# Recent progress in the investigation of the electronic and magnetic properties of $NpNi_5$

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$ReT_5$ (Re = rare earth, T = Transition metal) compounds have been studied in the past in the frame of its magnetic properties (small Re to T stoichiometric ratio, large spontaneous magnetization and high Curie temperature) [1-2]. Extending these investigations to actinide analogues is interesting, as the wider radial extension of the *5f* electronic shell compared to the *4f* one should result in a larger inter-sublattice exchange interaction, and in non-negligible An-An exchange coupling. The spin-orbit interaction in the *5f* configuration for the actinide atoms is also larger than the *4f* spin-orbit interaction. For these reasons, a magnetic behaviour even richer than the one observed in the rare earth compounds is expected.

$NpNi_5$ [3] was synthesized by arc-melting and X-Ray powder diffraction enabled to confirm a $CaCu_5$ ($D_{6h}$) P6/mmm hexagonal crystallographic structure having one Np atom per unit cell, with room-temperature lattice parameters a = 4.8501 (5) Å and c = 3.9841 (5) Å. Physical properties were measured by the means of Superconducting – Quantum – Interference – Device (SQUID) magnetometry, $^{237}$Np Mössbauer spectroscopy (Fig. 1), specific heat measurements (Fig. 2) and X-Ray magnetic circular dichroism (XMCD) (Fig. 3).

$NpNi_5$ is a ferromagnetic binary system, where the Np *5f* electrons seem to be essentially localized. Magnetization curves (not shown) indicate that $NpNi_5$ is a soft ferromagnet with a $T_C$ ~16 K with a clear Curie–Weiss behaviour above $T_C$ ($\mu_{eff}$ ~ 3.7 $\mu_B$, $\theta_P$ ~ 14.6 K).
Mössbauer spectroscopy data (Fig. 1) suggests a $Np^{3+}$ oxidation state ($5f^4$ electronic configuration), The hyperfine field inferred from the spectrum at 4.2 K (~439 T) yields an ordered moment at the Np site $\mu_{Np}$ ~ 2 $\mu_B$. Comparison with saturated magnetization suggests an average moment of only 0.04 $\mu_B$ on the Ni sites.
The specific heat (Fig. 2) shows a clear and narrow anomaly at ~16 K corresponding to the onset of magnetic order. In applied magnetic fields the peak is shifted towards higher temperature and broadened (not shown), as expected for a ferromagnet. The magnetic transition can be extracted form the total specific heat by subtracting the phonons, electron, and nuclear contributions. Inset shows the low temperature part indicating the presence of the nuclear Schottky contribution.

In this communication we will present the results obtained (including preliminary data from XMCD) and discuss them in the light of theoretical considerations.

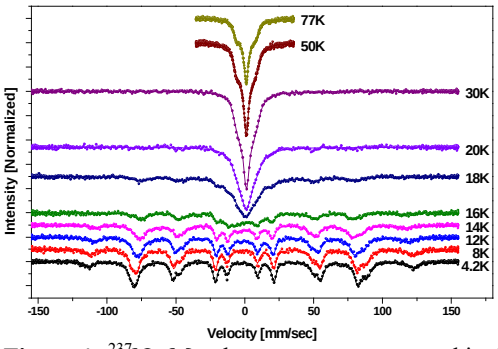


**Figure 1:** $^{237}$Np Mössbauer spectra measured in the temperature range 4.2 - 77 K.

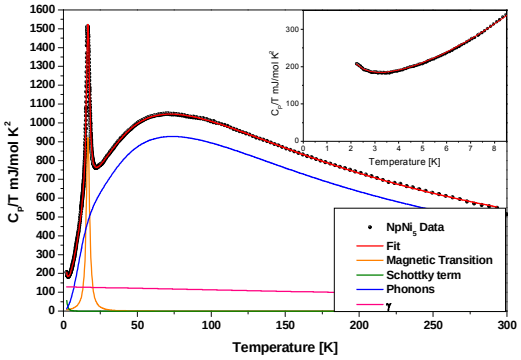


**Figure 2:** Normalized specific heat as a function of temperature, Solid lines – theoretical fit and its components. Insert – low temperature specific heat.

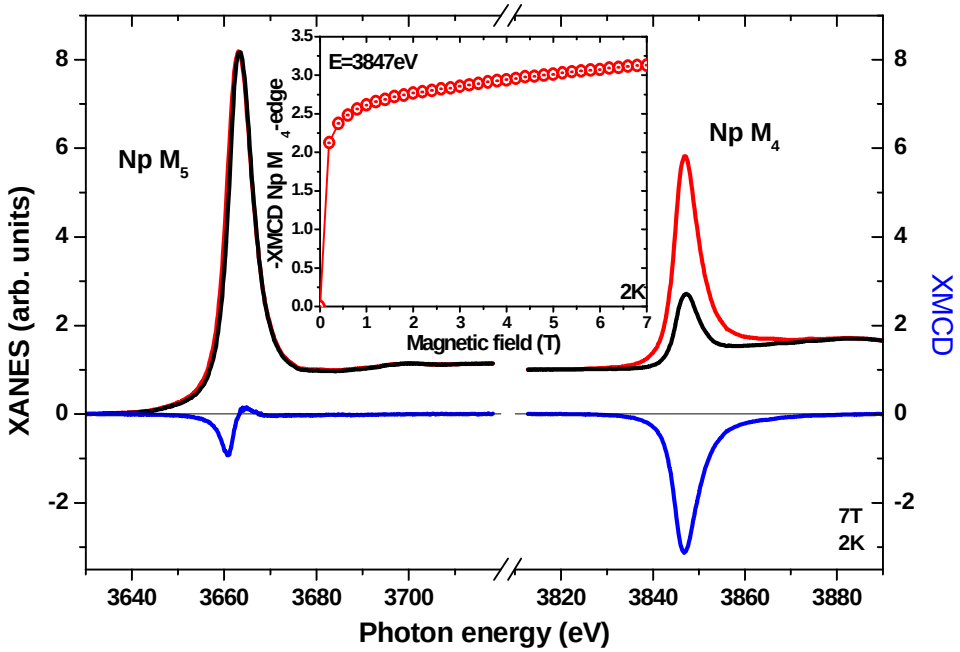


**Figure 3:** X-ray absorption spectra $\mu^+$ (red line), $\mu^-$ (black line) measured at 2 K and $H_{ext}$=7 T at the $M_{4,5}$ Np absorption edges; Blue line – XMCD signal, inset – field dependence of the XMCD signal at the $M_4$ edge.

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## References

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