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Substrate dependence of H_C coercive field in Fe/Ag thin films

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Abstract: Iron/Silver (Fe/Ag) Thin films are prepared by molecular beam epitaxial technical on to kinds of substrate: Magnesium dioxide(Periclase) single crystalline substrates (MgO (001)) and Silicon polycristalline one (Si (100)/SiO_2). The magnetic layer thickness is fixed at 300Å and the buffer layer Ag films thickness is varied from 0Å to 150Å by a step of 50Å. We are used two kinds of substrates, to find the effect of the variation in the kind of substrate on the magnetic properties such as the coercive field (H_c) of these thin films. The magnetic properties of these films are characterized by the Magneto optical Kerr effect (MOKE) technical at room temperature with a static magnetic field applied parallel to <100> and <110> Fe film directions. The analysis of the hysteresis loops who registered by MOKE indicates the presence of an in plane easy magnetization axis in the two kinds of samples and shows a dependence of the uniaxiale anisotropy on the Ag buffer layer thickness in the case of sample how's deposited into Mgo single crystalline substrates, and it appear in the large values of coercive fields in the case of <100> applied field direction, which also depend with the variation of the Ag buffer layer thickness.

Keywords: Fe, Ag, Si (100)/SiO_2, MOKE, Monocristal, Polycristal, Hysteresis loops, Magnetization, Coercive Field, Roughness, Anisotropy Magnetic

1. Introduction

Thin magnetic films separated by non-magnetic spacer layer namely (Bilayers) have been largely investigated by many experimental and theoretical works, because of their relevance for magneto-resistive applications. They magnetic properties hwo is differ significantly from those of the bulk ferromagnets [1] such us the magnetic anisotropy, the coercive field,….

The study of interfacial roughness and magnetism of Fe/Ag multilayer's has received much attention because of the magnetic properties of these systems depend strongly on the change of the interface structure who is do by the change of the type of used substrat.

The structure of Ag thin films deposited on MgO(001) has been studied in a number of works [2-4]. It is established that the Ag thin films grow strained and form a square network of misfit dislocations at the interface, and that these dislocations are oriented along the <110> directions [2]. On the contrary, Fe thin layer grow perfectly on MgO(001) with much less strain than Ag [5,6].

J. A. Venables and coll [7] were noted when depositing of a layer of Ag on a Si (100) surface layer by layer growth and the formation of an interface with a concentration gradient of Si without determining the structure of the silicates formed. Thus, we found that the growth of the Fe layer on Ag layer in this case is done by an interdiffusion between these two layers, which leads to a big value of roughness of surfaces or interfaces. So the polycristallinite of the Fe layer is related to the topology of the surface and/or interface and it can be linked to the type of the used substrate.

In this paper, we present the results of the influence of substrate kinds on the coercive field with different Ag buffer layer thickness.

2. Sample Preparations

The samples were prepared at K.U. Leuven university, by molecular beam epitaxial technical (MBE) under Ultra High Vacuum (U H V) and at room temperature (RT).

We are prepared our samples as following:

The single commercial crystal substrates MgO (001), was cleaned by propanol-2, and dried by gaseous nitrogen before being introduced into the introduction chamber of the MBE. To eliminate the impurities at the surface, it undergoes a heat treatment for 20 minutes at a temperature of 600 ° C, under an ultra-vacuum of 10^{-7} Torr.

We are used also, a polycristalline commercial substrate, who was that, composed of the Si (100) single crystal, that was deposited on it a 100Å of quartz (SiO_2), to result a Silicon substrate covered with their native oxide amorphous.

We are evaporated the Fe films by an electronic bombardment with a growth rate of 0.3Å/s and an applied voltage of 10.6KV plus an electric current of 1.6A. The thickness of this layer is fixed and equal to 300Å. In opposition to, the silver layer's who is evaporated from Knudsen cells by heating of the Joule effect, with a growth rate of 1Å/s, while their thickness is varied in the range 0-150Å with a step of 50Å. The Fe and Ag thicknesses have been controlled using a quartz crystal oscillator.

