ESRF	**Experiment title:** Atomic vibrations in $L1_0$ FePt thin films	**Experiment number:** HS 3845
Beamline: ID18	**Date of experiment:** from: 13.05.2009 to: 15.03.2009	**Date of report:** 27.07.2009
Shifts: 6	**Local contact(s):** A. Chumakov	*Received at ESRF:*

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Report:
The aim of this experiment was to resolve the anisotropic phonon density of state (PDOS) of FePt in the $L1_0$ phase. For that purpose, we employ the technique of nuclear inelastic scattering (NIS), which allows to obtain the contribution of the ^{57}Fe atoms to the total PDOS of FePt with sub-meV resolution. A particularity of the technique is that only vibrational modes which are parallel to the photon beam can be excited. Performing NIS along the different crystalline axis would practically allow to measure the phonon DOS anisotropy. This of course requires high quality single crystalline material, and FePt in bulk is polycrystalline. However, it is possible to grow high quality single crystalline FePt thin films by molecular beam epitaxy. By choosing a proper substrate orientation, it is possible to modify the growth direction of the FePt crystal.
For this experiment, we have grown 30 nm thick ^{57}FePt layers by molecular beam epitaxy on MgO(100) and MgO(110) substrates. The two substrates were placed one next to each other during the deposition, ensuring that the growth parameters were identical for the two samples. FePt grown on MgO(100) has its c-axis out of the film plane whereas FePt grown on MgO(110) has a 45° out of plane oriented c-axis. Therefore, by measuring NIS spectra on these two samples it is possible to extract the phonon DOS projected along the a-axis and (a+c)-axis respectively. The c-axis can then be extracted by simple substraction.

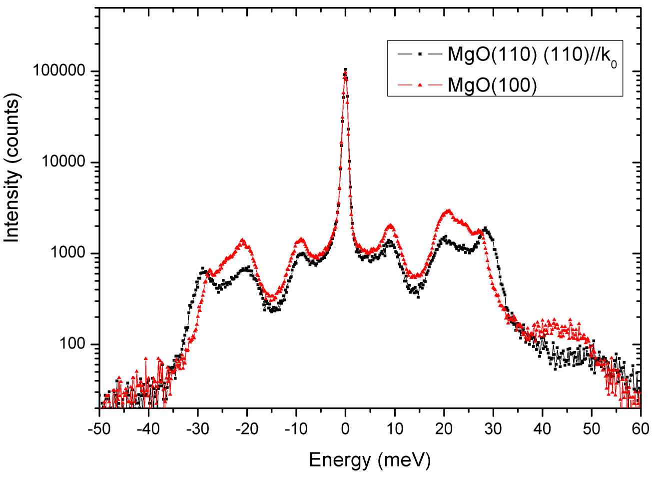

Fig. 1: Nuclear inelastic spectra recorded with 0.8 meV resolution on 30 nm FePt grown on MgO(100) and MgO(110) substrates.

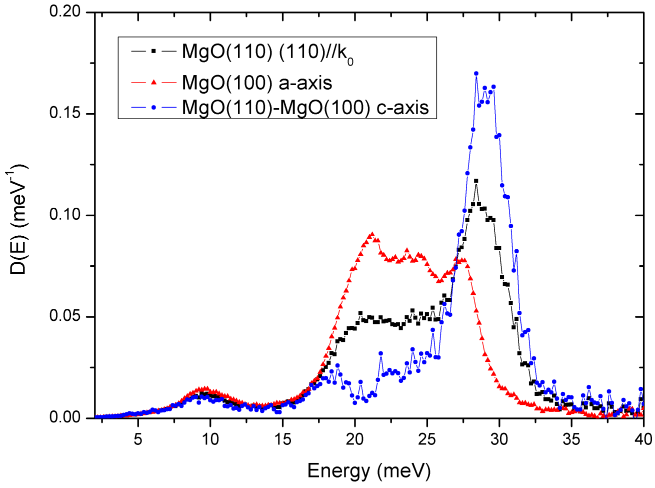

Fig. 2: Phonon density of state of the FePt along the different crystalline axis, extracted from the NIS spectra. Notice the high anisotropy between the a- and c-axis PDOS.

The experiment was carried out at the ID18 beamline which is equipped with a high resolution monochromator of 0.8 meV. NIS spectra were recorded on the two samples along two different crystallographic orientations each time. Each energy scan took approximately 1 hour to record and was repeated 10 times to obtain sufficiently high statistics.
The sum of the NIS spectra for the (100) and the (110) samples are shown in Fig. 1, where one can already see strong differences between the two orientations. The phonon DOS were extracted using the DOS program of A. Chumakov and are plotted in Fig. 2, together with the extracted c-axis DOS. One sees the very strong anisotropy between the a- and c-axis DOS. The c-axis DOS shows a narrow peak at energy, in contrast to the a-axis DOS, which is broader and contains softer modes as well.
Ab-initio calculations have been performed and show very good agreement with the experimental data. The extreme sensitivity to the surface in the grazing incidence geometry used here also allow us to rule out any surface related effects on the observed DOS. We are able to conclude that these epitaxial FePt layers are mainly Pt terminated, and that the Fe layer underneath already behaves almost like in the bulk.
This precise picture of the anisotropic phonon DOS have important implications, especially because FePt thin films and nanostructures are expected to be used in future storage media. The knowledge of the phonon DOS along the different axis will allow a better understanding of the heat dissipation mechanisms in this anisotropic material. These results are therefore highly relevant for the scientific community and will be the subject of a journal article in the near future.