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# Magnetization reversal dynamics in Au/Co/Au(111) ultrathin films: Effect of roughness of the buffer layer

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ABSTRACT

We present a study of the magnetization reversal dynamics in ultrathin Au/Co/Au films with perpendicular magnetic anisotropy, for a Co thickness of 0.5, 0.7 and 1 nm. In these films, the magnetization reversal is dominated by domain nucleation for $t_{Co}$=0.5, 0.7 nm and by domain wall propagation for $t_{Co}$=1 nm. The prevalence of domain nucleation for the thickness range 0.5–0.7 nm is different from results reported in the literature, for the same system and for the same thickness range, where the magnetization reversal took place mainly by domain wall motion. We attribute this difference to the effect of roughness of the Au buffer layer on the morphology of the magnetic layer.



## 1. Introduction

The dynamics of magnetization reversal is very important for systems with perpendicular magnetic anisotropy used in high-density recording [1,2], since it governs the written domain size, irregularity, and stability. Therefore, it is essential to understand the magnetization reversal mechanism for further improvement of recording performance as well as for the fundamental understanding of magnetism in films with perpendicular anisotropy. The direct observation of domain by means of magnetic imaging techniques [3–5] has shown that magnetization reversal in these systems occurs via two competing processes: domain nucleation and domain wall motion. Several studies of the magnetization reversal dynamics of ultrathin Au/Co/Au films have been reported in the literature [6–11]. However, these studies did not discuss in detail the correlation between the magnetization reversal dynamics and the buffer layer morphology for very small cobalt thicknesses such as 0.5 and 0.7 nm.

The aim of this paper is to establish a correlation between the film morphology and the dynamics of magnetization reversal in polytextured (textured with a full in-plane mosaicity) Au/Co/Au sandwiches with perpendicular magnetic anisotropy, by taking into account the measured profile of the Au/Co interface roughness. The surface of the Au buffer layer was analyzed by atomic force microscopy (AFM). The magnetization reversal processes were investigated by magneto–optical Kerr magnetometry and Kerr microscopy.

In Section 2, we present the structural investigation of the samples. Section 3 is devoted to static and dynamic magnetic results and to a discussion on the correlation between structure and magnetic properties.

## 2. Sample and structural characterizations

Au/Co/Au films were prepared by electron beam evaporation in an ultrahigh vacuum chamber, with a base pressure of about $10^{-9}$ Torr and approximately $10^{-8}$ Torr during deposition. The substrate is sapphire with orientation (0 0 0 1) (Fig. 1), preliminary cleaned ex-situ by ultrasounds in an acetone bath. All deposition processes were performed at room temperature after in-situ degassing.

A first 25 nm thick Au film is deposited on the substrate at a deposition rate of 2.5 nm/min, as calibrated with a quartz microbalance, followed by annealing at 423 K during 1 h to reduce the surface roughness. The Au film is (1 1 1) textured, as shown by X-ray diffraction (Fig. 1). Fig. 2(a) shows the AFM image of the Au buffer layer after annealing. The surface roughness (root mean square: Rms) was measured to be about 0.61 nm. Using the surface corrugation obtained from this figure, we estimate a lateral grain size of 20–30 nm.

Cobalt layers with different thicknesses ($t_{Co}$=1, 0.7 and 0.5 nm) are then deposited on the Au layer at a deposition rate of 0.2 nm/min. The (1 1 1) texture of the Au layer suggests a

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possible epitaxial growth of the cobalt layers with the hcp (0 0 0 1) structure [12–14].

Finally, a second Au layer with a thickness of about 5 nm is deposited on top of the cobalt layer.

## 3. Magnetic investigations

### 3.1. Magnetic anisotropy and coercivity

Magnetic hysteresis loops, at a field sweep rate of 1.2 mT/s, and relaxation curves of these films were recorded at room temperature (RT) by Kerr magnetometry in the polar configuration (PMOKE) using a He–Ne laser. Images of the domain structure during relaxation under field were recorded by Kerr microscopy using a xenon light source, also at RT.

Fig. 3 shows PMOKE hysteresis loops for samples with different Co thicknesses. The full remanence found in all cases shows that the magnetization is oriented fully perpendicular to the films for all thicknesses. For the sample with $t_{Co}=1$ nm the nucleation field, at which the magnetization reversal starts, is well defined. The square shape of this loop suggests that magnetization reversal takes place by the nucleation at a few centers followed by fast domain wall motion. On the other hand, for the samples with $t_{Co}=0.7$ nm and $t_{Co}=0.5$ nm the hysteresis loops have a more rounded and irregular shape, suggesting a significant pinning of domain walls and thus a larger role played by nucleation processes. The loop of the sample with $t_{Co}=0.7$ nm presents a small jump, which could be due to simultaneous nucleation of an important number of centers at $\mu_o H=12$ mT. The measured coercivity is nearly independent of thickness, as can be seen in Table 1. Our coercivity values are slightly lower than the ones reported in the literature for similar systems [6,7,10]. Let us note that the coercivity of truly epitaxial layers can be a few mT only [15]. Magnetic anisotropy being an important ingredient for coercivity let us discuss the anisotropy of our samples. Anisotropy fields were determined by the measurement of the perpendicular magnetization component when the magnetic field is applied along a direction slightly tilted with respect to the in-plane direction, with tilt angle $\alpha$. A coherent rotation behavior is observed and fitted by