We are founded two types of samples:

The first kind's of sample was deposited on the MgO (001) single crystal substrate. The second type's one is a samples deposited on the polycrystalline substrate Si (100).

The 20Å of Ag layer is an oxidation protecting layer.

The final sample structure is:

1st sample: Ag (20Å)/Fe (300Å)/t_{Ag}/MgO (001)

2nd Sample: Ag(20Å)/Fe(300Å)/t_{Ag}/Si(100)/SiO_2

3. Results and Discussion

3.1. The Orientation Relation Ships

When, The are not a relationsships between the Fe, Ag layers and the polycristal Si(100) substrate's, which is a polycristalline growth(3D).

The are an orientational relationships of the Fe, Ag films and single crystal MgO (001) substrate's given by RHEED:

Fe(001)<110>//Ag(001)<100>//MgO(001)<100>

Fe(001)<100>//Ag(001)<110>//MgO(001)<110>

Who is corresponding to a 45° rotation of the Fe (001) lattice with respect to the Ag (001) lattices [8-14], This Fe, Ag layer relations is like shown us in the growth of Ag/Fe superlattices grown on MgO (001) by using the ion-beam sputtering technique and the no RHEED oscillations evaporation [15].

3.2. Magnetic Results

The figure 01 is represented the hysteresis loops of the two kinds of sample, measured at 300K.

We show for the two kinds of sample, there is the same magnetic behaviour, such as the magnetization, which is saturated very easy in the direction of applied field.

