Preparation and recording characteristics of rigid disks using Co-Zn ferrite sputtered films for high density magnetic recording with perpendicular anisotropy

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Abstract — The improved magnetic recording system with higher potential were proposed to surpass the conventional systems in recording density. In isotropic recording system, the recording magnetization were arranged obliquely to the film plane. Because of large magnetocrystalline anisotropy, the stability of the recorded magnetization and sharpness of reproducing field were expected to be almost same as perpendicular recording system. In this study, Co-Zn ferrite films prepared by Facing Targets Sputtering (FTS) method at relatively low substrate temperature were used for isotropic media using conventional ring head. The higher recording density such as D_{50} of 31 kfrpi were obtained.

I. INTRODUCTION

The spinel type of Co ferrite was expected to be applicable for high density magnetic recording media because of their high coercivity, corrosion resistivity and hardness. Since the easy axes of well (111) oriented Co ferrite films are distributed as corn-like shape, the films can be regarded as isotropic media for high density recording[1]. It had been clarified that Co ferrite films deposited on ZnO underlayer by Facing Targets Sputtering (FTS) method were composed of crystallites

with well (111) orientation[2,3]. However, these Co ferrite/ZnO bilayer films possessed too high coercivity H_c above 3 kOe and not so large magnetization $4\pi M_s$. In addition, the surface roughness of the films prepared at substrate temperature T_s above 400 °C were so large that they were not suitable for recording media with low head flying-height[2].

Zn substituted Co ferrite (Co-Zn ferrite) films possess well (111) orientation and lower H_c because of the ordered crystallite growth due to the site preference of Zn atoms to tetragonal sites in spinel structure and the reduction of the large magnetic anisotropy originated from Co ions[4].

In this paper, the dependences of the crystallographic and magnetic properties on the Zn content were studied. The Read/Write characteristics of 2-inch Co-Zn ferrite thin film hard disks were also investigated.

II. EXPERIMENTAL

All Co-Zn ferrite films were prepared by FTS method[5]. Sintered Co-Zn ferrite plates with different compositions were used as sputtering tar-

Fig. 1 Schematic images of principles of isotropic recording system.

gets. The composition of the targets were controlled by adjusting the ratio of starting materials. Specimen films were prepared on thermally oxidized silicon wafers at the substrate temperature T_s in the range from 100 °C (without heating substrate) to 500 °C. The crystallographic characteristics were analyzed by X-ray diffraction method, and the magnetic properties such as $4\pi M_s$ and H_c were evaluated by VSM.

III. RESULTS AND DISCUSSION

A. Crystallographic and Magnetic Characteristics

Fig. 2 shows the X-ray diffraction patterns of Co-Zn ferrite films prepared at various T_s using the targets with the composition of $\text{Co}_{0.5}\text{Zn}_{0.46}\text{Fe}_{2.04}\text{O}_y$. It was observed that only spinel (222) diffraction peak was appeared at low T_s of 100 °C. However, spinel (311) peak intensity increased, while (222) peak intensity decreased at higher T_s . Finally, at T_s above 400 °C, Co-Zn ferrite films were composed of only crystallites with (311) orientation.

The surface morphology of the films were esti-

Fig. 2 XRD patterns at various T_s of 100 ~ 400°C.

Fig. 3 Typical hysteresis loop of (111) orientated films.

mated by using atomic force microscopy and the center-line average roughness R_a and the root-mean-square roughness R_{rms} of the film prepared at T_s of 100 °C were 1.42 and 1.73 nm, and those of the film prepared at T_s of 400 °C were 94.9 and 116.8 nm, respectively[5].

The value of $4\pi M_s$ of the films prepared at T_s of 100 °C with (111) orientation were 260 emu/cm^3 (3.3 kG) and the maximum value of 380 emu/cm^3 (4.8 kG) were obtained in the film prepared at T_s of 250 °C where a large (222) peak and the minimum $\Delta\theta_{50(111)}$ value of 2.8° were observed by XRD analysis.

The in-plane and perpendicular coercivity H_c were almost the same value of 1.5~2.0 kOe over all range of T_s [5]. The shape of the hysteresis loop was isotropic for highly (111) oriented film as shown in Fig. 3.

B. Dependences on Zn Content

The specimen films were deposited by using three types of targets. The composition of the targets are listed in Table 1. In Fig. 4, the quality factor for (111) orientation $f_{c(111)}$ were evaluated from following equation:

$$f_{c(111)} = \frac{p-p_0}{1-p_0}, \quad p = \frac{\Sigma I(111)}{\Sigma I(hkl)}, \quad p_0 = \frac{\Sigma I_0(111)}{\Sigma I_0(hkl)}$$

where $I(hkl)$ is the peak intensity of (hkl) refrec-

Fig. 4 Dependences of $f_{c(111)}$ on T_s for each target composition.

