International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 23 No. 4 Jul. 2018, pp. 569-574

http://www.ijias.issr-journals.org/

The substrate thickness effect on the magnetic properties of some atomic plans of cobalt

***A. Adanlété Adjanoh*[1] *and R. Belhi*[2]**

[1]Département de Physique, Faculté des Sciences et Techniques, Université de Kara, B.P : 404, Kara, Togo

[2]Département de Physique, Faculté des Sciences de Tunis, Université de Tunis El Manar, Tunis 1060, Tunisia

ABSTRACT: We study the influence of the thickness of the glass substrate on the magnetic properties of the Au/Co(1 nm)/Au systems deposited on thick ($2\ mm$) and thin ($100\ \mu m$) glass by electron beam evaporation. The magnetic investigations were carried out by using Polar Magneto-Optic Kerr Effect (PMOKE).

KEYWORDS: Thin glass; Domain wall; nucleation; nucleation field; magnetic anisotropy constant; Barkhausen volume.

1 INTRODUCTION

The magnetization reversal dynamics in thin solid films with perpendicular anisotropy has been extensively studied during the last years for fundamental reason [1-3], as well as for magnetic recording applications [4,5], where the reversal process of domain is inherently involved. Thus to continue by improving the devices of the magnetic recording, it is crucial to understand and control the parameters which govern the magnetism in the condensed matter.

2 MATERIAL AND METHODS

2.1 ELABORATION OF THE SAMPLES

The Au/Co films are grown by electron beam evaporation on two-float glass substrate after prior deposition of a 30 nm gold buffer layer at room temperature. The two-float glass used has respective thicknesses of $2\ mm$ (thick glass) and $100\ \mu m$ (thin glass). The Au polycrystalline buffer is annealed at 450 K during one hour. Annealing increases the grain seize and smoothes the surface. We then obtained a well-textured polycrystalline film. The (111) close-packed planes on the face centered cubic structure of gold are preferentially parallel to the surface film and the lateral seize of the grains is about 100 - 200 nm. At room temperature, cobalt grows epitaxially on this Au buffer with hcp (0001) structure. For each sample, 1 nm of cobalt layer (approximately four atomic plans of cobalt) was deposited intermittently with an object to favor a good relaxation of the successive atomic plans and to have an hexagonal compact structure [6,7]. The relaxation favors the reduction of constraints and consequently minimizes the magneto-elastic contribution anisotropy. A 10 nm thick Au capping layer is finally deposited for protection. The magnetic properties of these films were measured, at room temperature, by Kerr magnetometer in polar configuration. Measurements are realized using a modulation technique of polarization state of the light.

2.2 MAGNETIC MEASUREMENTS

Quasi-static hysteresis loops and magnetics anisotropy were performed at room temperature on the two samples, by applying the magnetic field perpendicular to the plan of the magnetic layer. On the figure 1 are presented the hysteresis loops of the two samples. We note in both cases that the full remanence (the remanence magnetization M_r and that of saturation M_s are the same). Thus, the two square cycles show that the magnetization easy axis is perpendicular to each magnetic layer.

