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Preparation of Co-containing Spinel Ferrite / Ni-Zn Ferrite Thin-Film Double-Layered Perpendicular Recording Media using Reactive ECR Sputtering

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Co-containing spinel ferrite / Ni-Zn spinel ferrite double-layer perpendicular magnetic recording media were fabricated using a reactive sputtering method utilizing an Electron-Cyclotron-Resonance (ECR) microwave plasma. The Ni-Zn spinel ferrite thin-films deposited at temperatures lower than 200 degrees Celsius had preferential orientation of (400), relatively low coercivity of 2.4 Oe, relative initial permeability of 46, and almost same composition as the sputtering target. A Co-containing spinel ferrite thin-film with high perpendicular coercivity was deposited on the Ni-Zn ferrite thin-film backlayer at 150 degrees Celsius by reactive ECR sputtering. Although the Co-containing ferrite single-layer thin-film deposited directly on the substrate was preferentially oriented in (311), the Co-containing ferrite thin-film deposited on the (400) oriented Ni-Zn spinel ferrite backlayer showed (400) preferential orientation showing the hetero-epitaxial growth.

Key words : spinel ferrite thin-film, perpendicular magnetic recording, Ni-Zn ferrite backlayer, ECR plasma, hetero-epitaxial growth

1. INTRODUCTION

Ferrite thin-film recording media are promising as high density perpendicular magnetic recording media because protective overcoat layer is not necessary.[1]-[2] We have already reported that Co-containing ferrite thin-film single-layer perpendicular media deposited by reactive sputtering method utilizing ECR (Electron-Cyclotron-Resonance) microwave plasma[3]-[4] showed high perpendicular coercivity over 3000 Oe and perpendicular magnetic anisotropy and are available as perpendicular magnetic recording media. [5]-[8] It was well known that the introduction of a soft magnetic backlayer drastically improves recording and reproducing performance when the media are used in combination with a single-pole type perpendicular heads.[9]

We are now developing the low-temperature and high-rate deposition technology of Ni-Zn soft magnetic thin-films using reactive ECR sputtering. .[10] In this study, Co-containing spinel ferrite / Ni-Zn spinel ferrite double-layer perpendicular magnetic recording (PMR) media were fabricated using a reactive sputtering method utilizing an ECR microwave plasma

2. EXPERIMENTAL

2.1 Deposition of Ni-Zn ferrite thin-films

Ni-Zn ferrite thin-films used as a soft magnetic backlayer were deposited by using a ECR sputtering apparatus (SHIMADZU Corp.: SLC75-ES). Reactive sputtering was performed using three Ni-Zn-Fe alloy platelet targets in the mixture gas of argon and oxygen. Total sputter gas pressure was fixed at 0.55 Pa and oxygen partial pressure was varied to survey optimal condition. Microwave input power and target voltage were fixed at 1.7 W/cm^2 and −350 V, respevtively. The films were deposited without substrate heating. However, the substrate temperature rose up from room temperature to 200 degrees Celsius during film deposition because of the bombardment of large amount of plasma. The 200 nm thick Ni-Zn ferrite thin-films were deposited directly onto the surface oxidized Si substrate without seed layers.

2.2 Deposition of Co-containing ferrite thin-films

In the deposition of Co-containing ferrite thin-films used as recording layer, reactive sputtering was employed using an another type of ECR sputtering apparatus (AFTI Corp.: AFTEX-3400U) whose configuration was illustrated in Fig.1. Plasma was generated by the combination of 2.45 GHz microwave and 875 Gauss magnetic field which satisfied ECR condition. Reactive sputtering was performed using a cylindrical Fe-Co alloy target with a Co content of 6

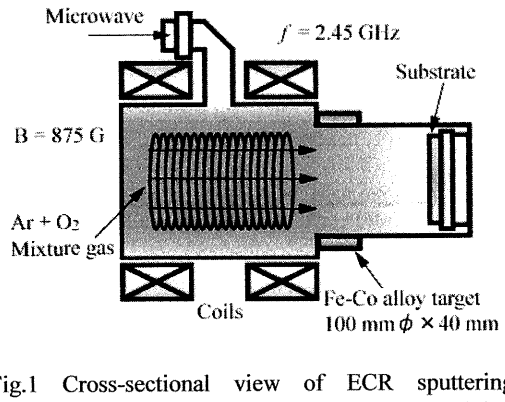
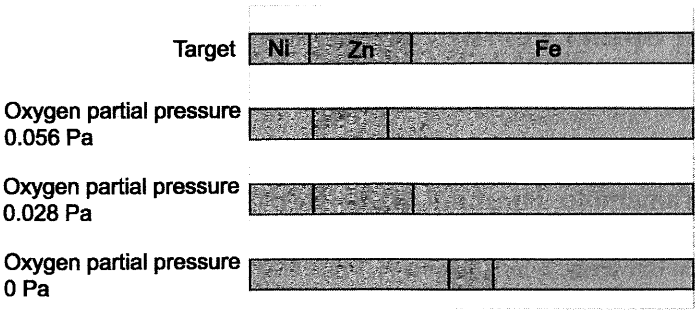


Fig.1 Cross-sectional view of ECR sputtering apparatus used in the deposition of Co-containing ferrite thin-film.



