ESRF	**Experiment title: The Perpendicular Magnetic Anisotropy of amorphous NdCo thin films studied by EXAFS using linearly polarized X-rays**	**Experiment number**: HE-2326
Beamline: BM 25	**Date of experiment**: from: 8 November 2006 to: 14 November 2006	**Date of report**: 7/March/2007
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EXPERIMENT REPORT

Amorphous NdCo alloys deposited on fused quartz substrates by magnetron sputtering were studied by EXAFS. The studied thin films were 100 nm thick and had three different compositions: $NdCo_3$, $NdCo_5$, and Nd_2Co_{17}. All the three alloys looked amorphous by x-ray diffraction, and had perpendicular magnetic anisotropy at room temperature [1]. The proposed experiment searched differences in the Nd-Co, Co-Co and Nd-Nd interatomic distances and atomic coordination when they were measured parallel or perpendicular to the magnetic easy axis of the samples, to explain their perpendicular magnetic anisotropy. A similar experiment proved that the perpendicular magnetic anisotropy in TbFe amorphous alloys was caused by differences in coordination for Tb and Fe between the two mentioned directions [2].

The experiment was done in BM25 (Spline beamline) at room temperature using partial fluorescence detection with a *single element* Si detector borrowed from the ESRF pool. This detector proved to be inadequate to answer the question concerning the possible existence of a dichroic effect, the main experimental goal. The main detector problem was concerning the relative low saturation level, obliging us to cut in flux for spectra acquisition, with the result of noisy spectra. We needed to average over 30 spectra to obtain an spectrum of reasonable quality. Figure 1 shows the EXAFS spectra of one of the samples obtained at the Co K edge. The spectrum with the thicker line was averaged over the other 30 spectra represented in the figure. The dip at the highest photon energy was caused by detector saturation. The spectra above that photon energy were useless, reducing the k-range studied. The noise level was higher than the dichroic signal observed in TbFe, lower than 6% [2], making impossible its detection. Those problems can be overcompensate if a multi-elements solid state (Si or Ge) detector is used, since the acquisition rate increase proportional to the number of detector elements. However, the beamtime results were sufficient to solve the local atomic configuration. The results were quite surprising. They are summarized as follows:

(1) Co environment was very similar in the 3 studied thin films, despite that their different compositions. Their EXAFS spectra at the Co K edge are represented in figure 2. They do not show any significant difference between them.

(2) The fit of the EXAFS spectra shows that Co atoms are in a bcc structure. Figure 3 shows that the fit was of good quality. The fit sees up to three shells. The Debye-Waller factors obtained from the fits were about 5 times larger than the expected in a perfect Co crystal, indicating that this bcc environment was disordered, what explains why x-ray diffraction did not detect crystal plane reflections in these thin films. Co-Nd environments were not needed in the fits.

(3) The EXAFS amplitude at the Nd L edges (the ones accessible in the beamline) was negligible in the studied films. Figures 4 and 5 shows that the EXAFS region above the Nd LIII and LII edges was flat in $NdCo_3$ and $NdCo_5$. This is consistent with the absence of Nd neighbours in the Co K edge EXAFS spectra, and with the similarity of the Co EXAFS between films with different Nd concentrations.

These results do not support those obtained in TbFe. Nd seems to have a too disordered environment, at least when it is observed at room temperature. Co is in a cubic structure, which has very low anisotropy unless it were distorted. We propose to repeat the experiment with 4 fundamental changes:

(1) Improved x-ray detector. Noise level should allow to measure a dichroic signal in the EXAFS spectra of the order of 6% in EXAFS amplitude.
(2) Experiments should be done at low temperature to decrease the Debye-Waller factors and be able to detect the Nd atomic environment.
(3) Include a wider range of Nd concentrations: NdCo and $NdCo_2$. And a film with a low Nd concentration to determine when Co environment changes from hcp to bcc.
(4) Measure a multilayer with alternate Nd and Co layers, to artificially create an anisotropy in the atomic environment of Nd and Co. This sample will serve to check if the experiment is able to see such an anisotropic atom distribution in the film, and have it as a reference.