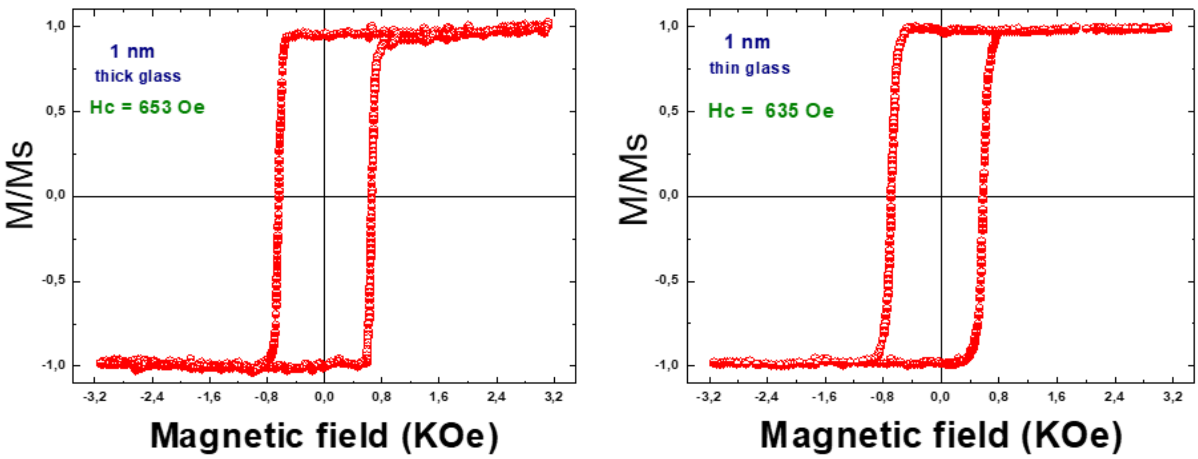

Fig. 1. Quasi-static loops at room at 300 K of Au/Co (1 nm)/Au on thick and thin glass.

We have measure for the two samples the nucleation field (H_n) , the coercive field (H_c) and the first and second order of constants of anisotropy (K_1 and K_2). The measurement technique of the anisotropy constants was described in our previous works [8]. The values obtained are consigned in table 1.

Table 1. Values of K_1 and K_2 obtained by fitting the coherent rotation parts of loops measured in tilted field.

Substrate	thick glass	thin glass
Cobalt thickness, t_{Co} (nm)	1	1
Remanence (M_r/M_s)	1	1
$H_c(Oe)$	653	635
$H_n(Oe)$	552	353
$K_1(10^6\ erg/cm^3)$	3.4 ± 0.1	2.32 ± 0.1
$K_2(10^6\ erg/cm^3)$	0.89 ± 0.05	0.73 ± 0.05

3 RESULTS AND DISCUSSIONS

The value of the field of nucleation in the sample deposited on thin glass is relatively low. This lets think that nucleation would have started early in the sample deposited on thin glass.

With regard to the uniaxial anisotropy, we note that it passes from $3.4 \times 10^6\ erg/cm^3$ in the sample on thick glass to $2.32 \times 10^6\ erg/cm^3$ in that on thin glass. According to our former work [8], this reduction of anisotropy could influence the magnetization reversal dynamics or the parameters that control it. This correlation will be discussed in this paper.

To clarify more the above results and precisely on the magnetization reversal dynamics we have used the Raquet's model [9, 10]. This model, which is an extension of the one of Labrune [11] in the case of a variable applied field in the time, allows a modeling of hysteresis while considering simultaneously the dynamical effects and the complex competition between domain wall motions and domain nucleation and assume that the elementary mechanisms of the reversal magnetization are thermally activated process. The calculations are lead in the same way as in the initial publication of Fatuzzo [12] while introducing a number of nucleation centers depending of $\frac{dH}{dt}$ and verifying the differential equation:

$$\frac{dN(H, dH/dt)}{N_0 - N(H, dH/dt)} = \frac{R(H)dH}{dH/dt}, \quad (1)$$

where N_0 is the number of centers who can been nucleated on the sample, $R(H)$ the apparition frequency of the centers. So the temporal variation of magnetization is, after calculations, given by:

$$\frac{M(x, dx/dt)}{M_S} = 2\exp\left(-2\alpha k^2\left[\frac{N\left[x,(dx/dt)\right]}{N_0}\left(1-\frac{1}{k}+\frac{1}{2k^2}\right)\right]\right)$$
$$\times\exp\left(\frac{R_0}{(dx/dt)}\left[\exp(-x)-1\right]\left(1-\frac{1}{k}\right)+\frac{R_0^2}{2(dx/dt)^2}\left[\exp(-x)-1\right]^2\right) \quad (2)$$

R_0, x ($x=\frac{V_B M_S H}{k_B T}$) and dx/dt are, respectively, the nucleation rate in zero field, the reduce field and the reduce field variation rate. V_B is Barkhausen volume, α represents the density of nuclei sites and k defines the relative importance of nucleation and domain wall propagation in the reversal [a predominance of wall motion (nucleation) implies k >> 1(respectively, k << 1)]. Fig. 2 presents the adjustment of the measured dynamic hysteresis loops to the model (2).

