Magnetic properties of $NpCoGa_5$

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The recent discovery of super-conductivity in Pu-based systems [1,2,3] have opened new perspectives in the chemistry and physics of transuranium compounds, positioning actinide materials as possible emerging new class of super-conductors.

In the frame of the search for new transuranium systems, we have investigated the magnetic and electronic properties of the neptunium counterpart $NpCoGa_5$ using SQUID magnetometry and resistivity. Specific heat measurements are reported in the contribution of P. Javorsky et al. [4].

The polycrystalline ingot was obtained by arc melting stoichiometric amounts of the constituent elements under an atmosphere of high purity argon on a water-cooled copper hearth, using a Zr getter alloy. X-ray diffraction studies revealed that $NpCoGa_5$ is isostructural to $PuCoGa_5$ (s.g. P4/mmm). The refined structural parameters thus obtained are a = 4.2377(1) Å, c = 6.7871(3) Å and zGa = 0.3103(4).

At low field, the magnetization shows a typical antiferromagnetic transition at $T_N \approx 47$ K (see insert of figure 1). At high fields, the shape of the transition changes considerably (fig.1), indicating the occurrence of another type of magnetic order, probably of ferrimagnetic type.

This metamagnetic transition is clearly observed on the M(H) curves (figure 2). From T = 5 K up to T = 30 K, the critical field vary only little, from $H_c = 4.5$ T down to $H_c = 3.7$ T. It then falls rapidly to $H_c = 1.7$ T at T = 45 K. From figure 2, one can see that the magnetization of $NpCoGa_5$ is far from saturation even at H = 7 T. It should be noticed that no hint of superconducting transition is observed down to T = 2 K.

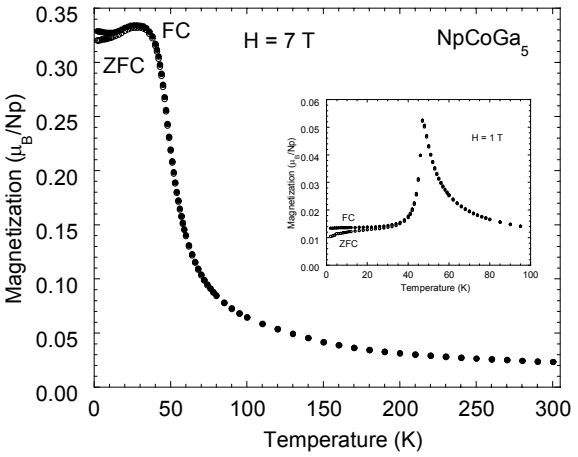

Fig. 1. Zero-field cooled (ZFC, open circles) and Field-cooled (FC, full circles) magnetization of $NpCoGa_5$ versus temperature at H=7T and H=1T (insert).

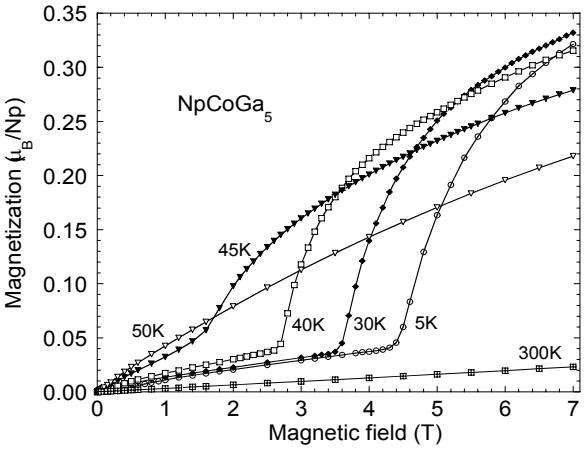

Fig. 2. Magnetization of $NpCoGa_5$ versus magnetic field at various temperatures.

