ESRF	**Experiment title:** **Magnetostriction studies using EXAFS**	**Experiment number**: HS-2102
Beamline:	**Date of experiment**: from: 30th April 2003 to: 6th May 2003	**Date of report**: July 2003
Shifts:	**Local contact(s)**: Dr Olivier MATHON	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Professor M R J Gibbs*

Department of Physics & Astronomy, University of Sheffield, Sheffield, S3 7RH, UK

Dr R F Pettifer*

Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

Report:

The experiments were conducted on beamline ID24, using the same experimental arrangement of EXAFS in transmission in the presence of a rotating magnetic field as was used in the previous experiments (MI510 and MI588). Details of the experimental arrangement, and the detection system used are given in the reports of these earlier experiments.

The primary objective of this set of experiments was to confirm the findings of our 2002 experiments in that it is possible to make a differential EXAFS measurement using magnetostrictive modulation. This leads to a significant increase in the resolution possible with EXAFS. We also wished to study a wider range of samples or differing crystal structures and absolute values of saturation magnetostriction constant in order to exemplify the possibilities of this technique for study of magnetostrictive materials.

We have confirmed that this differential technique is successful, opening the way for a range of applications in both EXAFS and the study of magnetostrictive materials.

Table 1 indicates the samples studied during this beamtime allocation. Unfortunately several of the samples were less than ideal for the experiment. The foils provided by Goodfellows did not have a sufficiently uniform thickness to prevent slight changes in absorption as the magnetic field rotated on the sample. This led to edge breakthrough in the difference signals. Problems in preparation at Sheffield resulted in having to use commercial amorphous

METGLAS alloy. This suffered from the same problem of non-uniformity. The Terfenol-D sample was in the amorphous state, and therefore had a low saturation magnetostriction constant compared with the devitrified nanocomposite material that would have been better suited to the experiment.

Description	Thickness	Type	Produced By
$Fe_{50}Co_{50}$	7 μm	Sputtered film	Sheffield
Co	3 μm	Foil	Goodfellows
METGLAS® 2605S2 $Fe_{78}S_9B_{13}$	9 μm	Ribbon	Honeywell
Terfenol-D $Tb_{0.3}Dy_{0.7}Fe_2$	10 μm	Sputtered film	MPI-Stuttgart

Table 1. Details of films studied.

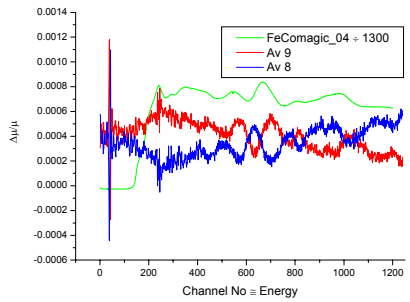

Fig.1 Fe-edge in FeCo using the magic angle technique.

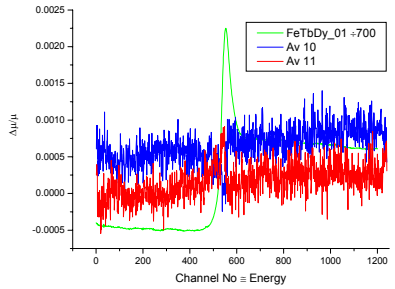

Fig.2 Terfenol-D EXAFS spectrum and difference spectra at the Dy edge (53788.5 eV)

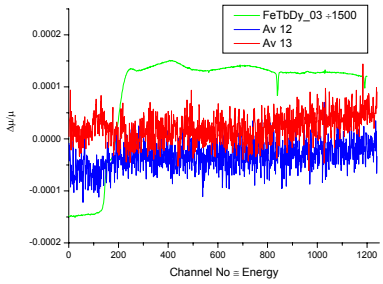

Fig.3 Terfenol-D EXAFS spectrum and difference spectra at the Fe edge. The dip in the absorption spectrum at about channel 850 is due to defects in the polychromator crystal.

Making use of the magic-angle theorem[1] we extended our study of the FeCo sample examined during MI588 to the Fe edge. Fig.1 shows the eye-pattern obtained. The magic angle theorem is used to overcome the texture created by spontaneous magnetostriction as we have a <110> texture in the film plane. The large spikes very close to the edge are ascribed to structure from the Fe EXAFS signal.

