%. The absolute value of $\Delta\rho/\rho$ gradually increases with rising temperature towards T_N. The overall shape of the field variations of the magnetoresistivity is reminiscent of the behavior of Kondo systems.

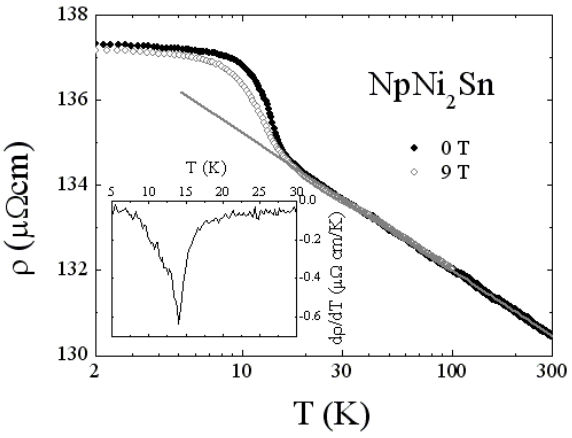

Fig. 3.

In conclusion, the experimental results obtained for $NpNi_2Sn$ strongly suggest that this new compound is an antiferromagnetic Kondo lattice, possibly moderately-enhanced heavy fermion system, one of very few known so far among Np-based intermetallics.

References

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