Synthesis and magnetic properties of a new ferromagnetic Kondo-lattice system Np_2PdGa_3

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A number of intermetallic of the stoichiometric compounds U_2TM_3, where T = 3d, 4d and 5d electron transition metals and M = Si or Ga have been discovered [1-3]. Generally, these compounds adopt two well known types of crystal structures, i.e., the hexagonal AlB_2- or orthorhombic $CeCu_2$-type, respectively. Most of the compounds which crystallize in the hexagonal AlB_2-type are those containing M = Si and showing spin-glass or ferromagnetic cluster glass behavior [1,4]. On the other hand, the compounds with M = Ga favor the $CeCu_2$-type and exhibit various types of magnetic ordering including the spin fluctuation, ferromagnetic and antiferromagnetic order at low temperatures [3,5]. Amongst U_2TGa_3 , the magnetism of the Pd- and Pt-based compounds appears to be an enormously complex subject owing to a competition between the Kondo effect and randomness for long range antiferromagnetism. Therefore, in order to made a systematic study, an investigation of systems being isostoichiometic and/or isostructural to $U_2(Pd,Pt)Ga_3$ would be useful. In this contribution, we present the synthesis and crystallographic characterization, and as well magnetic properties for a new Np-based Np_2PdGa_3 compound.

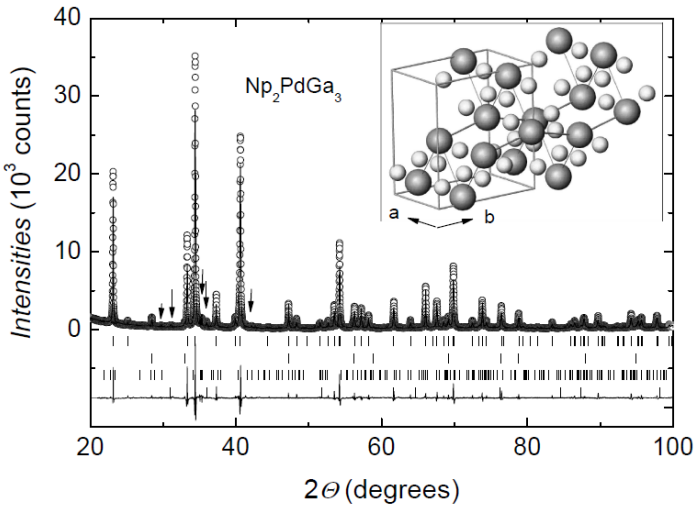

Fig. 1 X-ray powder diffraction pattern of Np_2PdGa_3. The observed (open circles), calculated (solid line), positions of Bragg reflections (vertical lines) and the difference between observed and calculated data (bottom). Inset: Crystal structure of Np_2PdGa_3. Large balls represent the Np atoms and small ones the Pd or Ga atoms. Note that the nearest Np neighbors form zigzag chains parallel to the b axis (thick line) and the next-nearest Np neighbors are connected by zigzag chains along the a axis (thin line).

The X-ray diffraction data collected in the range 20 – 100 *deg*, shown in Fig. 1, revealed that the majority phase (> 95 mass. %) has the orthorhombic $CeCu_2$-type structure. We were able to identify NpO_2, $Np_3Pd_3Ga_8$ and NpC to be the main impurities. Traces of these impurities are denoted by arrows in the diffraction pattern. The observed Bragg reflections for Np_2PdGa_3 could be indexed with lattice parameters a = 0.4445(2) nm, b = 0.7089(3) nm and c = 0.7691(3) nm. Taking into account the size of An^{3+} and An^{4+} ions and comparing the lattice parameters of U_2PdGa_3 and Np_2PdGa_3 one suspects the 3+ valence of the magnetic Np ions.

