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Experimental Report : SUV proposal

ultra-thin MnPt/FePt exchange-coupled bilayers on Pt(001)

Aims of and scientific background

The overall scientific scope of our study is understanding the interaction between antiferromagnetic (AFM) and ferromagnetic (FM) materials at well-defined interfaces by combining structural, electronic and magnetic techniques using synchrotron light. We are particularly interested on the growth and structural properties of AFM layers (MnPt and CoO) exchanged coupled to a thin FM FePt film with perpendicular magnetic anisotropy (PMA) grown on Pt(001) single crystal. The main sample of this study was ultra-thin exchange-coupled MnPt/FePt bilayers with $L1_0$ structure.

In a previous experiment, we studied a 2.8nm MnPt/Pt(100) film grown at room temperature by alternate deposition of monoatomic layers of Mn and Pt under UHV conditions. No long-range chemical order was observed by X-ray diffraction, even after post annealing up to 500°C for 1 hour. Nevertheless, the experiments showed a diffuse scattering close to the ordering peak, indicating a short-range order developped and incipient L10 domains were present in the annealed sample. These $L1_0$ domains turned out to be oriented both out-of-plane and in-plane, with coherence lengths of about 1.6 nm. An Fe thick film was deposited on top of that sample and their magnetic properties were studied *ex-situ* by MOKE. The exchange bias shift observed in the magnetization loop clearly demonstrated that such a MnPt film was AFM (with Néel temperature in the 50 K range) and coupled strongly to the FM Fe film. This evidence demonstrated that even short-range ordered structures, with coherence lengths as short as 1.6 nm, are coupled antiferromagnetically. Increasing chemically ordered coherence must be the clue to increase coupling and raise the Néel temperature to room temperature.

Experimental results

We succeeded the growth of an ultra-thin layer of MnPt coupled to a layer of FePt in chemically ordered $L1_0$ phases. Alternate monoatomic deposition were used to grow both alloys on a Pt(100) substrate.

In a first experiment, we started by the Mn deposition directly on Pt(001). It was possible to follow at each step of the growing the evolution of ordering peak (Fig. 1). The scattered intensity is plotted against the perpendicular momentum transfer, in reciprocal lattice units (l.r.u.). One can observe a clear development of the order peak as the number of layers is increasing. The growth was stopped when 8 Mn/Pt bilayers were completed. The structure of this layer was studied by exploring the truncation rods in the reciprocal space for many reflections. After that an FePt film was deposited on top of the MnPt film. The FePt was composed of 4 Fe/Pt bilayers. The sample was covered by 8 ML of Pt for ex situ studies. Before taking the sample out, a complete structural study was performed in the whole film. Data deserves now a lot of analysis to refine all parameters.

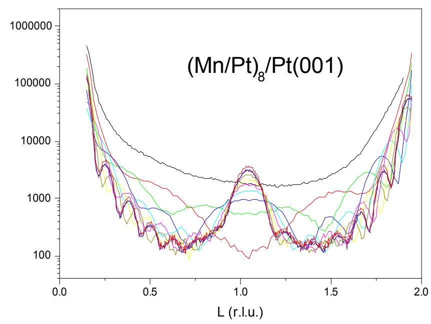
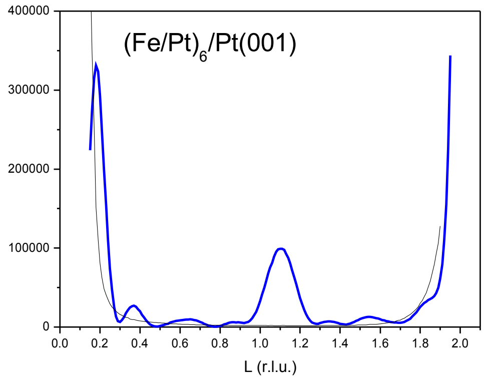


Figure 1: Intensity evolution of the chemical ordering peak perpendicular to the surface.

The room temperature perpendicular magnetic anisotropy associated to the this sample has already been measured by performing ex situ MOKE experiments. The coercivity is found much smaller than for a typical FePt ordered thick layer. This could come either from the degree of order or from the thickness effect on the Curie temperature, which could impose a FM order below room temperature. The complete temperature dependence of the magnetic properties has been performed. As a preliminary result, we could identify the AFM ordering temperature close to 300K and a weak exchange bias shift at 5K. A complete analysis has to be done.

During our *in situ* surface X-ray diffraction experiment at BM32, we combined alternating deposition of Fe and Pt and the high temperature of the substrate (about 600 K) to generate a high-chemically ordered $L1_0$ layers of FePt/Pt(001) with the tetragonal c-axis perpendicular to the substrate (Fig. 2). No traces of $L1_2$ FePt phase were found. Such an FePt(001) surface layer is flat with large terraces and can be used as a starting point to study the growth of a CoO or MnPt layer directly on a FM surface. The proximity to a FM layer with PMA can play an important role in the spin orientation of the AFM layer.



After growing a 6 bilayer-thick FePt(001) sample, a MnPt layer was deposited following the same method of alternating deposition at a bit smaller temperature (575 K). This sample was covered by 8 ML of Pt for protection.

The complete temperature dependence of the magnetic properties of the MnPt/FePt system has been measured, and a strong exchange bias coupling at the AFM/FM interface is found. The room temperature perpendicular magnetic anisotropy associated to the $L1_0$ phase has already been observed by performing ex situ MOKE experiments. In the next few weeks a complete MOKE characterization will be performed at low temperatures and under field cooling conditions to study the exchange bias effect.