Crystallographic and Magnetic Characteristics of Ba Ferrite Sputtered Films for High Density Magnetic Recording Disks

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Abstract. Ba ferrite films with non-stoichiometric composition were deposited using Facing Targets Sputtering apparatus. The films with well *c*-axis orientation and remarkable perpendicular anisotropy were attained even at the substrate temperature below 600 °C. Sufficiently large saturation magnetization $4\pi M_s$ of 3.7 kG and small crystallite size below 20 nm were attained using the targets with Fe-excessive composition. Their good crystallographic and magnetic characteristics were thought to be satisfactory for high density magnetic recording media.

1. INTRODUCTION

Thin films of a magnetoplumbite type of Ba ferrite (BaM: $\text{BaO} \cdot 6\text{Fe}_2\text{O}_3$) have been deposited for applying them to the perpendicular magnetic recording medium. Ones of a W-type of Ba ferrite (BaW: $\text{BaFe}_{18}\text{O}_{27}$) may be more useful for high density recording medium because of their larger saturation magnetization $4\pi M_s$. The Facing Targets Sputtering (FTS) system is attractive for the low temperature synthesis of BaW ferrite crystallites, since the BaM ferrite films with excellent *c*-axis orientation and magnetic characteristics could be deposited at relatively low substrate temperature T_s below 550 °C[1]. In this study, the crystallographic and magnetic characteristics of Ba ferrite sputtered films with non-stoichiometric composition were investigated systematically and it was found that these characteristics were closely related to the creation of spinel crystallites at the grain boundaries. The target composition was varied in the range of *n* from 5.5 (a little Ba-excessive) to 8.5 (Fe-excessive).

2. EXPERIMENTS

The specimen preparation and sputtering conditions are listed in Table I. The sintered plates with the compositions of $\text{BaO} \cdot n\text{Fe}_2\text{O}_3$ (*n* = 5.5, 6.5, 7.5, 8.5) were used as sputtering targets and the mixture of Xe, Ar and O_2 at various mixing ratio was used as sputtering gas for suppressing plasma-damage on growing surface of the Ba ferrite layer[2]. Well *c*-axis oriented ZnO underlayer was deposited previously on thermally oxidized Si (SiO_2/Si) wafer at T_s of 300 °C and Ba ferrite layer was deposited successively on ZnO layer at T_s of 600 °C, using FTS apparatus. The crystallographic and magnetic characteristics were determined by X-ray Diffractometry (XRD) and Vibrating Sample Magnetometer (VSM), respectively.

3. RESULTS AND DISCUSSION

Figure 1 shows the XRD diagrams of Ba ferrite/ZnO bilayered films deposited using the mixture of Xe and O_2 as sputtering gas.

TABLE I
Specimen preparation and sputtering conditions.

Targets:	$\text{BaO} \cdot n \text{Fe}_2\text{O}_3$ (<i>n</i> = 5.5, 6.5, 7.5, 8.5)
Substrate:	SiO_2/Si
Substrate temperature T_s :	600 °C
Sputtering gas:	mixture of Xe, Ar and O_2
Total gas pressure p_{total} :	0.20 Pa
Thickness of BaM layer t_{BaM} :	200 ~ 400 nm
Thickness of ZnO layer t_{ZnO} :	~ 300 nm

Sharp diffraction peaks corresponding to (00n) planes of BaM ferrite crystallites, parallel to the film plane, were observed for all specimen films and relatively weak ones of spinel(mmm) were seen at n above 6.5. These diffraction peaks were very faint at n of 8.5. The spinel crystallites in these films were expected as $\text{Fe}_{3-6}\text{Ba}_x\text{O}_{4-x}$ or $\text{Fe}_{3-6}\text{O}_4$, which are low temperature phase in the oxides of Ba-Fe system, presented at the boundary among BaM ferrite crystallites[3]. Because of small structural difference between BaM(00n) and spinel(mmm) planes, the (00n) orientation of BaM crystallite seems not to be fluctuated by the additional growth of spinel crystallites and the (00n) dispersion angle of BaM crystallites $\Delta\theta_{\text{ZnO}(002)}$ were as small as 4° . Figure 2 shows the dependences of the interplanar distance between ZnO(002) planes $d_{\text{ZnO}(002)}$, the perpendicular coercivity $H_{c\perp}$ and the uniaxial anisotropy energy K_1 on the parameter of target composition n . $d_{\text{ZnO}(002)}$ tends to decrease with increasing n and it seems to correlate with stress relaxation between Ba ferrite and ZnO layers due to the formation of spinel crystallites. $H_{c\perp}$ and K_1 took the maximum values at n of 6.5 and tend to decrease with increasing n in the range above 6.5. The decrease of K_1 seems to be caused by the excessive growth of spinel crystallites.

Figure 3 shows the dependences of the saturation magnetization $4\pi M_s$ and the mean size of BaM(00n) crystallites $\langle D \rangle_{\text{BaM}}$ on the parameter of target composition n . $4\pi M_s$ and $\langle D \rangle_{\text{BaM}}$ tend to decrease with increasing n . The decrease of $\langle D \rangle_{\text{BaM}}$ was resulted from the segregation of spinel crystallites including the excessive Fe ions. Although $\langle D \rangle_{\text{BaM}}$ were very small at n of 8.5, $4\pi M_s$ was as sufficiently large as 3.7 kG. Considering the slight decrease of $4\pi M_s$ with increasing n , most of the spinel crystallites among BaM ferrite grains seemed to reveal a berthollide type of magnetite ($\text{Fe}_{3-6}\text{O}_4$) and were expected to be coupled magnetically with BaM ferrite grains strongly.

It is well known that the existence of very thin grain boundaries causes the magnetic decoupling between recording domains and is valuable for achieving the sharp magnetization transitions and low media noise. For the Co-Cr films, the microstructural segregation of non-magnetic Cr-rich region plays a role of separator between the magnetic Co-rich regions. In the case of Ba ferrite, size limitation of magnetic regions by the low temperature synthesis causes a poor magnetic characteristics because it is very difficult to control the thickness and composition of grain boundaries for attaining the densely packed structure of BaM ferrite crystallites. In this study, the segregated spinel crystallites among grain boundaries in the deposited films with Fe-excessive compositions seemed to produce not only the size limitation of grains, but also the well c -axis orientation of BaM ferrite crystallites and large $4\pi M_s$, simultaneously.

4. CONCLUSION

The Ba ferrite sputtered films with Fe-excessive composition at n above 7.5 deposited using FTS apparatus exhibited the sufficiently large $4\pi M_s$ above 3.2 kG and small $\langle D \rangle_{\text{BaM}}$ below 20 nm. They may be advantageous for reducing media noise level and these films seemed to be useful for the perpendicular magnetic recording media.

References

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Figure 1: XRD diagrams of Ba ferrite/ZnO bilayered films for various n .

Figure 2: The dependences of $d_{\text{ZnO}(002)}$, $H_{c\perp}$ and K_1 on the parameter of target composition n .

Figure 3: The dependences of $4\pi M_s$ and $\langle D \rangle_{\text{BaM}}$ on the parameter of target composition n .