Study Of Co\textsubscript{90}Fe\textsubscript{10} Magnetic thin Film On MgO Substrate Using In-situ Moke Technique

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Abstract. Growth behavior of Co\textsubscript{90}Fe\textsubscript{10} film on MgO substrate has been studied. In-situ magneto-optical Kerr effect measurements have been used to study evolution of the magnetic properties of the film with increasing film thickness. Extrapolating linear variation of Kerr signal with film thickness provides the evidence of a magnetic dead layer of thickness 2.2 nm at the interface with MgO substrate. X-ray reflectivity fitting confirms presence of an intermixed layer of about 2 nm.

Keywords: MOKE, Magnetic dead layer, Co90Fe10 film, XRR.

1. Introduction

Conventional MTJ with amorphous Aluminum Oxide barrier have been extensively studied for device applications but low magneto resistance limits the feasibility of such spintronics devices. MgO based MTJ is widely used device of this type and high tunnel magneto resistance (TMR) values are critical for high performance. Magnetic tunnel junctions involving MgO barrier, show promising application as non-volatile storage cells used in high performance magnetic random access memories (MRAM). Modification at the interfaces of thin film, significantly affect the performance of MTJ. Hence interfacial study and characterization of growth of magnetic thin film on MgO substrate provides relevant information for improving the performance. Moreover in high density MRAM, since lateral dimensions of magnetic cells are expected to be in nano scale range and to reduce critical current density for current induced Magnetization switching (CIMS), thickness of magnetic layer in free layer structure needs to be minimized. Therefore from application point of view, it is important to precisely determine the magnetic dead layer, because magnetic dead layer does not contribute to magnetic volume [1].

In the present work, development of the magnetic properties of Co\textsubscript{90}Fe\textsubscript{10} alloy film on MgO substrate as a function of film thickness has been done using in-situ MOKE measurements.

2. Experimental

Thin films of Co\textsubscript{90}Fe\textsubscript{10} were deposited on MgO (100) substrate in a ultra high vacuum chamber using electron beam evaporation. Film thickness was measured in situ using a calibrated quartz crystal thickness monitor. Base pressure in the deposition chamber was 2x10\textsuperscript{-7} mbar. Deposition rate was
maintained at 0.004 nm/s. Thickness dependent Magneto-optical Kerr effect measurements were done simultaneously with deposition in Longitudinal geometry (L-MOKE) using He-Ne laser of wavelength 632.8 nm. Magnetic field inside chamber was applied using a pair of Helmholtz coils. Ex-situ x-ray reflectivity measurements were done on the deposited film using Bruker D8 diffractometer with a Gobbel mirror, so as to generate parallel monochromatic beam of Cu Kα radiation of energy 8.04 KeV.

3. Results and discussion

Figure 1 represents the dependence of the intensity of Kerr signal on film thickness. Initially Kerr signal increases linearly with film thickness and then saturates beyond a particular thickness. The linear

![Figure 1](image1.png)

**Figure 1.** Kerr Signal as a function of film thickness. Inset of figure shows magnified curve in lower thickness region, which is fitted by straight line.

![Figure 2](image2.png)

**FIGURE 2.** Few representative hysteresis loops of deposited film on MgO substrate at different film thickness.
dependence of Kerr Signal with film thickness up to 8 nm is shown in the inset of the figure. In the limit of the thickness of the magnetic layer being much smaller (typically of the order of 20 to 30 nm), the saturation Kerr signal is linearly proportional to the thickness of the magnetic layer [2]. Therefore, thickness dependence of saturation Kerr signal can yield information about a possible magnetic dead layer. The intercept of straight line on the x-axis, obtained by linear fitting, gives thickness of magnetic dead layer. In the present case of Co90Fe10 film on MgO substrate there is a magnetic dead layer of 2.2 nm.

Figure 2 depicts the development of MOKE hysteresis loops of deposited film with increasing film thickness. One can note that a faint signal starts appearing beyond 2 nm which improves with increasing film thickness. Therefore, thickness dependence of saturation Kerr signal can yield information about a possible magnetic dead layer. The intercept of straight line on the x-axis, obtained by linear fitting, gives thickness of magnetic dead layer. In the present case of Co90Fe10 film on MgO substrate there is a magnetic dead layer of 2.2 nm.

Table 1: Fitting parameters obtained from XRR

| Material       | Thickness (nm) | Roughness (nm) |
|----------------|----------------|----------------|
| Oxide layer    | 2.6±0.1        | 0.4±0.05       |
| Co90Fe10       | 44.5±0.1       | 1.5±0.05       |
| Intermixed layer | 2.0±0.1      | 0.8±0.05       |
| MgO substrate  | -----          | 0.6±0.05       |
Figure 3 shows X-ray reflectivity pattern of Film on MgO substrate taken after Deposition. The continuous curve represents the best fitting of the experimental data done using Parratt’s formalism [3]. From the fitting, thickness of film comes out to be 44.5 nm. Fitting parameters is shown in the Table 1.

It can be seen from XRR fitting parameters that there forms an intermixed layer at the interface with MgO substrate, of thickness around 2nm. This agrees very well with the thickness of the magnetic dead layer as obtained from In-situ MOKE measurement.

4. CONCLUSIONS:

Evolution of magnetic properties of ultrathin Co90Fe10 films on MgO(001) surface has been studied using in-situ MOKE measurements. The measurements provide clear evidence for the existence of a magnetic dead layer at MgO / Co90Fe10 interface, the thickness of which is found to be 2.2 nm. The presence of intermixed layer is also corroborated by X-ray reflectivity. The observed non-monotonous behavior of coercivity with film thickness can be understood in terms of a combined effect of superparamagnetic relaxation, and surface pinning of domain walls.

5. REFERENCES

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