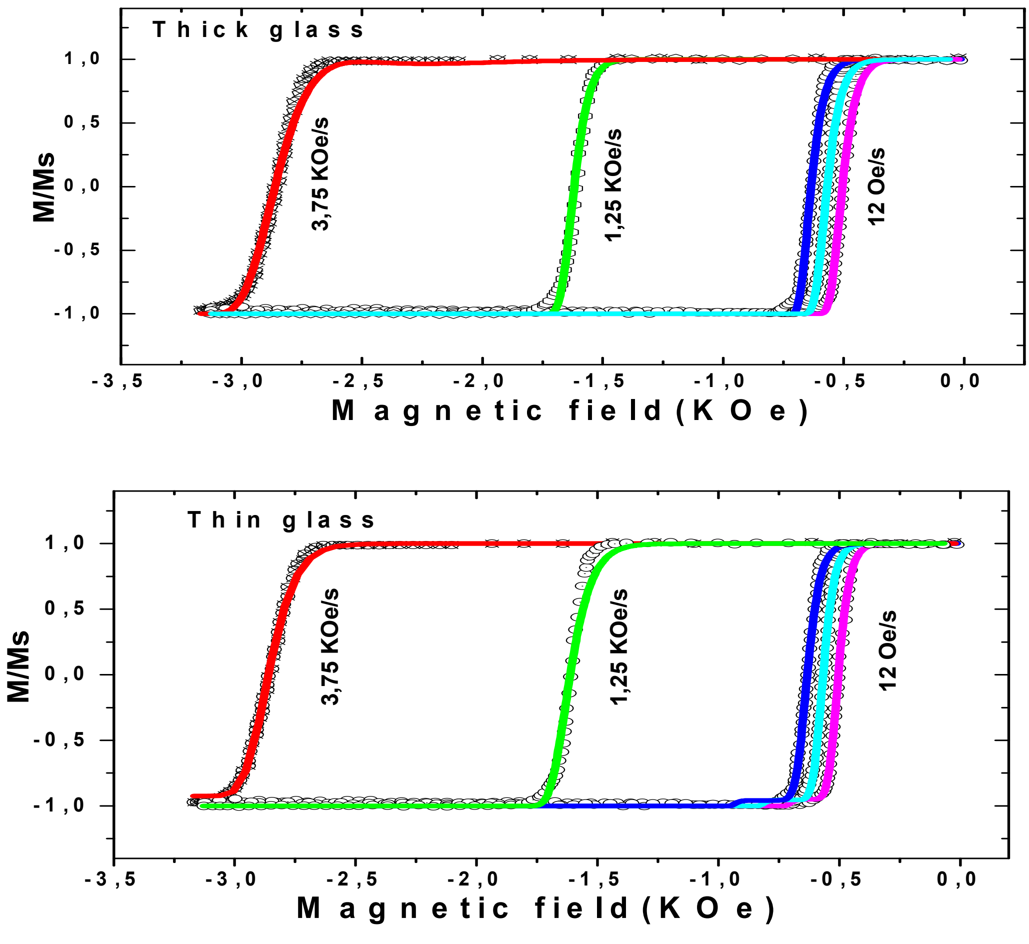

Fig. 2. ***Simulation by the model of Raquet (solid lines) of the measured dynamic hysteresis loops. The symbolic values represent the low, intermediate and strong*** $\frac{dH}{dt}$.

One notices that a good theory-experience agreement exists whatever $\frac{dH}{dt}$. The agreement is very remarkable around the coercive field. The only disagreements are at the nucleation and the saturation. These disagreements are due to the fact that this model considers that the nucleation starts from the imperfections having same amplitude. These disagreements at the nucleation and the saturation let think that the energy barrier would not be single in the layers and let suggest that layers contain imperfections of several natures having different energies.

In the table II and III are consigned the values of the parameters (k, α, R_0 and V_B) deduced from the fits (line) of the hysteresis loops in negative field (point).

