HI SATURATION FE ALLOY FILMS DEPOSITED ON NON-MAGNETIC UNDERLAYERS
WITH PREFERRED CRYSTAL ORIENTATION

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Abstracts--- FeSi alloy films with low magnetostriction were deposited on SiO₂, ZnO and MgO underlayers and magnetic softness and thermal stability were measured.

The best results were obtained for the films on MgO. The films on MgO have the smallest crystal size and subsequently the lowest H_c. Double layer films on MgO showed lowest H_c and best thermal stability.

Introduction

Polycrystalline Fe alloy films with magnetic softness is of interest because of their high saturation magnetization.

In order to obtain magnetic softness in thin films, very weak crystalline anisotropy and low magnetostriction are generally required. But Fe polycrystalline alloy films with high saturation magnetization do not satisfy the above conditions.

However, various Fe alloy films with low H_c have been reported recently. Their low H_c are attributed to the microcrystalline structures which are brought about by various film deposition conditions, such as radiation of Ar ion beam to the film surface during deposition⁽¹⁾, or introducing N₂ gas to suppress crystal growth. Another method to obtain magnetic softness is to deposit different materials alternatively⁽²⁾.

However, all of those films suffer from thermal instability of magnetic softness due to crystal growth or atomic diffusion at relatively low temperatures.

The authors have been studying crystal structures and magnetic softness of Fe alloy

films deposited on various non-ferromagnetic underlayers. These underlayers are favorable to the thermal stability of magnetic softness since they control crystal growth of Fe alloy films and sometimes suppresses further crystal growth.

High saturation magnetization FeSi films with Si content up to 8wt% deposited on ZnO was studied previously⁽³⁾. The films show lower H_c for 2~3 wt%Si where the macroscopic magnetostriction becomes zero. They show much lower H_c when they are double layered. Reason for the improvement of magnetic softness is probably due to magnetostatic interactions of the crystals through the thin intermediate films. This may bring about an effect similar to that of the interaction between the grains when the films are in a microcrystalline state⁽⁴⁾.

Since various factors such as multilayering effect, microcrystalline structure and macroscopic magnetostriction affect the softness of high saturation films, it is usually difficult to find out how to make further improvements.

Here, some experiments on Fe-7 ~ 8wt% Si films with intrinsically low magnetost-

riktion deposited on SiO_2 , ZnO and MgO are described. The purpose of the experiemnt is to obtain better understanding of the effect on the crystal structure, and subsequently on thermal stability of magnetic softness without influence from magnetostriction, and multilaying effect using those films as intermediate films is studied.

Experiments

The samples were deposited by ion beam sputtering and by D.C.magenetron sputtering. Since sputtering was made in pure Ar atomosphere, some deficiency of oxygen in the oxide films were detected by Augier spectroscopy, although clear Xray peaks corresponding to ZnO or MgO were observed.

Film thickness is about 1000 Å for magnetic and Xray measurements. The films with this thickness were selected since they show good orientation of crystal growth and as a function of thickenss H_c exhibits minimum at about 1000 Å. Substrate tem-

perature was set at 300°C or 400°C depending on the growth condition of the underlayers.

Saturation magnetostriction measured for a few samples is in the range $1 \sim 3 \times 10^{-6}$ for 7 ~ 8 wt.%Si. The calculation based on the bulk data predicts $1 \sim 2 \times 10^{-6}$ for 7 wt.%Si and $0 \sim -2 \times 10^{-6}$ for 8 wt.%Si. The difference may be due to imcomplete formation of DO_3 structure in the films.

The films were annealed in an external field of 300 Oe for 30 min. at each temperature.

Results

Figure 1 shows Xray diffraction patterns of Fe-7wt.%Si film deposited on SiO_2 , ZnO and MgO . ZnO underlayer exhibits preferred growth of (002) parallel to the film plane and FeSi deposited on it exhibits preferential growth of (110). MgO underlayer exhibits preferred growth of (100) and FeSi on it shows growth of (100) plane. For-

Figure 1

Variation of Xray diffraction patterns by annealing for FeSi films deposited on various underlayers.

mation of DO_3 phase is indicated by (200) in the pattern. Since ratio of (400) to (220) is about 0.2 for FeSi with isotropic crystal structure, relatively intensive peak from (400) means the film has well oriented growth of (100) planes. The film on SiO_2 shows weak (110) peak indicating it is closest to the isotropic crystal structure among these three samples. As seen in the figure the preferential growth is more enhanced by annealing.

Figure 2 shows variation of the crystal size estimated from the width of the peaks from the oriented planes. It should be noted that the film on MgO has relatively small grain size and even after annealing at 600°C crystal growth seems to be suppressed.

Figure 2

Variation of the crystal size by annealing for FeSi films deposited on various underlayers.

