

Intrinsic magnetostrictive strain in Galfenol

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Magnetostriction is the variation in physical dimensions of a magnetic material in response to changing its magnetisation. Despite the large applications of such an effect in sensor and actuator devices, the strain produced in many common magnetic materials is only of the order of a few tens of parts-per-million at most.

Since the 1970s, with the discovery of ‘giant’ magnetostriction, considerable work has been undertaken to engineer magnetostrictive materials. Despite this, there has been a lack of experimental work to examine the fundamental mechanisms driving the magnetostriction effect, and therefore theoretical models for magnetoelasticity have not been easily verified. This is essentially due to the difficulty in detecting and quantifying atomic motion on the scale of femtometres. As a result, work to date has almost exclusively dealt with measuring magnetostrictive strain in a scaled-up form employing standard macroscopic techniques as strain gauges, where average strain is measured, but where atomic information is completely lost.

However, with the recent development of Differential X-ray Absorption Spectroscopy (DiffXAS) on ID24 at the ESRF, direct atomic-scale measurements have become possible [1]. We have recently started to apply DiffXAS to probe the atomic origin of the magnetostriction enhancement in the technologically important $\text{Fe}_{(1-x)}\text{Ga}_x$ alloy (Galfenol). The addition of Ga to Fe results in a remarkable increase in the tetragonal magnetostriction. Previously published *intrinsic* magnetostriction results have been obtained from DiffXAS measurements on nanocrystalline (grain size $\sim 0.1 \mu\text{m}$) samples [2]. Although measurements on polycrystalline samples (grain size of a few microns), have been attempted, experimental constraints related to the size of the beam on ID24 ($\sim 25 \mu\text{m}^2$) have made all these attempts fail.

In order to produce spectra of a higher quality whilst simplifying more complicated aspects of the data analysis, we have started investigating single crystals of Galfenol. This eliminates the need to configurationally average the magnetostriction signal over a distribution of crystallite orientations, and more importantly to obtain data that will help explain how atomic scale magnetostriction scales to that measured macroscopically with conventional techniques. These experiments then can provide a link between the numerous macroscopic-scale experimental studies that have been conducted to date, and theoretical models developed from first-principles which describe behaviour at an atomic level.

This talk will introduce the Differential XAS technique, and show its development through some of the most significant results obtained to date on the Galfenol system.

References

- [1] R. F. Pettifer et al. *Measurement of femtometre-scale atomic displacements by X-ray absorption spectroscopy*. Nature **435**, 78 (2005)
- [2] M. P. Ruffoni et al. *Direct Measurement of Intrinsic Atomic Scale Magnetostriction*, Phys. Rev. Lett. **101**, 147202 (2008)

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Preference: Oral