The measurements of magnetization specific heat, electrical resistivity, magnetoresistance and Hall effect for Np_2PdGa_3 indicated a ferromagnetic ordering below 62.5(5) K. The analysis of magnetic susceptibility (Fig. 2) and specific heat (Fig. 3) consistently suggests a CEF splitting with doublet-doublet-doublet scheme and Δ_{CEF} ~ 60 K and 180 K.

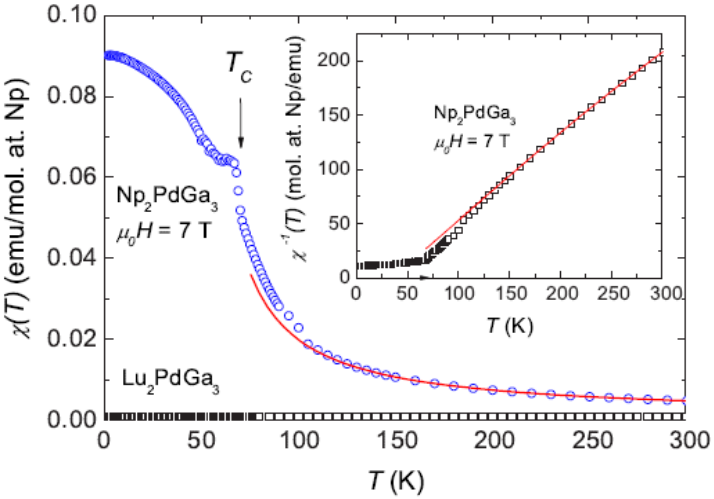

Fig. 2 Temperature dependence of magnetic susceptibility of Np_2PdGa_3 and Lu_2PdGa_3. The solid line is the CEF fit

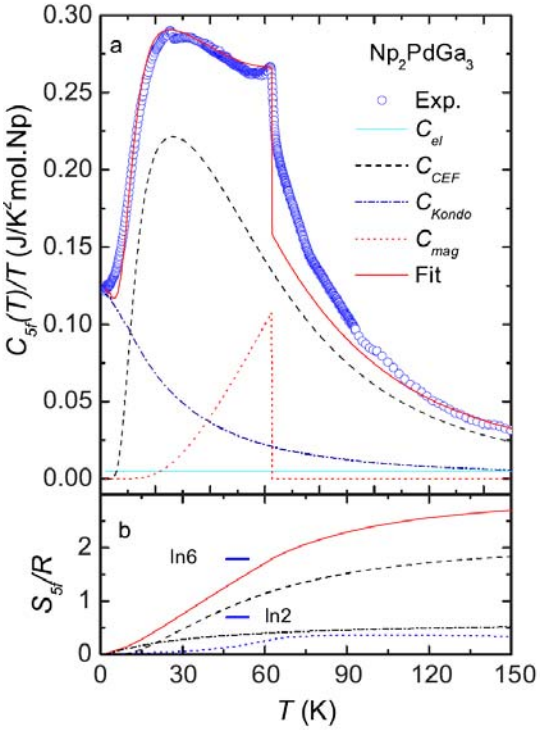

Fig. 3 Temperature dependence of the contribution of 5f-electron specific heat and 5f-electron entropy of Np_2PdGa_3. The lines are calculated CEF, Kondo and magnon contributions to the specific heat.

The enhanced Sommerfeld ratio at low temperature (C_{5f}/T = 120 mJ/K^{2}mol.Np at 2 K) and ln$T$ dependence of the resistivity can be interpreted due to the Kondo effect with T_K ~ 35 K (see dash-dotted line). The Hall coefficient exhibits a behavior for localized moment ferromagnets with low carrier concentration (0.17 carrier/f.u) and with enhanced effective mass (~ 144 m_0).

The presented data seem to be consistent with the underscreenced Kondo lattice model recently developed by Perkins et. al [6]. We argue thus that Np_2PdGa_3 is a new ferromagnetic Kondo lattice with $T_K < T_{RKKY} \sim \Delta_{CEF}$. Among Np-based compounds, ferromagnetic Kondo behavior was previously found for $NpNiSi_2$ [7].

References

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