***Table 2.** Values of k, α, R_0 and V_B obtained by fitting the hysteresis dynamic loops of the sample on thick glass, for several values of $\frac{dH}{dt}$ with Eq. (2).*

$\frac{dH}{dt}(Oe/s)$	k	$\alpha(10^{-2})$	$R_0(10^{-8})$	$V_B(10^{-19}cm^3)$
12	14.14	6.37	3.03	6.84
62	10.20	6.50	3.54	7.18
125	8.01	6.60	3.14	7.03
187	2.97	6.20	3.78	7.35
250	1.35	6.02	3.60	7.46
Average		6.33	3.41	7.17
312	0.96	6.47	3.33	7.30
375	0.84	6.70	3.86	6.83
437	0.80	6.44	3.70	6.52
500	0.79	6.81	3.56	6.15
563	0.70	6.69	3.26	5.94
Average		6.62	3.54	6.54
1250	0.46	6.41	7.26×10^2	2.97
2500	0.35	6.30	2.50×10^4	1.64
3750	0.23	6.70	1.39×10^5	1.24

***Table 3.** Values of k, α, R_0 and V_B obtained by fitting the hysteresis dynamic loops of the sample on thin glass, for several values of $\frac{dH}{dt}$ with Eq. (2)*

$\frac{dH}{dt}(Oe/s)$	k	$\alpha(10^{-2})$	$R_0(10^{-7})$	$V_B(10^{-19}cm^3)$
12	9.10	2.15	3.38	5.80
62	8.01	2.55	4.73	5.79
125	6.30	2.20	5.48	5.83
187	2.30	2.05	3.60	6.43
250	1.19	2.47	3.79	6.60
Average		2.28	4.19	6.09
312	0.92	2.31	6.43	6.19
375	0.70	2.14	5.28	6.12
437	0.63	2.50	4.36	5.96
500	0.60	2.20	4.11	5.80
563	0.55	2.23	4.97	5.52
Average		2.27	5.03	5.91
1250	0.42	2.04	1.30×10^4	2.26
2500	0.36	2.10	2.20×10^4	1.52
3750	0.30	2.51	7.60×10^4	1.09

For the two samples, results reveal three intervals of the sweep rate corresponding to three different possible situations. For sweep rate lower than 250 Oe/s k is superior to 1 what implies that the reversal by wall motion thermally activated is dominant. In each layer the model used find some same magnitude order of Barkhausen volume for this range sweep rate. The magnitude order of V_B found is, overall, included between $0.6\times10^{-18}cm^3$ and $0.7\times10^{-18}cm^3$ and this result is in harmony with the previous works [9,13]. Beyond a $\frac{dH}{dt}$ value superior to 250 Oe/s k becomes inferior to 1 indicating that the wall motion with thermal activation becomes less efficient compared to the nucleation [14]. A rigorous observation of data permits to divide this range of $\frac{dH}{dt}$ in two parts on which two behaviors of reversal magnetization can be considered. Between $250\ Oe/s$ and $1.25\ KOe/s$ the parameters values stay coherent, in every layer, with the values of the first range of field sweep rate, the average values of α, R_0 and V_B are, respectively, very near of those of the first range. The fact that, in the two layers, the k ratio is consisted between 1 and 0.5 on this second range of $\frac{dH}{dt}$ lets think that the wall motion by thermal activation contributes slightly to the magnetization reversal.

For $\frac{dH}{dt}$ values superior to $1.25\ KOe/s$ the k parameter becomes lower than 0.5 what lets suppose that a mode of pure nucleation appears gradually in the two systems. On this range the parameters R_0 and V_B are not constant any more in each sample. Concerning the sample on thick glass, for example, the nucleation rate in zero field (R_0) passed 10^{-8} order to the one of 10^{-3} for the strongest sweep rate, the Barkhausen volume passes $7 \times 10^{-19} cm^3$ order to the one of $1 \times 10^{-19} cm^3$, whereas for the second sample the values of these parameters pass respectively from 10^{-7} order to 10^{-3} for R_0 and $5.8 \times 10^{-19} cm^3$ to $1.09 \times 10^{-19} cm^3$ for V_B on all the range of $\frac{dH}{dt}$ applied.

Even if the nucleation rate in zero field (R_0) should be constant its increase according to $\frac{dH}{dt}$ could be due to a probable remanence of the coil at the high sweep rate of the magnetic field.

The reduction of the Barkhausen volume could be assigned to the disappearance of domain wall motion on this last range. Indeed the model used supposes that volumes of nucleation and propagation are identical to an elementary volume called the Barkhausen volume. The fact that this elementary volume decreases on a range of $\frac{dH}{dt}$ where the magnetization reversal seems to be done by a pure of nucleation process lets suggest that the volume of nucleation in our two samples is lower than the elementary volume of the wall jump.