In the paramagnetic state, the susceptibilty obeys a modified Curie-Weiss law :

$$\chi = \chi_0 + C/(T-\theta_p) \qquad (1)$$

with a positive $\theta_p \approx 42$ K, a reduced (compared to the free ion) effective moment $\mu_{eff} \approx 1.5\ \mu_B$ and a relatively high $\chi_0 \approx 820.10^{-6}$ emu/mol.

The resistivity of $NpCoGa_5$ (fig.3) is essentially constant from T = 300 K down to $T \approx 80$ K with a broad maximum around

$T \approx 170$ K. It then decreases more significantly and, in close agreement with SQUID experiments, a kink followed by a sharp decrease is observed at $T_N = 48$ K. No superconducting transition is detected down to T = 1.8 K. On the other hand, one has to notice the extremely low residual resistivity $\rho_0 \approx 1$ μΩcm and consequently the extremely high $\rho(300K)/\rho_0$. Below 40 K, the resistivity can be accounted for by the law :

$$\rho = a + b\,T^{3.2} \qquad (2)$$

with a = 1.29 μΩcm ; b = 0.0016 μΩcm/K.

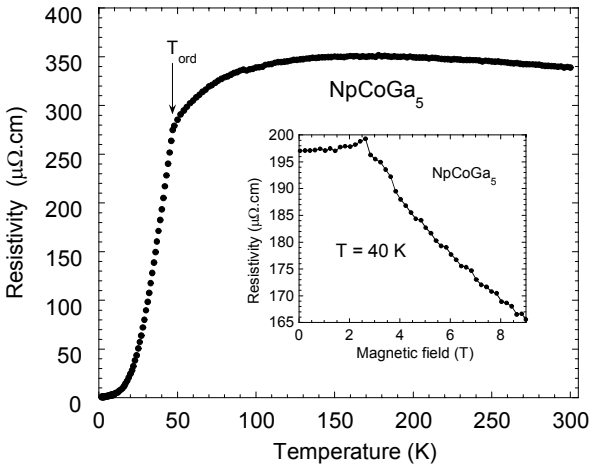

Fig. 3.Resistivity of $NpCoGa_5$ versus temperature and field (insert).

In the ordered phase, the field-dependance of the resistivity (insert of fig.3) shows two distinct regimes, reflecting the two magnetic phases observed by magnetization. Indeed, the resistivity breakdown separating the two regimes corresponds to the critical field of the metamagnetic transition.

As a conclusion, $NpCoGa_5$ does not show any hint of superconductivity down to T = 1.8 K but exhibits an antiferromagnetic state below $T_N \approx 47$ K. For moderate values of the magnetic field, a metamagnetic transition occurs and a ferrimagnetic-type order appears (figure 4).

^{237}Np Mössbauer experiments are planned in order to complete these macroscopic measurements by measuring the local properties of the neptunium ion in $NpCoGa_5$.

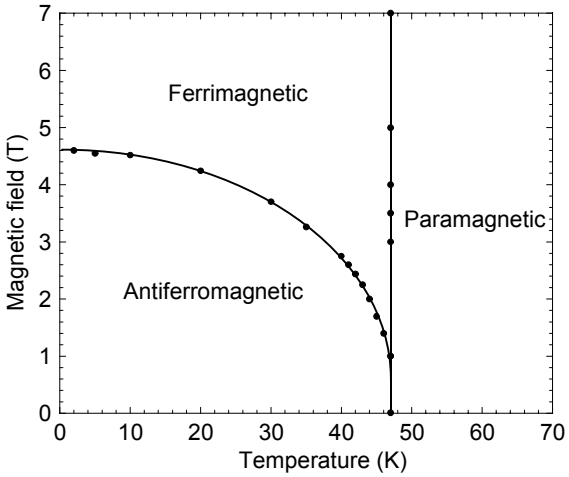

Fig. 4 : Magnetic phase diagram of $NpCoGa_5$ as inferred from magnetization and resistivity measurements.

Acknowledgements

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References

[1] J.L. Sarrao et al. Nature 420 (2002) 297.
[2] F. Wastin et al. Journal of Physics : Condensed Matter, in press.
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