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# Buffer layer annealing effects on the magnetization reversal process in Pd/Co/Pd systems

A. Fassatoui [a,*], R. Belhi [a], J. Vogel [b], K. Abdelmoula [a]

[a] LMOP: LR99ES17, Faculté des Sciences de Tunis, Université de Tunis El Manar, Tunis, 2092, Tunisie
[b] Institut Néel (CNRS and Université Grenoble Alpes), 25 rue des Martyrs, B. P. 166, Grenoble cedex 9, 38042, France

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ABSTRACT

We have investigated the effect of annealing the buffer layer on the magnetization reversal behavior in Pd/Co/Pd thin films using magneto-optical Kerr microscopy. It was found that annealing the buffer layer at 150 °C for 1 h decreases the coercivity and increases the saturation magnetization and the effective magnetic anisotropy constant. This study also shows that the annealing induces a change of the magnetization reversal from a mixed nucleation and domain wall propagation process to one dominated by domain wall propagation. This result demonstrates that the main effect of annealing the buffer layer is to decrease the domain wall pinning in the Co layer, favoring the domain wall propagation mode.



## 1. Introduction

Metallic thin layers and multilayers have been the subject of a lot of studies for decades [1–3]. The interest arises from the fact that at very low thicknesses these systems possess fascinating physical properties [4]. Thanks to their strong perpendicular magnetic anisotropy (PMA) they represent an interesting medium for exploring magnetic phenomena of fundamental importance such as magnetoresistance and magnetization reversal, which are essential for technological applications like high-density perpendicular magnetic recording. The magnetization reversal dynamics in these systems has been reported to show a quite contrasting behavior resulting from the competition between domain nucleation process and domain wall motion process. The magnetization reversal behavior has been found to be sensitively dependent not only on the layer thicknesses [5–7] and the fabrication conditions [8], but also on the buffer layer morphology [9], which depends on several parameters such as deposition rate, substrate and annealing [10]. In this paper, we focus on the effects of annealing the buffer layer on its morphology, on the static magnetic properties and especially on the magnetization reversal dynamics in 0.3 nm thick cobalt layers in Pd/Co/Pd sandwiches. This paper is organized as follows. Section 2 is devoted to the description of the deposition processes and of the characterization methods. In Section 3, we present the structural and the morphological investigation of the buffer layer. Section 4 deals with the static magnetic properties of the Pd/Co/Pd sandwiches. Section 5 summarizes the experimental data on magnetization reversal. The work is concluded in Section 6.

## 2. Experimental details

Pd/Co/Pd films were prepared by electron beam evaporation in an Ultra-High Vacuum chamber, with a base pressure of about $10^{-8}$ Torr and approximately $10^{-7}$ Torr during deposition. The deposits are performed at room temperature on (100) oriented silicon substrate (Fig. 1). An in-situ substrate degassing precedes each deposition process. A 25 nm thick Pd buffer layer was first deposited on two Silicon substrates with a deposition rate of 2.5 nm/min. One of these two layers was annealed at 150 °C for 1 h (sample S2) under vacuum ($10^{-5}$ Torr). The other has not undergone any heat treatment (sample S1). Then structural and morphological details of these buffer layers were investigated by X-ray diffraction (XRD) and Atomic Force Microscopy (AFM). A 0.3 nm thick cobalt layer was then deposited on the Pd layers at a deposition rate of 0.1 nm/min. Finally, a 4 nm thick Pd cover layer was deposited on top to prevent oxidation of the cobalt layers. The layers thickness was monitored by a quartz microbalance [11] which has an accuracy of 10%. The magnetic hysteresis loops of the samples were probed at room temperature by means of the VSM-SQUID for a field applied perpendicular to the plane of the films. The magnetic domain structure and its evolution has been studied using polar magneto-optic Kerr effect microscope (PMOKE). We have used an Evico magnetics Kerr microscope using highly stable and intense Xenon short arc light source. The microscope is

* Corresponding author.
*E-mail address:* Fassatouiaymen@Hotmail.com (A. Fassatoui).

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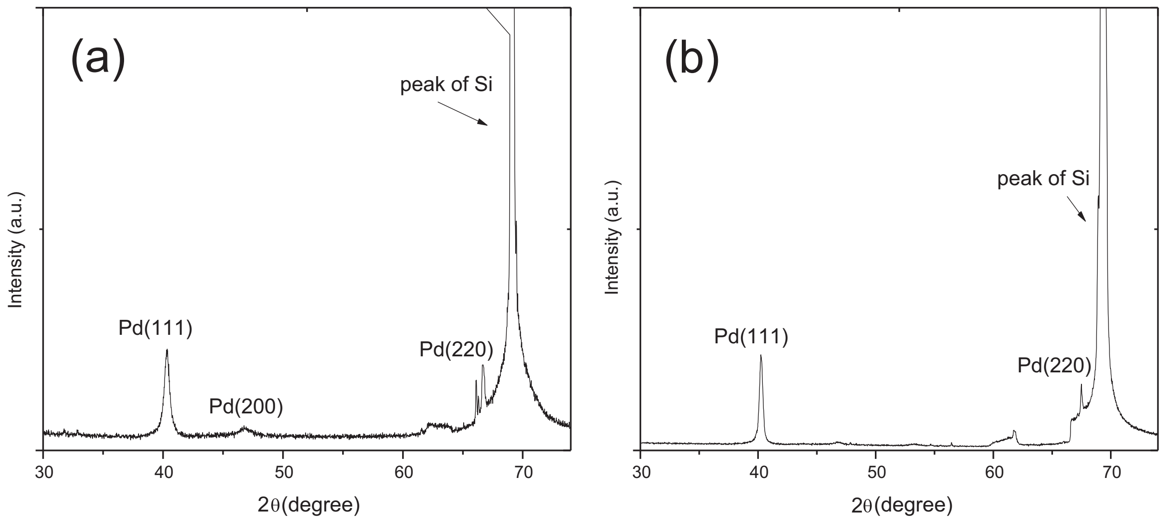


