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To cite this version:
Y. Hoshi, M. Seki, M. Naoe. MAGNETIC PROPERTIES OF IRON COBALT MULTILAYERED FILMS DEPOSITED BY OPPOSED TARGETS SPUTTERING. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-1793-C8-1794. 10.1051/jphyscol:19888818 . jpa-00229074

HAL Id: jpa-00229074
https://hal.science/jpa-00229074
Submitted on 1 Jan 1988

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MAGNETIC PROPERTIES OF IRON COBALT MULTILAYERED FILMS
DEPOSITED BY OPPOSED TARGETS SPUTTERING

Y. Hoshi (1), M. Seki (1) and M. Naoe (2)
(1) Tokyo Institute of Polytechnics, Faculty of Engineering, 1589 Iiyama, Atsugi-shi, Kanagawa-ken 243-02, Japan
(2) Tokyo Institute of Technology, Faculty of Engineering, 2-12-1 Oh-Okayama, Meguro-ku, Tokyo 152, Japan

Abstract. — Fe/Co multilayered films with about 3 000 Å thick have been deposited by an opposed targets sputtering apparatus. The films with deposition period $d_{\text{layer}}$ above 10 Å have layered structure. Their magnetic properties changes significantly with $d_{\text{layer}}$, and the film with $d_{\text{layer}}$ around 60 Å has the lowest coercive force of about 6 Oe and saturation magnetization about 1 600 emu/cc.

Introduction

Iron-cobalt alloy is well known to have large saturation magnetization $M_s$ as large as 1 900 emu/cc [1]. However, the soft magnetic properties of the alloy film are not enough to use for thin film magnetic recording head [2, 3]. On the other hand, multilayered magnetic film is very attractive since it can have quite different magnetic properties from those of the single layer film. In this work, we have deposited Fe/Co multilayered films with about 3 000 Å thick by an opposed targets sputtering system which can deposit the film under the condition of low high energy particle bombardment to the film surface [4, 5] and investigate their structure and magnetic properties.

Experimental

Figure 1 shows a schematic diagram of the opposed targets sputtering apparatus used in this work. This apparatus has two opposed targets sputtering sources and multilayered film can be deposited by rotating the substrate as shown in the figure. After evacuating the sputtering chamber below $1 \times 10^{-6}$ Torr, the films about 3 000 Å thick were deposited on a glass slide substrate without any heating. The main film preparation conditions are as follows; Ar gas pressure: 1.5 mTorr, target voltage: 850~900 V for Fe, 760~810 V for Co, discharge current: 0.5~1.5 Å for each source, deposition period $d_{\text{layer}}$: 3~600 Å, thickness ratio of Fe layer to Co layer $t_{\text{Fe}} / t_{\text{Co}}$: 0.33~3, deposition time: 10 min. $d_{\text{layer}}$ and $t_{\text{Fe}} / t_{\text{Co}}$ are varied by controlling the rotating speed and input power to the source.

Results and discussion

Figure 2 shows typical X ray diffraction diagrams of the Fe/Co multilayered film with $t_{\text{Fe}} / t_{\text{Co}}$ of 1 and $d_{\text{layer}}$ of 45 Å, 70 Å and 140 Å. The film with $d_{\text{layer}}$ below 60 Å has similar diffraction diagram to that shown in figure 2a, which shows that the film has bcc crystal structure. hcp or fcc phase cannot be detected in the film with $d_{\text{layer}}$ in the range of 10~60 Å. However, the diffraction diagram of the film with $d_{\text{layer}}$ above 70 Å has reflection peaks of both bcc and hcp phase.

Figure 3 shows the low angle X-ray diffraction diagrams of these multilayered film with various $d_{\text{layer}}$. Reflection peaks are only observed in the film with $d_{\text{layer}}$ above 10 Å. This indicates that only the film with $d_{\text{layer}}$ above 10 Å has a layered structure and the film with $d_{\text{layer}}$ below 10 Å has uniform single layer structure of Fe-Co alloy. The X-ray diffraction diagram of

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Fig. 1. — Schematic diagram of opposed targets sputtering apparatus.

Fig. 2. — Typical X-ray diffraction diagrams of Fe/Co multilayered films.
Fig. 3. - Low angle X-ray diffraction diagrams of Fe-Co multilayered films.

The film with layered structures shows that intermediate alloy layer is also formed in the multilayered film by the interdiffusion between Fe layer and Co layer. Corresponding to the changes in film structure from uniform alloy film to multilayered film, internal film stress changes abruptly as shown in figure 4, though all of the films take a compressive stress from the substrate. The stress in the film with \(d_{\text{layer}}\) below 10 Å (i.e., the film with uniform single layer) takes a value about \(-4 \times 10^8\) N/m². However, it takes a value about \(-12 \times 10^8\) N/m² in the film with \(d_{\text{layer}}\) around 15 Å which has layered structure and decreases monotonically as \(d_{\text{layer}}\) increases.

On the other hand, mean crystallite size \((D)\) decreases steeply with \(d_{\text{layer}}\) as shown in figure 4, which corresponds well to the increase in the film stress. These results indicate that the changes in the internal stress of the film with \(d_{\text{layer}}\) around 10 Å are caused by the suppression of the crystal growth due to the formation of layered structure.

The magnetic properties of these films change significantly with \(d_{\text{layer}}\) and differ from those of Fe, Co or Fe-Co alloy single layer film [1]. An uniaxial magnetic anisotropy is induced in the multilayered film by the dc magnetic field in which substrate is located during deposition. Figure 5 shows the changes in saturation magnetization \(M_s\), the uniaxial magnetic anisotropy field \(H_{\text{K}}\) and coercive force \(H_c\) with \(d_{\text{layer}}\). It is evident from the figure that \(H_{\text{K}}\) and \(H_c\) decreases as \(d_{\text{layer}}\) increases and \(H_c\) takes a minimum value of about 6 Oe at a \(d_{\text{layer}}\) around 60 Å. This value is about 1/5 of that for Co single layer film. These results indicate that the multilayered structure can lead the decreases in \(H_c\) of Co and Fe-Co alloy. Saturation magnetization \(M_s\) of the film with minimum \(H_c\) takes a value about 1 700 emu/cc, though \(M_s\) decreases monotonically as \(d_{\text{layer}}\) increases.

Conclusion

We deposited Fe/Co multilayered films by an opposed targets sputtering apparatus and investigated their structure and magnetic properties. The results obtained in this work are summarized as follows;

1) the layered structure is observed in the film with a \(d_{\text{layer}}\) above 10 Å;
2) the change in film structure from single alloy layer to multilayer leads the abrupt increase in compressive film stress and decrease in mean crystallite size;
3) magnetic properties of the multilayered film differ from those of the single layer Fe, Co or Fe-Co alloy films. The uniaxial magnetic anisotropy and coercive force of the film decreases as the \(d_{\text{layer}}\) increases and the coercive force takes a minimum value of about 8 Oe at a \(d_{\text{layer}}\) around 60 Å.