Figure 3 shows variation of H_c for the films on SiO_2 , ZnO and MgO by annealing. The film on MgO shows lowest H_c . This agrees with the result in Fig.2 where the film on MgO has the smallest grain size.

Figure 4 shows variation of H_c for double layer films with SiO_2 and ZnO as underlayer and intermediate layers. The multilayer structure of the former is $\text{SiO}_2/\text{FeSi}(900\text{\AA})/\text{SiO}_2(80\text{\AA})/\text{FeSi}(900\text{\AA})/\text{SiO}_2/(\text{sapphire sub.})$. Two kinds of multilayer structure were studied for the latter. One of them is $\text{SiO}_2/\text{FeSi}(900\text{\AA})/\text{ZnO}(40\text{\AA})/\text{SiO}_2(40\text{\AA})/\text{FeSi}(900\text{\AA})/\text{SiO}_2/(\text{sapphire sub.})$ (denoted by A in the figure) and the other is $\text{SiO}_2/\text{FeSi}(900\text{\AA})/\text{ZnO}(80\text{\AA})/\text{FeSi}(900\text{\AA})/\text{SiO}_2/(\text{sapphire sub.})$ (denoted by B in the figure). The difference is that the former has double intermediate layers. The reason is that ZnO shows good orientation of (002) on SiO_2 but becomes amorphous like on Fe surface. Here softness of these two kinds of double layer struc-

Figure 3

Variation of H_c by annealing for FeSi films deposited on various underlayers.

○: $\text{SiO}_2/\text{FeSi}/\text{ZnO}/\text{SiO}_2/\text{sub.}$
 ×: $\text{SiO}_2/\text{FeSi}/\text{SiO}_2/\text{sub.}$
 ■: $\text{SiO}_2/\text{FeSi}/\text{MgO}/\text{SiO}_2/\text{sub.}$ (e.a.)
 □: " (h.a.)

tures is studied.

It is clearly seen in Fig. 4 that for sample B H_c increases continuously as the annealing temperature increases while sample A shows good thermal stability. Xray diffraction intensity from (110) is always weaker for B than A but the ratio of the intensity is not reproducible. The film with SiO_2 intermediate layer shows less stable H_c . Similar experiments on MgO are shown in Figure 5. Sample A has a double layer intermediate structure $MgO(40A)/SiO_2(40A)$ and sample B has a single layer $MgO(80A)$. Little difference of H_c is seen for those samples. Xray diffraction intensity from (001) is about the same for those samples.

Discussions

In the present experiment influence of underlayer and intermediate layer to crystal growth in FeSi and subsequent change of H_c was studied.

On ZnO underlayer FeSi films show good growth of (110) and relatively large crystal size. This is effective to stabilize the macroscopic magnetostriction. In a study of FeNi films on ZnO it was found that the macroscopic magnetostriction is almost constant against annealing up to 600 °C. Since the saturation magnetostriction is low for the present samples, the dominant factor to determine the softness may be crystal size and, as seen in Fig. 3, the sample on MgO has the smallest crystal size resulting in lower and more stable H_c .

Another advantage of MgO is that MgO layer shows good orientation of (001) even on FeSi surface. This means that with combination of Fe alloy and MgO it may be possible to fabricate films with finer multilayer structure with smaller crystal size without deteriorating thermal properties.

Slight increase of H_c after annealed at 600 °C as seen in Fig. 4 and 5 may be explained by rapid increase of the crystal size as observed in Fig. 1 and 2, which

Figure 4

Variation of H_c for multilayered FeSi films deposited on ZnO.

- : $SiO_2/FeSi/SiO_2/FeSi/SiO_2/sub.(e.a.)$
- : " (h.a.)
- ▲: $SiO_2/FeSi/ZnO/SiO_2/FeSi/ZnO/SiO_2/sub.(e.a.)$
- △: " (h.a.)
- : $SiO_2/FeSi/ZnO/FeSi/ZnO/SiO_2/sub.(e.a.)$
- : " (h.a.)

Figure 5

Variation of H_c for multilayered FeSi films deposited on MgO.

- : $SiO_2/FeSi/MgO/SiO_2/FeSi/MgO/SiO_2/sub.(e.a.)$
- : " (h.a.)
- ▲: $SiO_2/FeSi/MgO/FeSi/MgO/SiO_2/sub.(e.a.)$
- △: " (h.a.)

cannot be overcome by the magnetostatic interaction between the crystals through the intermediate layers.

Conclusion

Magnetic softness and its thermal stability for single and double layer FeSi films deposited with SiO₂, ZnO and MgO under and intermediate layers was studied. Since FeSi films has intrinsically low magnetostriiction, it was clarified that MgO layer is the most effective to maintain low H_c.

Experiments on magnetic softness and thermal stability of FeNi films with macroscopically low magnetostriction deposited on MgO is in progress.

References

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