**Fig. 1.** XRD spectra of a 25 nm thick as-deposited (a) and annealed (b) Pd buffer layer deposited on Si, before the cobalt deposit.

equipped with a sensitive low noise digital cooled CCD camera of 1.37 million pixels (1344 × 1024) resolution and a frame rate of 43 frames/s.

## 3. Structural and morphological properties of Pd buffer layer

X-ray diffraction experiments were performed on the Pd buffer layers. XRD spectra are shown in Fig. 1(a) and (b), for samples S1 and S2, respectively. The observed peaks have been identified using JCPDS data as displayed in the figures. Indeed, no significant difference is observed between the two spectra except the absence of the Pd (200) peak and the slight narrowing of the Pd (111) peak in the annealed sample. The narrower width of the (111) diffraction peak indicates according to Debye-Scherrer's formula [12] that the grain size of Pd in sample S2 is larger than that in sample S1. In order to determine the texture of the Pd buffer layers, we have computed the intensity ratios of the observed peaks of Pd. These intensity ratios are compared to the ones of Pd powder (where there is no texture). For randomly oriented grains (the Pd powder ones), is equal to 0.47. For our samples, we found 0.25 for the un-annealed Pd and 0.33 for the annealed Pd. These values are small compared to 0.47. Thus, we infer from this that the Pd grows with the preferred (111) orientation. Such a texture was reported by several authors, e.g., in Co/Pd multilayers grown on silicon by thermal evaporation [13]. Moreover, it was also observed in Pd deposited on other substrates such as glass and Kapton [1]. However, studies have shown that Pd can also grow with other textures like (100) and (110) [14]. To investigate the surface morphology of the Pd layers, a quantitative analysis of the surface topography was carried out by AFM in the tapping mode. Fig. 2 (a) and (b) show the 3D AFM topography images of the Pd buffer layer surface before and after annealing. On these figures one can clearly see that in the two cases the Pd surface is not smooth and that the annealed Pd buffer layer exhibits a larger grain size. This result agrees with what the diffraction x-ray revealed. In Fig. 3 (a) and (b) the roughness profiles are presented. The surface roughness of the Pd layer was measured in the two samples. The average roughness (RMS: root mean square) of the un-annealed Pd layer is about 0.49 nm. Upon annealing the layer, the surface becomes less rough with an average roughness (RMS) of about 0.41 nm corresponding to a reduction of 0.08 nm (17%). Using the surface corrugation obtained from the 2D AFM images we estimated the lateral grain size of the Pd in each case. The average value ranges between 15–30 nm for sample S1 and 20–38 nm for sample S2.

## 4. Magnetic properties

### 4.1. Coercivity and saturation magnetization

Fig. 4 displays the magnetic hysteresis loops measured using VSM-SQUID magnetometry on Pd/Co/Pd/Si for 0.3 nm cobalt deposited on un-annealed (S1) and annealed (S2) Pd buffer layers. The reported hysteresis loops show that the cobalt layers exhibit a remanence ratio of $\frac{M_r}{M_s}$=0.84 and 1, for samples S1 and S2,

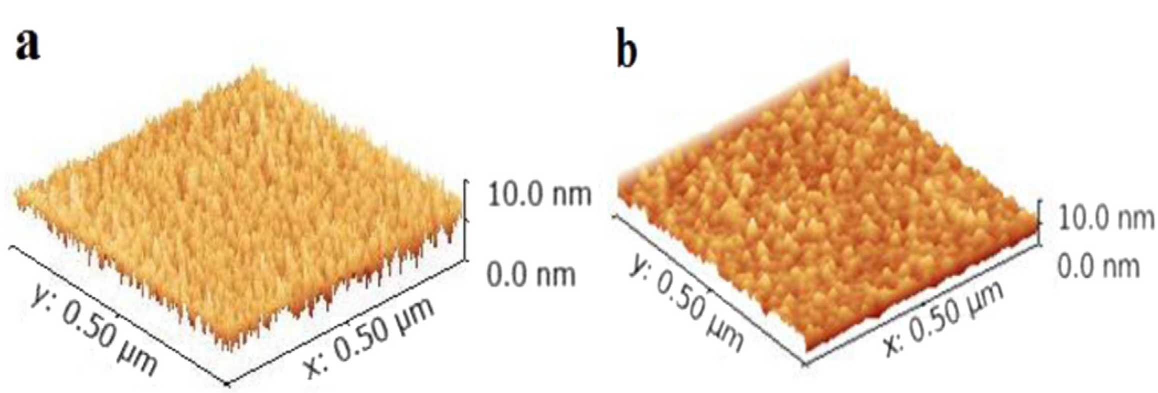


**Fig. 2.** 3D AFM images of the 25 nm thick Pd buffer layer deposited on Si, as-deposited (a), and annealed (b), before the cobalt deposit.