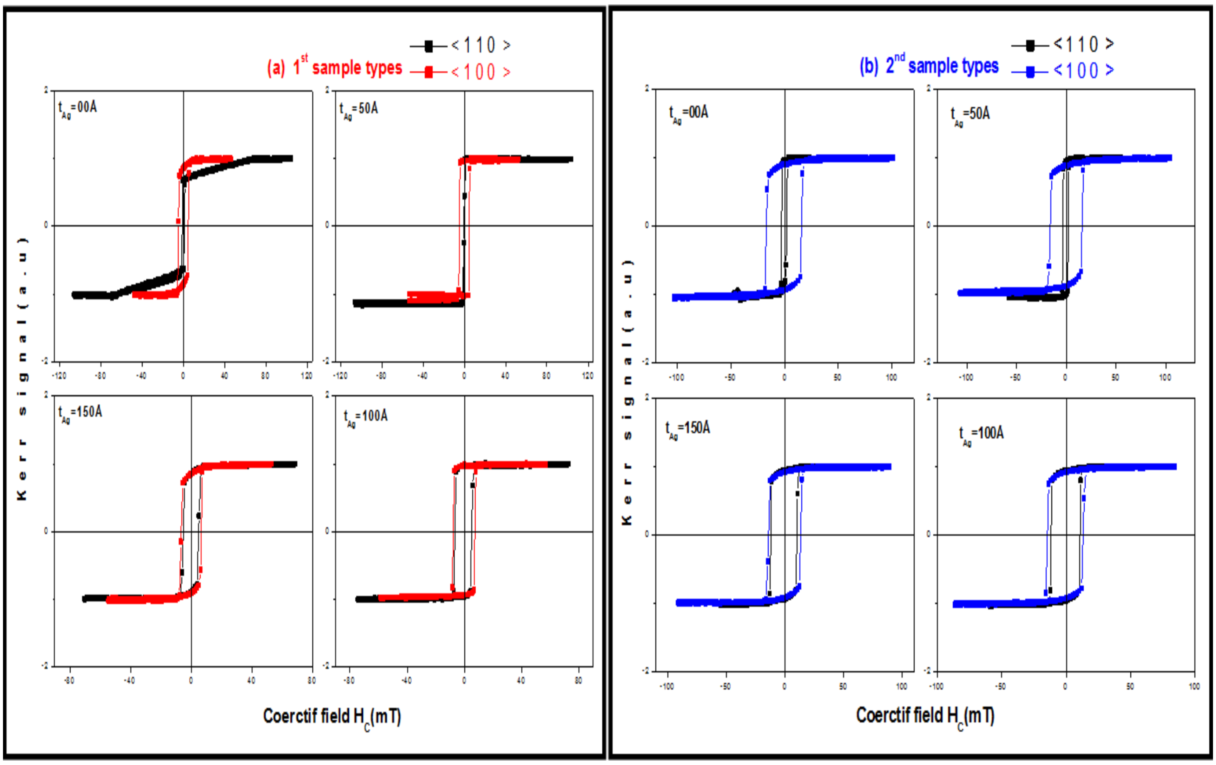

Figure 1. *Hysteresis loops of (a) 1st sample types, (b) 2nd sample types*

It is noted that the values of coercive field for 1st kinds of samples in the case of the direction <100> of the applied magnetic field has larger than their values in the case of <110>, which means that there is a plane uniaxiale anisotropy [8,9,13,16]. and these values are only reflect with the t_{Ag} buffer layer thicknesses (fig.02), or in the case of

<100> applied field direction, The coercive field H_C increases to its maximum values 7.32218mT at t_{Ag}=100Å and decreases to 4.53058mT in t_{Ag}=150Å, While when the directly deposition of Fe layer on the substrate (t_{Ag}=0Å), the values of H_C do not exceeded 0.01017mT, who is confirmed that, the Fe is growth epitaxially on MgO(001) under the following relation Fe(001) <110> //MgO(110) <100> and it's leads to a flat surface, as illustrated in figure 03. This result indicates that the coercive field increases as a function of roughening [16], and it is more sensitive to local structural properties layer.

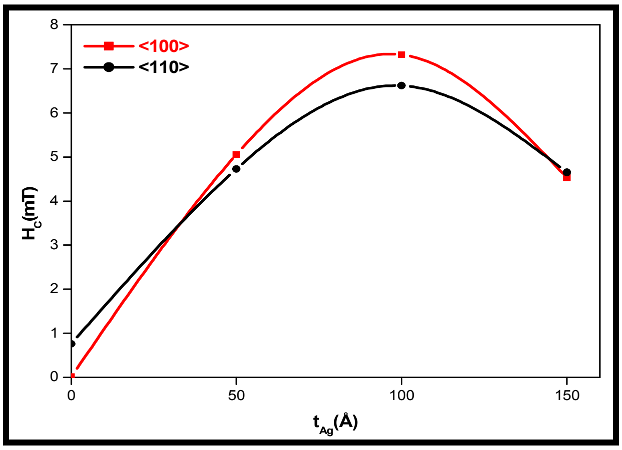

Figure 2. *The buffer layer corresponding of H_{c} in the <100> and <110> applied field direction.*

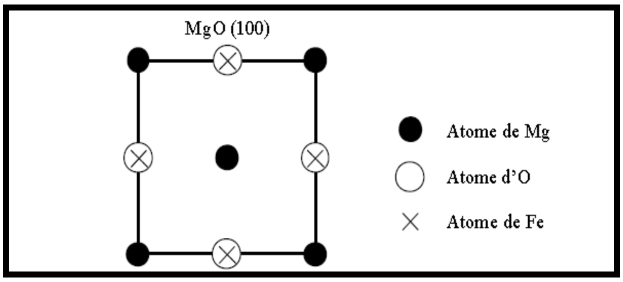

Figure 3. *Diagram showing of the respective stacked of Fe atoms with those of MgO [5].*

In opposite of their, in the case of 2nd type of samples, we show that, there has an isotropic behaviour in the plane. And there are no angular variations, whereas, we observed in the figure 01(b) that, the coercive field maintains almost the same value in the two direction case of applied field <100>, <110> for Fe layer, which indicating that, the surface roughness is not related to the application of field angle but only the type of user substrate type's.

Also, the hysteresis loops curves figure 01(b), inform us that there is a very high value of the roughness of surface, apparent in the very large curves, and leading to a large values of the coercive field that are caused by interdiffusion between the layer and which increases with the growing of the buffer layer thickness, this means that there is always a polycrystalline growth layer, so that the type of substrate, a very important effect on the structural and magnetic properties of the layers.

So, we make sure that, in the same type of sample: the values of H_c, is only depend with the buffer layer thickness as demonstrated in the table 01 and represented in the figure 04.

