ESRF	**Experiment title:** Investigating the intrinsic, atomic-scale magnetostriction of $Fe_{81}Ga_{19}$	**Experiment number**: **HE-3073**
Beamline:	**Date of experiment**: from: 22nd Apr 09 to: 28th Apr 09	**Date of report**: 29th Aug 09
Shifts:	**Local contact(s)**: M. P. Ruffoni	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

M. P. Ruffoni*, **S. Pascarelli**

ESRF

Q. Xing*, T. A. Lograsso*

Ames Laboratory, Ames, IA 50011, USA

Report:

Following a recent study of the *intrinsic*, atomic-scale magnetostriction of the technologically important $Fe_{(1-x)}Ga_x$ alloy [1], we have again employed Differential X-ray Absorption Spectroscopy (DiffXAS) to study the origins of magnetostrictive strain in this system. The aim was first to exploit our growing appreciation of the subtleties of the DiffXAS technique [2], and so produce spectra of a higher quality whilst simplifying more complicated aspects of the data analysis, but more importantly to obtain data that would help explain how atomic scale magnetostriciton scales up to that seen externally through conventional techniques. This would then be used to provide a link between the numerous macroscopic-scale experimental studies that have been conducted to date, and theoretical models developed from first-principles at an atomic level.

Previously published DiffXAS results were obtained from measurements on polycrystalline foils [1][3][4]. However, polycrystalline samples invariably contain crystallites of varying orientations, packed together in a non-perfect arrangement. Strain developed between individual atomic pairs on a local-scale does not, therefore, scale up that measured externally via, say, strain gauge measurements. Individual crystallites strain by different amounts depending on their own orientation with respect to an externally applied magnetic field, packing defects between crystallites 'absorb' strain without transmitting it to the outer edges of the sample, and stresses generated from irregularly shaped crystallites pressing into one another could modify a crystallite's strain independenly of magnetostriction. These results could not, therefore, be directly compared to those from macroscopic techniques in the literature.

Therefore, for this experiment we repeated the measurements published in [1], but on a single crystal of $Fe_{(1-x)}Ga_x$ at the important 19at.% Ga concentation. The perfect nature of such a sample – ideally being free of defects and dislocations, and certainly devoid of the aforementioned problems associated with polycrystalline samples – would, for the first time, permit a direct comparison between atomic-scale, and macroscopic magnetostrictive behaviour. Data analysis is still ongoing at the time of writing this report. However, we are pleased to announce that the experiment itself was a resounding success; producing DiffXAS spectra of a quality far greater than obtained in any other such experiment to date.

Eighteen shifts were allocated to this experiment, and of this time, 9 were used for data acquisition at the Fe K-edge, 1 for changing between the Fe and Ga edges, and finally, 8 shifts for measurements at the Ga K. Figure 1 shows a comparison between the DiffXAS spectra published in [1] and those from this experiment. Both datasets clearly contain the same signal – testifying to the validity of the published data – but the single crystal spectra are of considerably higher quality. The first point to note is that small regions of signal corruption in the polycrystalline dataset are seen to vanish in the single crystal data, particularly at very low or high values of k at the Ga K-edge. However, the most striking feature is the difference in signal-to-noise ratio, which is particularly visible in the Fe K data. This arises from an increase in signal amplitude rather than a reduction in experimental noise.

In the polycrystalline sample, the variation in crystallite orientations implies that many will not have their cubic 100 axes parallel to the external magnetic field, as is required for the maximum magnetostrictive strain to be developed. The resulting DiffXAS signal is therefore smaller than that from the signal crystal, where the whole area of sample illuminated by the beam was ideally aligned along the magnetic field. Consequently, the polycrystalline spectra in Figure 1 have been magnified in amplitude by a factor of 22 for comparison with the single crystal data. Preliminary analyses indicate that this improvement in signal-to-noise is accompanied by a significant reduction in errors in fitted magnetostriction coefficients.

Full results will be published elsewhere in the near future.

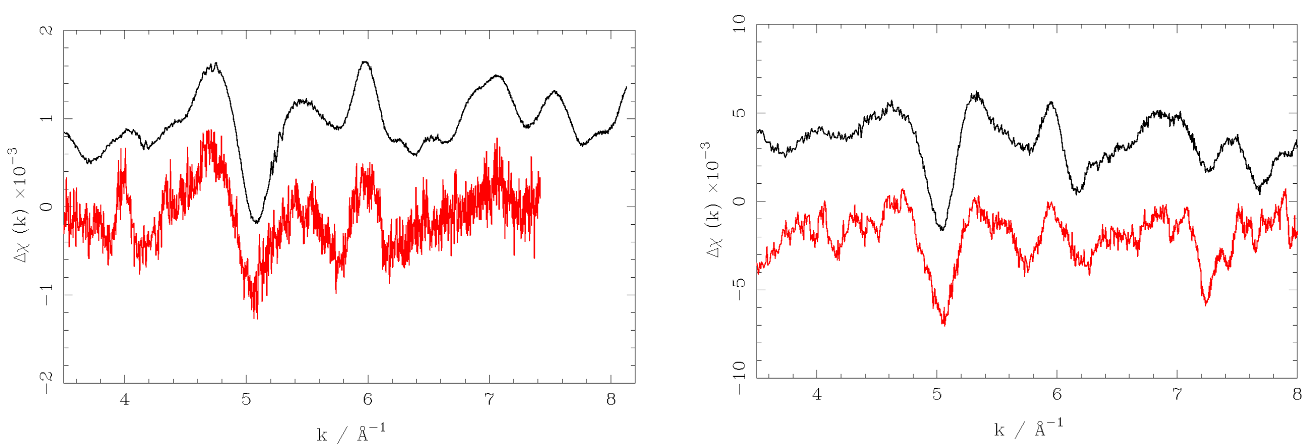

Figure 1: A comparison between polycrystalline (red) and single crystal (black) DiffXAS spectra taken from samples of $Fe_{81}Ga_{19}$ at the Fe K (left) and Ga K-edges (right). The polycrystalline spectra have been increased in amplitude by a factor of 22 for comparison with the single crystal data.

References:

[1] M. P. Ruffoni, S. Pascarelli et al., Phys. Rev. Lett. **101**, 147202 (2008)
[2] M. P. Ruffoni and S. Pascarelli, IEEE Trans. Magn., Intermag 2009 Proceedings, in press (2009)
[3] S. Pascarelli, M. P. Ruffoni et al., Phys. Rev. Lett. **99**, 237202 (2007)
[4] R. F. Pettifer, O. Mathon et al. Nature **435**, 78 (2005)