Figs. 2 and 3 show the EXAFS spectrum and difference spectra for the Terfenol-D sample at the Dy edge and at the Fe edge. It can be see from the EXAFS spectrum that the sample is amorphous. There are no features in the post edge region only a smooth profile. Little magnetostriction (compared to the crystalline counterpart) was expected from a sample in this state. This is shown by the lack of features in the difference spectra. The peak at the bottom of the Dy edge is thought to be due to the effect the changing magnetic field has on the quadruple moment of the Dy atoms. The bigger peak immediately after that is thought to be due to linear dichroism from the f-states of the Dy atoms.

Fig.4 shows the EXAFS spectrum and difference spectra for the METGLAS® sample. The dips in the absorption spectrum at about channels 850 and 1200 are due to defects in the polychromator crystal. The difference spectra are poor with a lot of edge breakthrough. This lies in the poor sample quality. However there is some evidence of anti-phase oscillations in the difference signals (see around channels 450 and 900 in particular). The absolute value of sdaturation magnetostriction constant in this sample is about one third of that in the FeCo, and this has to be convolved with the lack of well-defined short range order in these alloys which smears out the intrinsic EXAFS oscillations. We are confident that a well prepared sputtered sample (Sheffield now has the capability for this) would produce much higher quality data. This data demonstrates the power of differential EXAFS, as this type of information is not achievable from crystallography.

Fig.5 shows the EXAFS spectrum and difference spectra for the Ni foil sample. The difference spectra are poor with a lot of edge breakthrough. There is little evidence of any anti-phase signal.

Fig.6 shows the EXAFS spectrum and difference spectra for the Co foil sample. There is a clear anti-phase magnetostriction signal in the difference spectra.

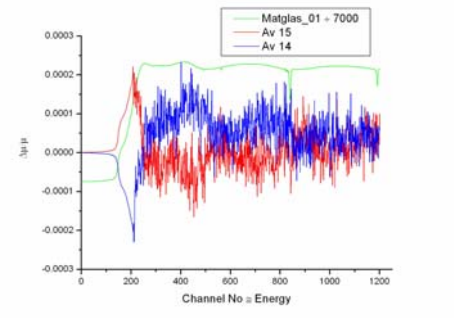

Fig.4 METGLAS EXAFS spectrum and difference spectra at the Fe edge.

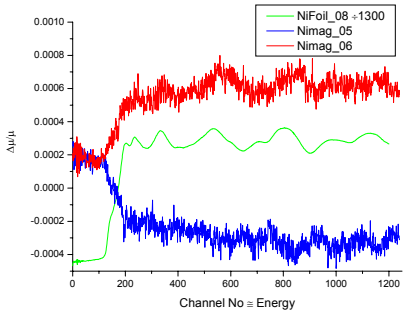

Fig.5 Ni foil EXAFS spectrum and difference spectra at the Ni edge (8332.8 eV).

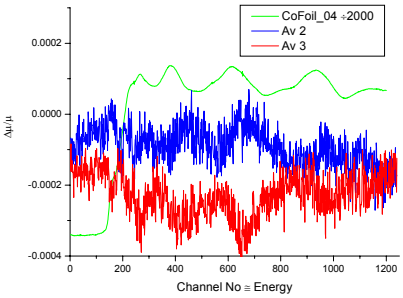

Fig.6 Co foil EXAFS spectrum and difference spectra at the Co edge (7708.9 eV).

The preliminary results from experiment MI588 were the subject of an oral presentation by MRJG at INTERMAG 2003, Boston, USA. The presentation details are M.R.J.Gibbs, R.Pettifer, M.P.Hollingworth, O.Mathon and S.Pascarelli "Magnetostriction measurement using EXFAS". It was from this presentation that MPI-Stuttgart offered the Terfenol-D sample for this experiment. There was also considerable interest from the Naval Surface Warfare Centre (Washington) and Hitachi Global Storage Systems (ex IBM Almaden).

It was agreed that no publication would result from this presentation as RFP is still in the process of the calculations necessary to fit the difference data. This is progressing well at this time. It is hoped that the first publication will be submitted within the next few months, to be followed by at least one further paper on the magnetostrictive aspects of this work.

This current experiment served as further research training for one Ph.D. student, M.P.Hollingworth, from the University of Sheffield.

We still plan to move the magnetostrictive studies on to work in a reflection geometry allowing study of ultra-thin films. For these materials the electronic reconfigurations at surfaces and interfaces lead to significant changes in magnetoelastic coefficients which must be understood for many nanotechnology devices.

[1]R.F.Pettifer et al, Phys.Rev.B **42** (1990) 37