Regarding the parameters, we note that only the rate of nucleation in zero field is sensitive to the reduction of the substrate thickness. Indeed, the magnitude order of $R_0(10^{-7})$ in the sample on thin glass shows that the probability to have a nucleation site would be high in this sample. This was confirmed by the rounded corner on its quasi-static hysteresis loop and by the low value found for the nucleation field ($H_n = 353\ Oe$). In this sample, even if the process of magnetization reversal at weak sweep rate of field seems to be done by propagation of wall, the nucleation of the sites would play also a considerable part. We can consequently affirm that the reduction of the constant of uniaxial anisotropy can be correlated with this mode of the magnetization reversal that would not exist in the sample on thick glass.

4 CONCLUSION

We have deposited approximately four atomic plans ($4PA$) of cobalt on thick glass and thin glass. The magnetic measurements revealed that the nucleation field (H_n) and the constant anisotropy (K_1) are reduced when one reduces the thickness of the substrate of glass. We used the model of Raquet to study the magnetization reversal in these two samples. The study showed that the reduction of the anisotropy constant was accompanied by a change of the magnetization reversal mode. Indeed, for low values of $\frac{dH}{dt}$ the magnetization reverse essentially by the domain wall motion in the sample on thick glass ($2\ mm$) whereas in that on thin glass ($100\ \mu m$) magnetization reverse by domain wall motion is accompanied by several nucleation sites.

ACKNOWLEDGMENTS

This work is the result of a collaboration between the LMOP laboratory (Tunisia) and the Université de Kara (Togo). We acknowledge the help of LMOP.

REFERENCES

[1] J. Ferré, J. P. Jamet, and P. Meyer, Phys. Status Solidi (a) 175, 213, 1999.
[2] S.-B. Choe and S.-C. Shin, Phys. Rev. B 57, 1085, 1998.
[3] S.-B. Choe and S.-C. Shin J. Appl. Phys. 83, 6952, 1998.
[4] J. X. Shen, R. D. Kirby, Z. S. Shan, D. J. Sellmyer, and Tl Suzuki, J. Appl. Phys. 73, 6418, 1993.
[5] J. Pommier, P. Meyer, G. Pénissard, J. Ferré, P. Bruno, and D. Renard, Phys. Rev. Lett. 65, 2054, 1990.
[6] R. Belhi, S. Jomni, N. Mliki, K. Abdelmoula, M Ayadi, G. Clugnet, A. Chrai, C. Leroux et G. Nihoul, Can. J. Phys. 79, 1011, 2001.
[7] R. Belhi, A. Adanlété Adjanoh, J. Vogel, M. Ayadi, K. Abdelmoula, J. Appl. Phys. 108, 093924, 2010.
[8] A. Adanlété Adjanoh, R. Belhi, J. Vogel, O. Fruchart, M. Ayadi, K. Abdelmoula, J. Magn. Magn. Mater. 322, 2498, 2010.
[9] B. Raquet, M. D. Ortega, M. Goiran, A. R. Fert, J. P. Redoules, R. Mamy, J, C. Ousset, A. Sdaq, and A. Khmou. J. Magn. Magn. Mater. 150, L5, 1995.
[10] B. Raquet, R. Mamy, and J. C. Ousset, Phys. Rev B 54, 4128 (1996); J. Magn. Magn. Mater. 165, 492, 1997.
[11] Labrune M., Andrieu S., Rio F., and Bernstein P. Time dependence of the magnetization process of re-tm alloys. J. Magn. Magn. Mater. 80:211, 1989.
[12] Fatuzzo E. Theoretical considerations on the switching transient in ferroelectrics. Phys. Rev., 127(6):1999, 1962.
[13] B. Raquet, M. D. Ortega, A. Sdaq, R. Mamy, M. Goiran, A. R. Fert, C. Armand, J, C. Ousset, J. Magn. Magn. Mater. 156, 197-198, 1996.
[14] A. Adanlété Adjanoh, Int. J. Adv. Res. 6 (3), 1215-1220, 2018.