Differential EXAFS: a tool to measure the effect of hydrostatic pressure on magnetostriction

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We have recently assessed the feasibility of performing X-ray differential EXAFS measurements of anisotropic (Joule) magnetostriction at high pressure on a test sample of polycrystalline FeCo. Joule magnetostriction is an anisotropic deformation which results from the application of an external magnetic field, and acts to transform a sample under the action of a 4^{th} rank tensor with the strain related to the magnetisation direction cosines measured with respect to the principle axes of the tensor. The phenomenon arises from changes in electron density and hence interatomic bonding as the electron spins follow the domain magnetic field through spin-orbit coupling [1]. The method we used, based on the measurement of a differential EXAFS signal, has been developed in the past 2 years on the dispersive XAS beamline [2] of the ESRF, ID24, through a collaborative effort between the beamline staff and the University of Warwick (UK). This pioneering work opened the field to measurements of tiny atomic displacements [3]. For these first tests at high pressure, a chip of annealed polycrystalline FeCo film provided by the University of Sheffield (UK), was inserted into a CuBe Diamond Anvil Cell which was then placed at the center of a rotating magnetic field device. The system allows the rotation of the magnetic field on a plane perpendicular to the propagation of the X-rays. EXAFS measurements at the Fe K edge were acquired with the magnetic field parallel ($\mu\|$) and perpendicular ($\mu\perp$) to the polarization of the electric field of the X-rays emitted by one of the planar undulators of the ID24 straight section. The normalized differential EXAFS signal is defined as: $(\mu\| - \mu\perp)/(\mu\| + \mu\perp)$. The maximum P-P amplitude is about 5 10^{-4}. We performed measurements up to a maximum pressure of ~ 7.5 GPa. A clear reduction of the amplitude is observed as pressure is increased, the signal at 0.5 GPa and 3.7 GPa being respectively of about 3.5 10^{-4} and 1.0 10^{-4}. At 7.5 ± 0.5 GPa no signal, or a very weak one, is visible within the noise level. Absorption spectra as a function of pressure up to 7.5 GPa clearly indicate that the ambient pressure bcc structure is preserved in this pressure range, and the reduction in frequency of the oscillations indicates that the lattice contracts uniformly.

For the future, we plan to carry out, as a function of pressure, Fe K- edge XMCD simultaneously to differential EXAFS on FeCo, in order to disentangle the evolution with pressure of magnetostriction from that of the magnetic moment on Fe.

[1] E.T. de Lacheisserie, Magnetostriction: Theory and Applications of Magnetoelasticity, CRC Press, Florida, p. 133 (1993)

[2] S. Pascarelli, O. Mathon, G. Aquilanti, J. of Alloys and Compounds, **362** 33-40 (2002)

[3] R. Pettifer, O. Mathon, S. Pascarelli, M. Cooke, M. Gibbs, submitted (2004)