$$H=\frac{(H_{1eff}\sqrt{1-\cos^2\theta}+H_2(1-\cos^2\theta)^{3/2})\cos\theta}{(\cos\theta\cos\alpha-\sqrt{1-\cos^2\theta}\sin\alpha)}, \quad (1)$$

deduced from the minimization of the energy taking into account the anisotropy and Zeeman terms. In expression (1), $\theta$ is the angle between the magnetization and the surface normal. The fit parameters $H_{1eff}$ and $H_2$ are, respectively, the first-order effective anisotropy field and the second order anisotropy field. They are written in the following form: $2K_{1eff}/M_s$ and $4K_2/M_s$ with $K_{1eff}$ a first-order effective anisotropy constant comprising shape anisotropy ($-2\pi M_S^2$ for a flat film) and $K_2$ the second-order anisotropy constant. $M_S$ is the spontaneous magnetization. Values of $M_S$, anisotropy fields and anisotropy constants measured at room temperature are given in Table 1. $M_S$ was measured by Superconducting Quantum Interference Device Magnetometer (SQUID). We find $K_{1eff}$ values ranging between $1.7\times10^5$ and $3.5\times10^5$ J/m$^3$ and those of $K_2$, almost constant, ranging between $0.26\times10^5$ and $0.29\times10^5$ J/m$^3$ (Table 1). The values of $K_{1eff}$ are almost twice smaller than the literature value of about $5\times10^5$ J/m$^3$ for 1 nm Co thickness [10]. We also note that the anisotropy decreases going to smaller thicknesses, in contrast to the general observations for Au/Co/Au systems of a linear increase of the anisotropy upon decreasing the cobalt thickness, irrespective of the deposit technique used [15–17]. However, the reduction of the anisotropy for low ($t_{Co}<1$ nm) thicknesses was already observed for Pt/Co/Pt systems [18]. A dependence of the perpendicular anisotropy on the thickness of Au buffer layers or cover layers has been observed previously [19,20] and was attributed to structural and electronic effects. The reduction of the anisotropy in our samples may be due to the effect of roughness

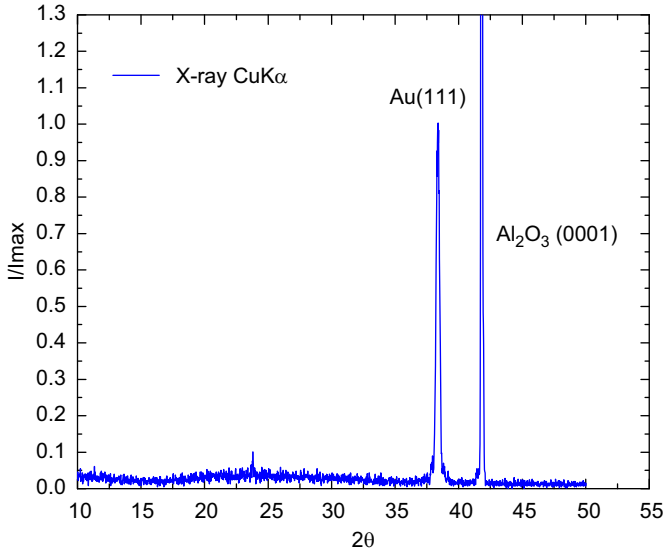


**Fig. 1.** Theta–2Theta X-ray diffraction of Au/$Al_2O_3$.

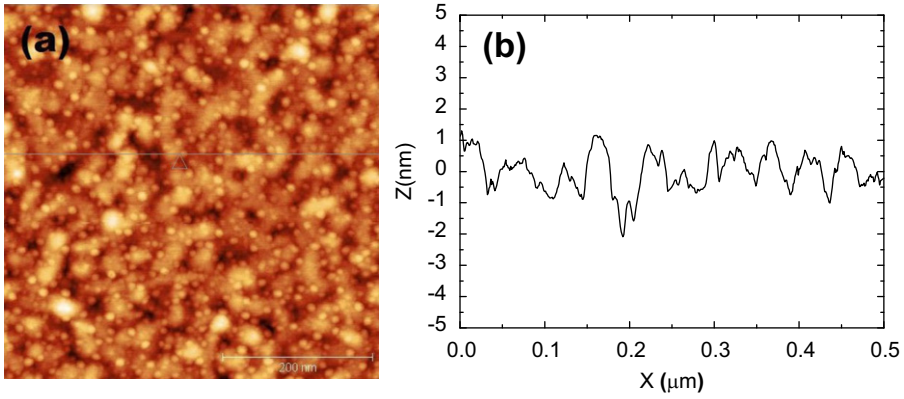


**Fig. 2.** The AFM data showing: (a) 0.5 × 0.5 μm topographic image of a gold buffer layer deposited on single crystal alumina, (b) the profile of the Au buffer layer along the line highlighted in (a).