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

M. Naoe, K. Noma, N. Matsushita, S. Nakagawa

To cite this version:

HAL Id: jpa-00255073
https://hal.archives-ouvertes.fr/jpa-00255073
Submitted on 1 Jan 1997

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Crystallographic and Magnetic Characteristics of Ba Ferrite Sputtered Films for High Density Magnetic Recording Disks

M. Naoe, K. Noma, N. Matsushita and S. Nakagawa

Department of Physical Electronics, Tokyo Institute of Technology, 2-12-1 O-okayama, Meguro, Tokyo 152, Japan

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 $4nM_s$ 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: BaO·6Fe$_2$O$_3$) have been deposited for applying them to the perpendicular magnetic recording medium. Ones of a W-type of Ba ferrite (BaW: BaFe$_{10}$O$_{27}$) may be more useful for high density recording medium because of their larger saturation magnetization $4nM_s$. 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 BaO·$n$Fe$_2$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.

| Targets: BaO·$n$Fe$_2$O$_3$ ($n=5.5, 6.5, 7.5, 8.5$) | Substrate: SiO$_2$/Si |
| Substrate temperature $T_s$: 600°C | Sputtering gas: mixture of Xe, Ar and O$_2$ |
| Total gas pressure $P_{gas}$: 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 Fe₈₋ₓBaₓO₁₈ or Feₓ₋₈BaₓO₁₈, 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 crystallites seems not to be fluctuated by the additional growth of spinel crystallites and the (00n) dispersion angle of BaM crystallites ΔθBaM were as small as 4°. Figure 2 shows the dependences of the interplanar distance between ZnO(002) planes Δd_{ZnO(002)} the perpendicular coercivity Hc⊥ and the uniaxial anisotropy energy Kc⊥ on the parameter of target composition n. Δd_{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. Hc⊥ and Kc⊥ 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 Kc⊥ seems to be caused by the excessive growth of spinel crystallites.

Figure 3 shows the dependences of the saturation magnetization 4πMₛ and the mean size of BaM(00n) crystallites ⟨D⟩BaM on the parameter of target composition n. 4πMₛ and ⟨D⟩BaM tend to decrease with increasing n. The decrease of ⟨D⟩BaM was resulted from the segregation of spinel crystallites including the excessive Fe ions. Although ⟨D⟩BaM were very small at n of 8.5, 4πMₛ was as sufficiently large as 3.7kG. Considering the slight decrease of 4πMₛ with increasing n, most of the spinel crystallites among BaM ferrite grains seemed to reveal a berthollide type of magnetite (Feₓ₋₈BaₓO₁₈) 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 4πMₛ 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 4πMₛ above 3.2 kG and small ⟨D⟩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