ESRF

Experiment title:

Growth and structure of ultrathin Co ferrite layers for spin-filtering: CoFe2O4/Ag(001)

Experiment number:

HC-2305

Beamline:

Date of experiment:

from: 26/04/2016 to: 03/05/2016

Date of report:

23/02/2017

Received at ESRF:

Shifts:

18

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Report:

The purpose of this proposal was to study growth and structure of high quality epitaxial Co ferrite ultrathin films on a Ag(001) substrate by in situ grazing incidence x-ray diffraction (GIXRD).

Ferrites are emerging in spintronic reserch as materials suited for spin-filtering (SF), which gives an alternative way for generating spin-polarized currents, with respect to the devices formed by two magnetic layers sandwiching a non-magnetic one. SF arises when tunneling through ferro- or ferrimagnetic materials, with different barrier heights for majority and minority spin electrons. Efficient SF has been demonstrated for ferromagnetic insulators such as EuS and EuO, which however can only be employed at low temperature due to their low Curie temperature values [Ref.1]. Spinel ferrites like $CoFe_2O_4$ are promising candidates for room-temperature (RT) SF

Bulk Co ferrite has the same spinel structure of magnetite. The transition metal cations (Co^{2+} and Fe^{3+}) are located in octahedral and tetrahedral sites of a close-packed face-centered cubic sublattice of oxygen anions. An inversed spinel structure was observed experimentally [2], with Co^{2+} ions occupying half of the (octahedral) B sites. The cations distribution has a direct influence on the band gap, as shown by the theoretical calculations [3].

In this experiment we succeded in growing high-quality $CoFe_2O_4$(001) ultrathin films on Ag(001) following a three steps method employed previously to grow magnetite layers [4]. First, 1 nm of $CoFe_2$ alloy was epitaxially grown on the substrate by MBE using two e^- beam evaporators, then an oxide was grown by dosing, still at room temperature, with $\sim 5\times10^{-6}$ mbar O_2, and finally long range order is established by annealing in oxygen up to 850 K. A template layer with is then obtained with spinel structure, sharp interfaces and (001) orientation. Its thickness can then be increased by reactive codeposition in oxygen at 650 K or above. Figure 1a shows a scan in the reciprocal space along a diffraction rod characteristic of the spinel $CoFe_2O_4$(001) structure (a sketch of the reciprocal space indexed in the Ag surface cell is reported in Fig. 1b).

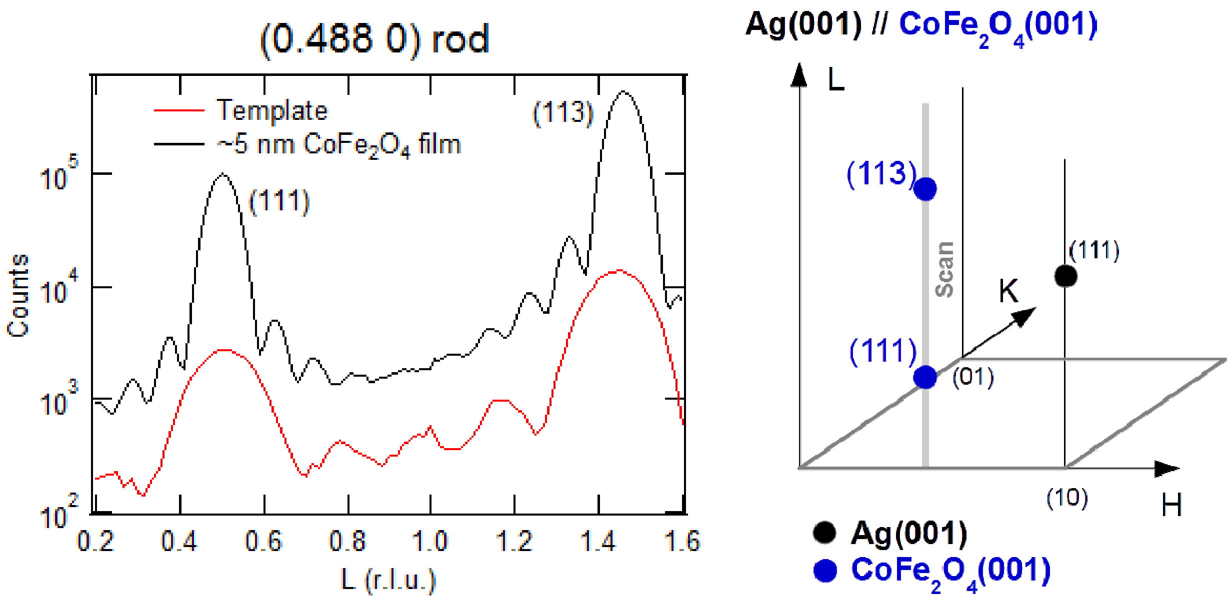

FIG. 1. a: Lscan along a rod characteristic of the $CoFe_2O_4$(001) film with spinel structure; b: sketch of the scanning direction in the Ag surface reciprocal space basis.

A large set of diffraction rods has been measured to model the film structure at an atomic layer, the detailed modelisation is still in progress.

Resonant GIXRD at both the Fe and Co K edges was also measured on several ferrite peaks. Great attention was payed in measuring (2+4n 0 2) and (2+4n 2 2) peaks, which probe the tetrahedral and octahedral sites, respectively. Results clearly indicate that Co is present mainly on the octahedral site, i.e. the structure is inverse, which as discussed is fundamental for applications.

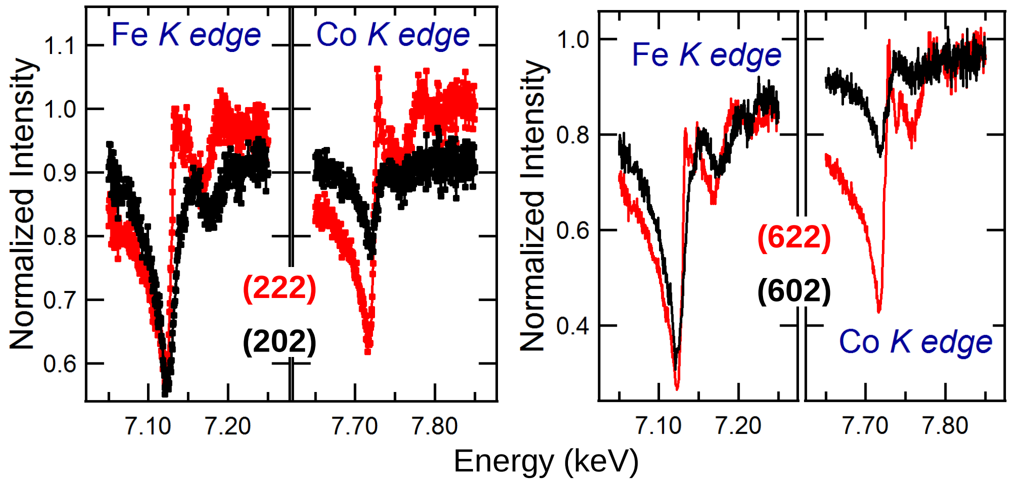

FIG. 2. $CoFe_2O_4$/Ag(100) : ferrite peaks resonant scattering at the iron and cobalt *K* edges (black line, reflections sensitive to the tetrahedral site).

References

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[4] A. D. Lamirand, S. Grenier, V. Langlais, A. Y. Ramos, H. C. N. Tolentino, X. Torrelles, M. De Santis, Surf; Sci. 647, 33 (2016)