Measuring strain at the atomic-scale with Differential X-ray Absorption Spectroscopy

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Strain-inducing phenomena, such as magnetostriction, lie at the heart of transducer technologies. Knowledge of their origin and mechanics, and how they manifest themselves in different materials, underpins the development and optimisation of sensor and actuator devices.

DiffXAS has been developed to permit strain measurements at an atomic-scale, and thus verify theoretical models for transducer behaviour.

Proof-of-concept

By exploiting the intrinsic stability and time resolution of the dispersive XAS set-up, the development of DiffXAS on ID24 at the ESRF has made atomic-scale strain measurements possible.

The first experiment studied the magnetostriction of FeCo foil, where strain in the cubic 100 direction is 210ppm, and 60ppm in the 111.

Quantitative DiffXAS

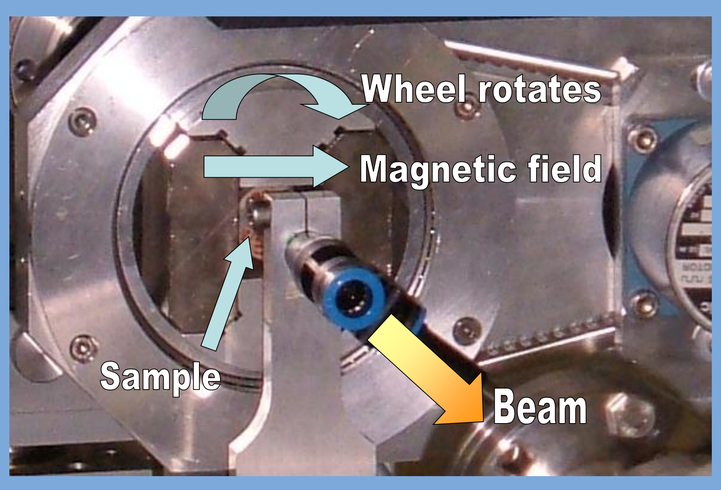
Subsequent development of DiffXAS analysis techniques has allowed atomic, and element-specific, strain coefficients to be obtained directly from theory fits to DiffXAS spectra.

Studies of the technologically important FeGa system showed magnetostrictive strain emanated from the environment surrounding Ga-Ga pair defects.

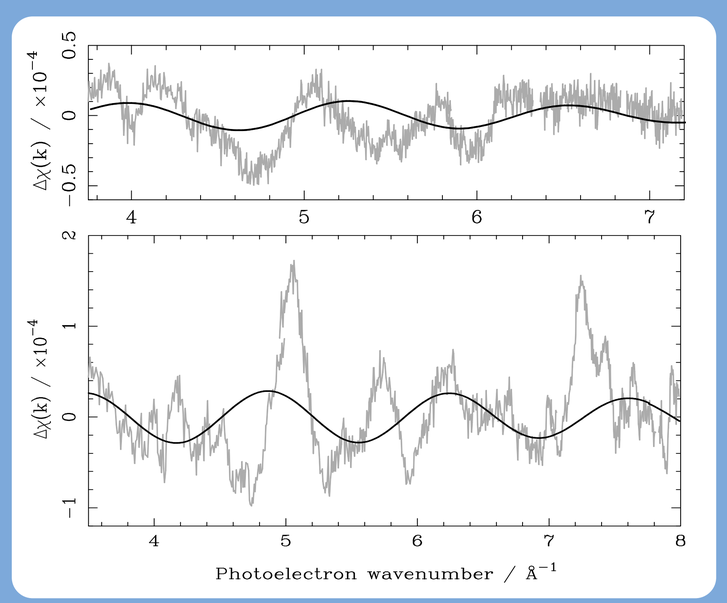
Magnetoelastic coupling

With the application of external hydro-static pressure, strain may be studied whilst modifying a sample's elastic properties, thus revealing information on its magnetoelasticity.

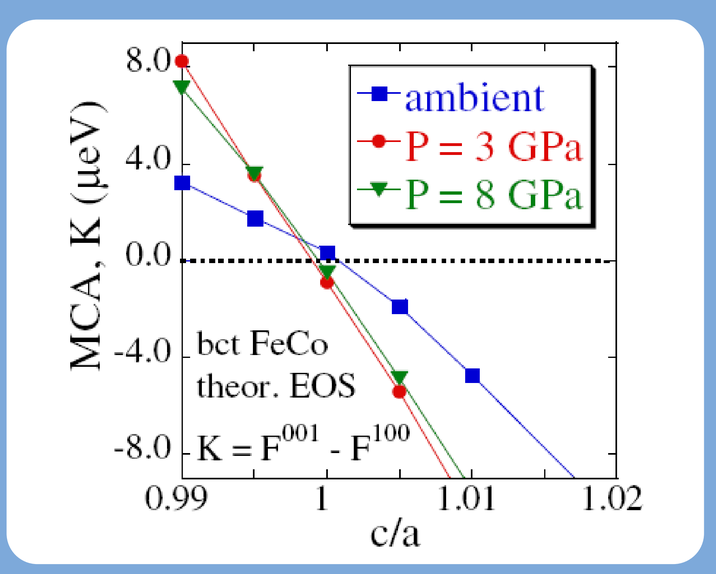
Studies of FeCo up to 8GPa showed that, under pressure, the magnetostriction is enhanced. This counter-intuitive trend confirmed new theoretical calculations.

