Controlling the magnetic anisotropy in the cobalt bilayer with hydrogen

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The control of magnetic anisotropy in thin films opens the way to a variety of applications[1]. Thus, research efforts have been devoted to the study of systems where the interplay of roughness, thickness and strain can be revealed. Cobalt or cobalt alloys is widely used in industrial applications[2]. Cobalt is a prototypical ferromagnet with two different crystal structures in bulk, hcp for low temperatures and fcc for temperatures >700K. The magnetic properties of Co thin films on Ru(0001) are determined by the number of the layers. The magnetic easy-axis is in-plane for one layer films or films with three layers or more; on the other hand, the second layer presents perpendicular magnetic anisotropy, i.e. the easy axis is perpendicular to the film plane [2]. This fact makes this system a good model for the study of spin reorientation transitions(SRT).

In this work we present a characterization of the growth and the magnetism of thin Co films on Ru(0001) at two different temperatures. We also study the change in the magnetization of the films upon hydrogen exposure in both cases. The structural characterization was done by low energy electron microscope (LEEM) [3], low energy electron diffraction (LEED) and scanning tunneling microscope (STM). The magnetism of the films and their response to the hydrogen were studied by spin polarized low energy electron microscope (SPLEEM). This microscope allows to determine the magnetization direction of the sample in real time with a lateral resolution of 15nm.

Our results show that the islands of the first and second layer of Co/Ru(0001) grown at room temperature (RT) present a triangular shape with a unique stacking sequence in each terrace. For three or more layers, Co islands present two different stacking sequences in the same terrace. Likewise films grown at 550 K present larger triangular islands with two stacking sequences in the same terrace from the third layer as shown in figure 1. The same interlayer spacing for the Co layers was obtained in both cases.

Cobalt thin films present different magnetic signals depending on the growth mode. For the case of films grown at RT, we did not obtain any magnetic contrast in-plane or out-the-plane for the first two layers. Only for three or more layers of cobalt, a magnetic signal (in-plane) was obtained. This is shown in figure 2(a). This contrast with the films grown at 550 K, where the second layer presents a perpendicular magnetization for temperatures below 400 K. Three layer or more films grown at 550 K always present in-plane magnetization.

On the other hand the second layer of Co on Ru(0001) presents in-plane magnetization when it is grown at RT on Ru(0001) presaturated with hydrogen [figure 2(b)]. This in-plane magnetization of the cobalt bilayer can be also obtained if hydrogen is dosed on the second layer of cobalt grown at 550K. When the hydrogen is bonded to Co it induces a spin reorientation transition of the easy axis, from perpendicular to in-plane magnetization. This change is very sensitive to the hydrogen concentration. By monitoring the change in the anisotropy we could be able to use this system as a gas sensor [patent WO/2010/129390].

STM data confirms that there is no significant changes in the morphology of the Co islands grown on Ru(0001) or on H-Ru(0001). LEED-IV data also do not show changes in the interlayer spacing of layers. Ab-initio calculations showed that the change in the anisotropy of the cobalt is due to electronic effects.

