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Report:

Eighteen shifts have been allocated on the BL6 beam line in order to study the Ce magnetisation profile in Cc/Fe multilayers by X-ray Resonant Magnetic Scattering (XRMS) at the L2 edge of Ce.

Recently, it has been shown that Cc/Fe multilayers prepared by sputtering have sharp interfaces. From macroscopic measurements, we know that the Fe magnetic moments tend to be ferromagnetically aligned. From x-ray absorption spectroscopy and XMCD measurements, carried out at the $L_{2,3}$ edges of Ce, the following properties have been inferred [1]: over the length scale of - 10-15A near the interfaces, Ce adopts the electronic structure of the a-phase. These et-like Ce atoms (but not the γ-like ones in the centre of thick Ce layers) carry an ordered magnetic spin moment on their 5d states in antiparallel orientation to the Fe-layer magnetisation.

The goal of the experiment was to investigate the capability of XRMS to probe the shape of the magnetic profile into the Ce layers. In ferromagnets the magnetic and charge scattering are coincident in reciprocal space. We thus measured the asymmetry ratio $R=(I^+ - I^-)/(I^+ + I^-)$ where I^+ and I^- are the diffracted intensities for two opposite directions of the magnetisation. Since it has been shown theoretically [2] and experimentally [3] that the imaginary part of the XRMS amplitude can be identified to the XMCD signal, it is noteworthy to recall that the amplitude of the dichroic signal is of the order of 10-2 and then the changes in the diffracted intensities are thus expected to be rather weak.

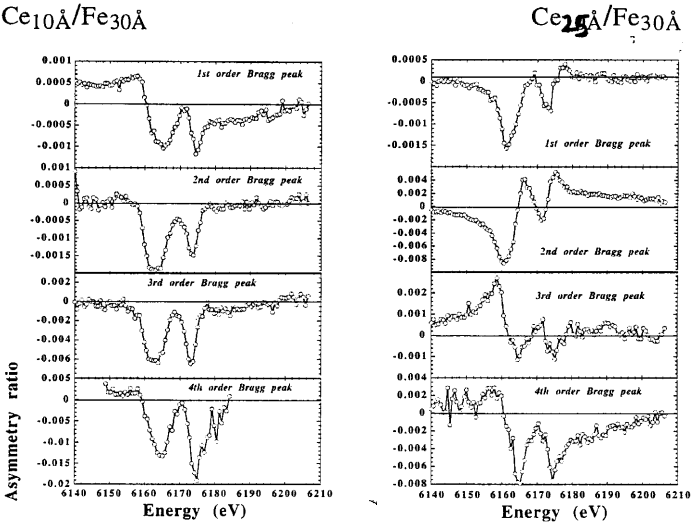
Two samples, with different thicknesses, have been investigated. With respect to the previous absorption results, we decided to study first a sample with a Ce thickness of 10Å for which a constant magnetic profile is expected. We chose a thickness of the Fe layer of about 30A to have a Curie temperature far above room temperature. We selected a second sample with the same nominal Fe thickness (30Å), in order to avoid possible Fe thickness effect on the results. Its Ce thickness was set to 25A m order to have in the centre of the layer less or no polarisation of the Ce atoms.

The diffracted patterns for both samples, where the Fe layers are crystalline and the Ce layers are amorphous, show several Bragg peaks, related to the multilayer periodicity, at small angles and none at high angles. In order to probe the distribution of the magnetic moment of the Ce atoms within a layer, with a reasonable spatial resolution, it is necessary to collect the asymmetry ratios on as many small angle Bragg peaks as possible.

To perform the experiment, we brought a $\theta/2\theta$ diffractometer diffractometer with horizontal axis, equipped with a magnetic field (up to 1000 G) applied along the intersection of the diffraction plane and the sample surface plane. We thus took fully advantage of the 100% circularly polarised incident beam of BL6, since in that configuration, the angular dependence of R is proportional to $\cos^3(\theta)$ [3]. Usually R is measured in the horizontal plane with linearly polarised incident photons and transverse magnetic field which leads to an angular dependence of R in $\tan(2\theta)$ [4] and a weak magnetic effect at small angles.

The results we obtained are the following (see figures):

- we observe asymmetry ratios with, at maximum, values ranging from 1.5 10^{-3} to 1.8 10^{-2}
- for the same sample, depending on the order of the Bragg peak, we observe strong changes in the shape of the energy dependence of R as well as in its amplitude.
- for the same peak, R is different from one sample to the order
- by comparison with XMCD data measured for both samples, the amplitude of the magnetic scattering effect may be up to one order of amplitude bigger depending on the order of the peak (1.5 10^{-2} for the fourth order of $Ce_{10Å}/Fe_{30Å}$ against 110-3 for XMCD)
- while for $Ce_{10Å}/Fe_{30Å}$ the absolute values of the maximum of R are increasing continuously with the order of the Bragg peak (moreover they do not occur at the same energy), for $Ce_{25Å}/Fe_{30Å}$ they show an oscillatory behaviour.



At first glance all these features indicate that the magnetic profiles in both samples are rather different which actually was expected. What was not expected is the intensity of the "dichroic" signal detected by XRMS which make this technique a very sensitive probe to measure the induced magnetic moment in multilayers. We are presently performing calculations, assuming different magnetic profiles across the Ce layers, to simulate the observed features. Up to know, we have not been able to reproduce in detail the shapes and the changes in intensity of R for the four orders of a sample. However from the calculation performed we can draw some trends:

- the first one concerns the dependence of the shape of R with energy on the charge structure factor. For example, by assuming a constant magnetic profile, keeping the same thickness for the Ce and Fe layers, but changing the number of Ce planes in the layer by +1 and, as a consequence, adjusting the d spacing of the Ce layers, it is possible to change strongly the shape of R
- in order to get a strong changes in the maximum of the amplitude from one order to an other one, it is necessary to change significantly the magnetic profile.

Work is in progress to better analyse these data and we are confident that a detailed information on the magnetic profile will be obtained. We like to point out that, even for the 10A-Ce layer, the magnetic profile cannot assumed to be constant and that the Ce magnetic polarisation is preferentially concentrated in the middle of the layer. This is not expected from available XMCD data and shows the interest of XRMS for this kind of studies.