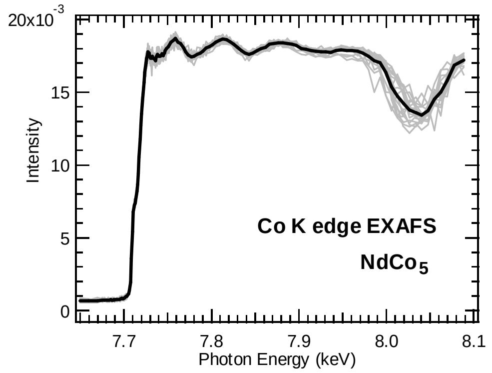


Figure 1. EXAFS spectra of $NdCo_5$ thin film at the Co K edge. Thicker line is the averaged spectrum over 30 spectra. Dip at 8.05 keV was caused by detector saturation.

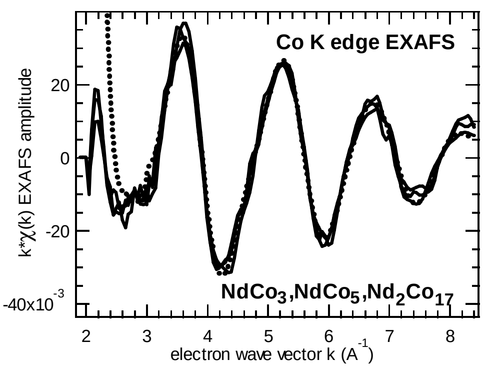


Figure 2. EXAFS spectra of $NdCo_5$, $NdCo_3$, and Nd_2Co_{17} thin films at the Co K edge in k-space. The dotted line is the fit of the spectra.

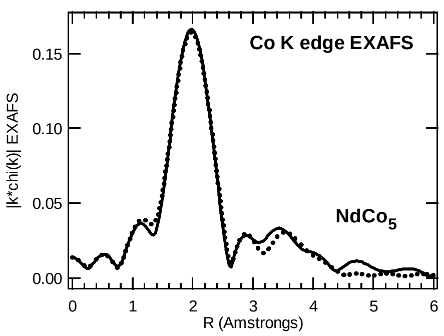
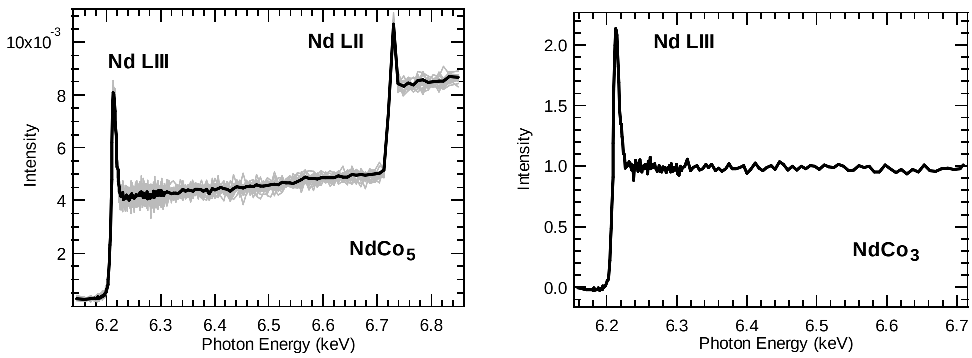


Figure 3. EXAFS spectra of $NdCo_5$ thin film at the Co K edge in R-space. The dotted line is the spectrum resulted from the fit of a Co bcc structure.



Figures 4 and 5. EXAFS spectra of $NdCo_5$ and $NdCo_3$ thin films at the Nd LIII edge.

References

[1] R.Cid, G. Rodríguez, L. M. Álvarez-Prado, J. Díaz, J. M. Alameda. Journal of Magn. and Mag. Mat. (2007) (Accepted)
[2] V. G. Harris. Phys. Rev. Lett. 87 (2001) 67207