Table 1 Composition of targets analyzed by ICPS (content of metallic ion is normalized for $C_{Zn} + C_{Co} + C_{Fe} = 3.0$).

	C_{Zn}	C_{Co}	C_{Fe}
target-A ($x=0.3$)	0.313	0.655	2.031
target-B ($x=0.7$)	0.722	0.543	1.735
target-C ($x=0.9$)	0.894	0.207	1.899

tion and I_0 is taken from the reference of JCPDS cards. The crystal orientations were drastically changed by T_s for each target composition, and the appropriate T_s to attain well (111) orientation in the films were different for each composition.

It has to be noted that H_c of the films were controllable by changing Zn content x , and they had a little dependence on T_s for each composition as shown in Fig. 5. Therefore, Co-Zn ferrite films with preferable characteristics such as well (111) orientation and moderate H_c about 1.5 ~ 2.0 kOe can be obtained by optimizing the target composition and sputtering conditions, especially such as T_s .

C. Read/Write Characteristics

The specimens for measuring R/W characteristics were prepared on thermally oxidized 2-inch silicon wafer at T_s of 200 and 400 °C by using

Fig. 5 Dependences of H_c on T_s for each target composition.

the $Co_{0.5}Zn_{0.46}Fe_{2.04}O_y$ targets. The thickness of the films were around 200~300 nm. The crystallographic orientations of them were (111) at T_s of 200 °C and (311) at T_s of 400 °C, respectively. Typical values of $4\pi M_s$ and H_c of these films were shown in Table 2.

The R/W characteristics of the disks were measured by contact recording system using thin film head with Co-Zr-Nb amorphous core with the gap length of 0.35 μm . The revolution velocity of the disks were set at 1,200 r.p.m and then the relative velocity was 2.51 m/sec.

The reproducing signals seemed to be dipulse-like and the dipulse ratio at 385 frpi were about 0.4 for the disk with (111) orientation (disk-1) and 0.1 for the disk with (311) orientation (disk-2), respectively. The output waveform at the recording density of 385 fpi for disk-1 is shown in Fig. 6. These results suggest that the recorded magnetization in these disks contain perpendicular component of magnetization. The linear

Table 2 Magnetic and other properties of Co-Zn ferrite hard disks

	T_s [°C]	orien- tation	$4\pi M_s$ [kG]	H_c [kOe]	thickness [nm]
disk-1	200	(111)	3.9	1.8	230
disk-2	400	(311)	4.4	1.2	280

Fig. 6 Output waveform of isolated pulse.

recording density characteristics for both disks are shown in Fig. 7. The amplitude of reproducing signals for disk-1 was smaller than that for disk-2. It was because that the remanent magnetization M_r of (311) oriented films were larger than that of (111) film.

But the recording density D_{50} for disk-1 was larger than that for disk-2. One of the reason is that H_c of the (111) oriented film was higher than that of (311) film. However, since the dipulse ratio for disk-1 was larger than that for disk-2, the recording mode of disk-2 seemed to be the in-plane one and that of disk-1 was the isotropic one.

Fig. 7 Read/Write Characteristics on linear recording density.

IV. CONCLUSION

Co-Zn ferrite films for isotropic recording media were investigated by using FTS method. It was clarified that for each target composition, there was the optimized T_s for obtaining the films with well (111) orientation and by changing the Zn content, H_c of Co-Zn ferrite films were controllable.

By comparing R/W characteristics of the disk with (111) orientation and (311) orientation, the former disk seemed to be recorded in isotropic recording mode and have higher potential to improve magnetic recording density. In this study, the linear recording density D_{50} of 31 kfrpi was obtained.

REFERENCES

- [1] J. U. Lemke: IEEE Trans. on Magn., **MAG-15** p.1561 (1979)
- [2] N. Matsushita, S. Nakagawa and M. Naoe: IEEE Trans. on Magn., **MAG-28** p.3108 (1992)
- [3] N. Matsushita, K. Noma, S. Nakagawa and M. Naoe: Proc. of the 6th Conference on Ferrites, p.428 (1992)
- [4] R. M. Bozorth, E. F. Tilden and A. J. Williams: Phys. Rev. **99** p.1788 (1955)
- [5] N. Matsushita, K. Noma, S. Nakagawa and M. Naoe: Proc. of 1st International Conference on Processing Materials for Properties, p.1169 (1993).
- [6] N. Matsushita, K. Noma, S. Nakagawa and M. Naoe: J. of Appl. Phys., **75** p.5975 (1994)
- [7] S. Iwasaki: IEEE Trans. on Magn., **MAG-21** p. 71 (1985)