Table 1. *The buffer layer thickness dependence of H_{c}.*

t_{Ag}(Å)	Hc (mT)	
	1st type of sample	**2nd type of sample**
0	0.01017	2.14083
50	5.0569	10.75391
100	7.32218	13.69132
150	4.53058	16.06269

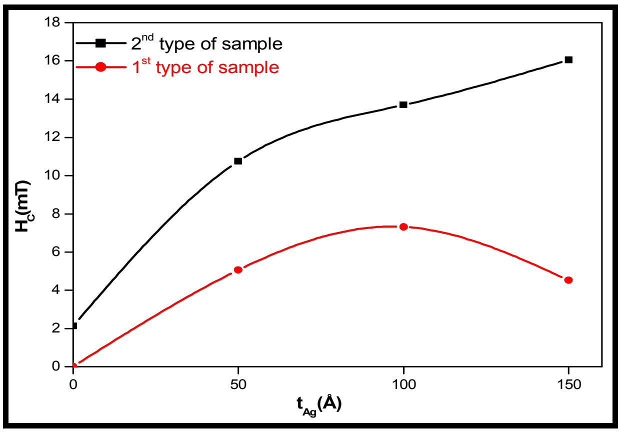

Figure 4. *The buffer layer dependence of the H_c in the two kinds of sample.*

We show that the only difference between sample is the coercive field values, how is there very larger corresponding the case of 2nd sample than in the case of the 1st one, which is indicate that the surface and the interface in the 1st sample (fig.01a) is very smooth than the 2nd. The dependence of H_C coercive field on the Ag buffer layer thickness presented into the figure04 indicated that H_C increase with increasing roughness [15].

Also, for the 1st kind of samples, the maximum value of H_C is corresponds to t_{Ag} = 100 Å. This means that, there is an island growth (3D) of the Fe layer corresponding to this silver thickness, which is caused by incomplete diffusion of Fe atoms on the Ag buffer layer leading to an interdiffusion between there. But the addition of 50Å of silver (t_{Ag}=150Å) is sufficient to make the growth layer by layer or 2D and reduced of the roughness ordering. In opposition, the growth of Fe layer on the polycristalline substrates (2nd type of sample) is remain 3D and confirmed in the larger values of H_C, who is increasing when the buffer layer thickness grow.

We know that, there are three mechanisms that are responsible for the coercivity in polycrystalline samples:

1. Irreversible spin rotation.
2. The delay in the nucleation of domain wall.
3. The delay in the motion of the domain walls by the walls.

The first point and the second one corresponding to a hysteresis loops form. Or the third mechanism which caused a jump occurs in the hysteresis cycle, once the domain nucleation has occurred, because the motion of the domain wall through the film is caused by inhomogeneities in the film.

The shape of the hysteresis cycles of our case is dominated by the motion and nucleation of domain walls, and the large difference between the layers, it is the value of the coercive field which corresponds with the thickness of the layer.

4. Conclusion

We have presented in this work the effect of the type of used substrate on the magnetic properties of molecular beam epitaxial growth of Fe/Ag thin films. We have used for this a comparative study between two kinds of samples: The first kind's was deposited on the MgO (001) single crystal substrate. The second type's one is a samples deposited on the polycrystalline substrate Si (100).

The magnetic property was studied by the MOKE technical at room temperature. The relationship given by The RHEED patterns during the growth of 1^{st} kind of samples is: <100>MgO, Ag// <110> Fe, indicate a 45° rotation for the Fe film with respect to Ag layer or MgO substrate. While for the 2^{nd} type of sample indicates that, there is a polycristalline growth. The study of the magnetic properties confirmed the presence of a stress formation during the growth of the two kinds of samples .Than we conclude that there is a correlated of the magnetic properties (anisotropy and coercive field…) with the Ag buffer layer thickness. But we show that

The using of an MgO single substrate in the 1^{st} sample series decreases completely they showed coercivity effect of the polycristalline substrate in the 2^{nd} sample type. Than we conclude that the kind of used substrates are a strongest effect on the H_C coercive field behavior.

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