References

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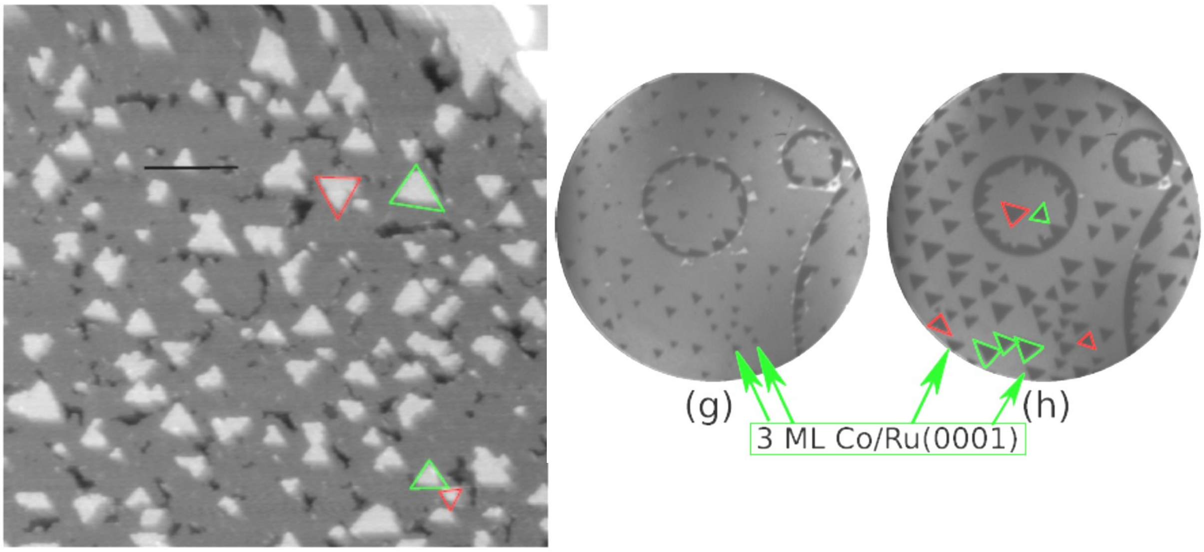
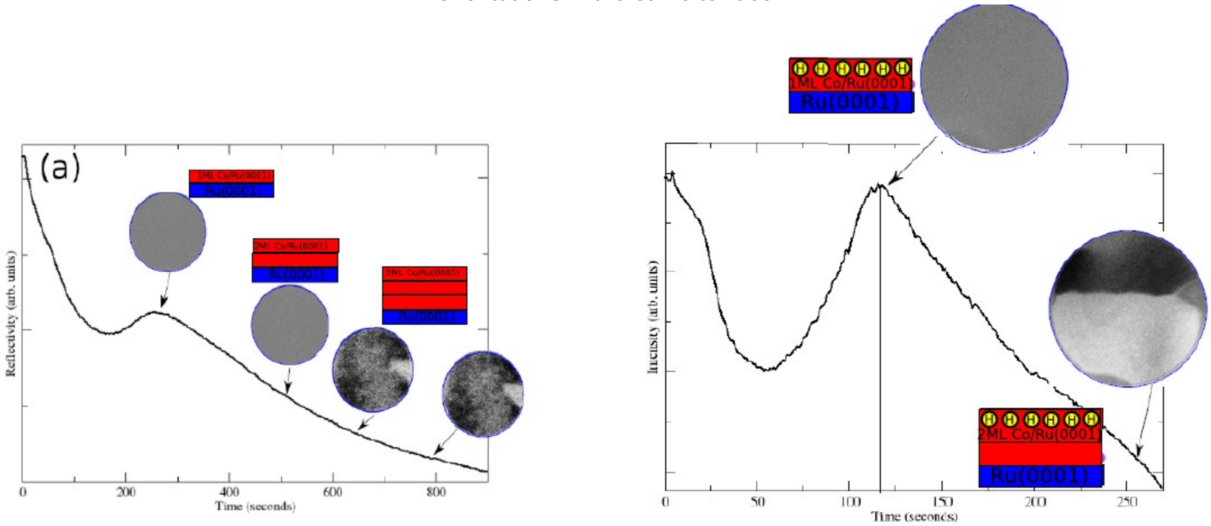
Figures



(a) (b)

Figure 1: (a)STM image of 2,5ML of Co/Ru(0001) grown at RT, 200nmx200nm (b) LEEM image of 2.5 ML of Co/Ru(0001) grown at 550 K. Field of view was 8 µm. In both cases the triangular islands of Co show two different orientations in the same terrace.



(a) (b)

Figure 2: Reflectivity curves acquired while the Co films were grown. The magnetic signal of each film is shown. Field of view was 8 µm in both cases (a) for films grown at RT on clean Ru(0001) (b) for films grown on Ru(0001) saturated with hydrogen.