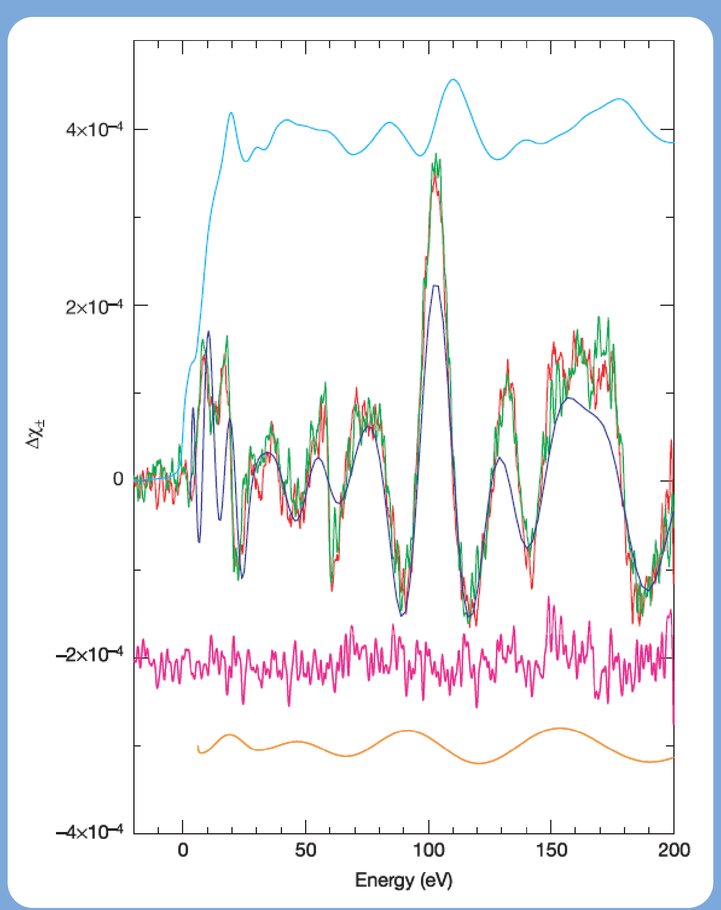


The DiffXAS apparatus *in situ* on beamline ID24 (ESRF)



$Fe_{81}Ga_{19}$ DiffXAS: Fe (top) and Ga (bottom)





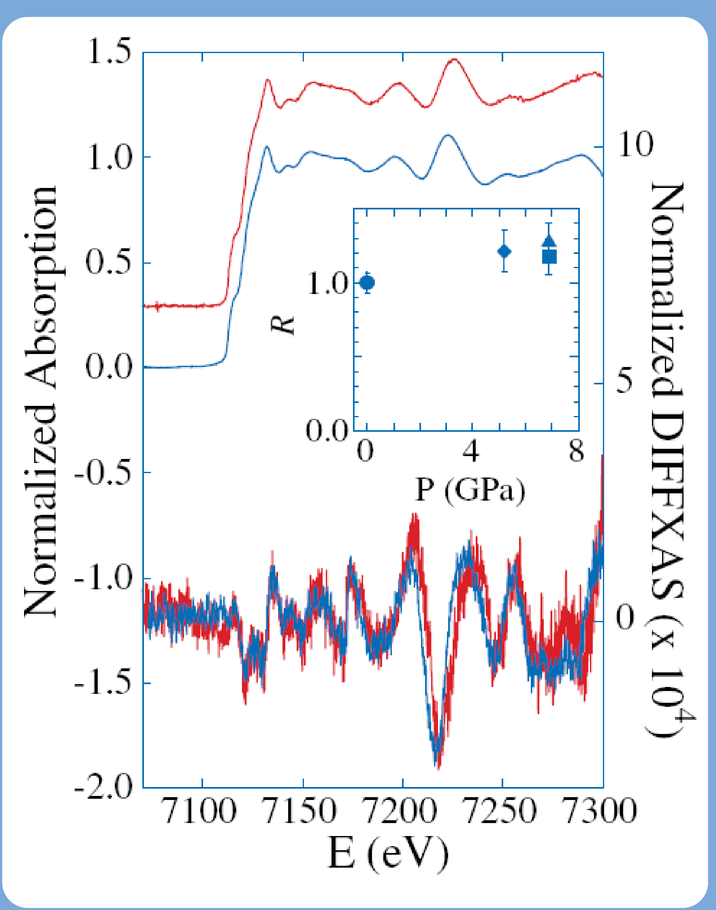
Magnetostrictive DiffXAS from FeCo

	1st shell	2nd shell
Fe environment	5 Fe-Fe 3 Fe-Ga	5 Fe-Fe 1 Fe-Ga
Ga environment	8 Fe-Ga	5 Fe-Ga 1 Ga-Ga

The disordered cubic structure

	$(3/2)\lambda_{100}$	$(3/2)\lambda_{111}$
Fe env.	(40±10)ppm	(−32±5)ppm
Ga env.	(390±40)ppm	(−10±20)ppm

The magnetostriction coefficients around each atomic site



FeCo DiffXAS as a function of pressure

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