Saturation magnetization [kG]	In-plane coercivity [Oe]
0.238	101
1.30	2.4
12.2	88

Fig.2 Composition analysis of sputtering target and Ni-Zn ferrite thin-films deposited at various oxygen pressure.

at.% in the mixture gas of argon and oxygen. Total sputter gas pressure and oxygen gas partial pressure were set at 0.080 Pa and 0.011 Pa, respectively. A microwave input power, target voltage and substrate temperature were set at 2.4 W/cm^2, -250 V and 150 degrees Celsius, respectively. The 100 nm thick Co-containing ferrite thin-film was deposited both on the Ni-Zn ferrite backayer and directly onto the surface oxidized Si substrate as a reference.

Measurements of magnetic and crystallographic properties and surface morphology of the media and composition analysis were performed using a vibrating sample magnetometer (VSM), X-ray diffraction (XRD (Cu-Kα)), an atomic force microscopy (AFM) and EPMA, respectively.

3. RESULTS AND DISCUSSION

Fig.2 shows the Ni, Zn, Fe (except for O) composition and magnetic properties of the sputtering target and the Ni-Zn ferrite thin-films deposited at various oxygen partial pressure. The Ni-Zn ferrite thin-film deposited at oxygen pressure of 0.028 Pa has the almost same composition as the target and exhibits the lowest coercivity of 2.4 Oe.

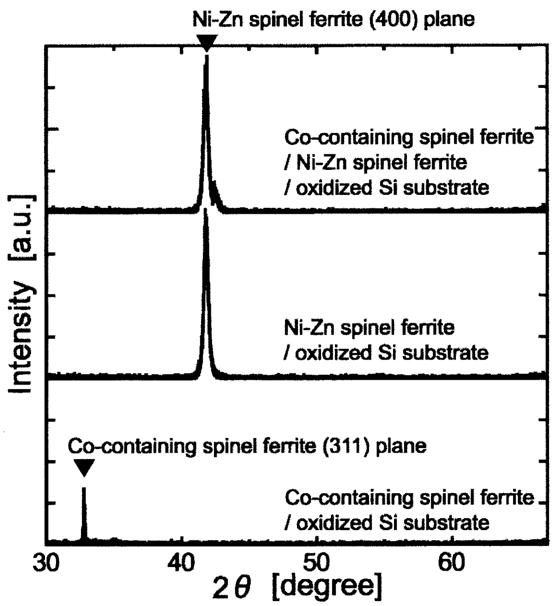
Table 1 and 2 show the magnetic properties of a Ni-Zn ferrite thin-film and a Co-containing ferrite thin-film deposited onto the surface oxidized Si substrate. Saturation magnetization, in-plane coercivity and relative initial permeability of Ni-Zn ferrite thin-film were 1.30 kG, 2.4 Oe and 46, respectively. In Co-containing ferrite thin-film, saturation magnetization and perpendicular coercivity were 3.95 kG and 2400 Oe.

Table 1 Magnetic properties of Ni-Zn ferrite thin-film.

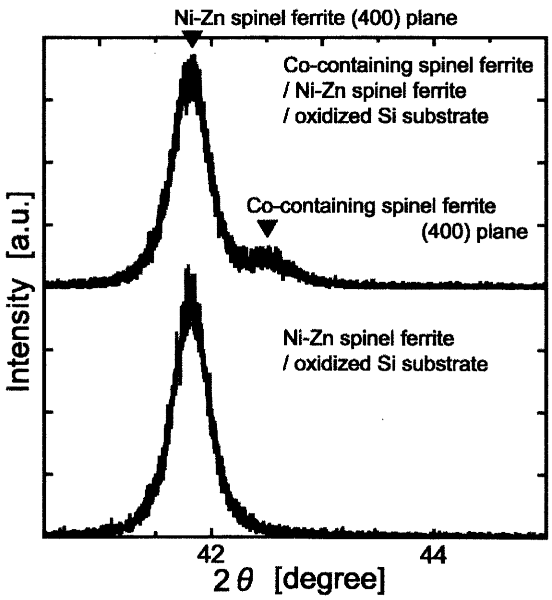
	Saturation magnetization [kG]	*In-plane coercivity [Oe]*	*Relative initial permeability*
Ni-Zn ferrite film	1.30	2.4	46

Table 2 Magnetic properties of Co-containing ferrite thin-film.

	Saturation magnetization [kG]	*Perpendicular coercivity [Oe]*
Co-containing ferrite film	3.95	2400

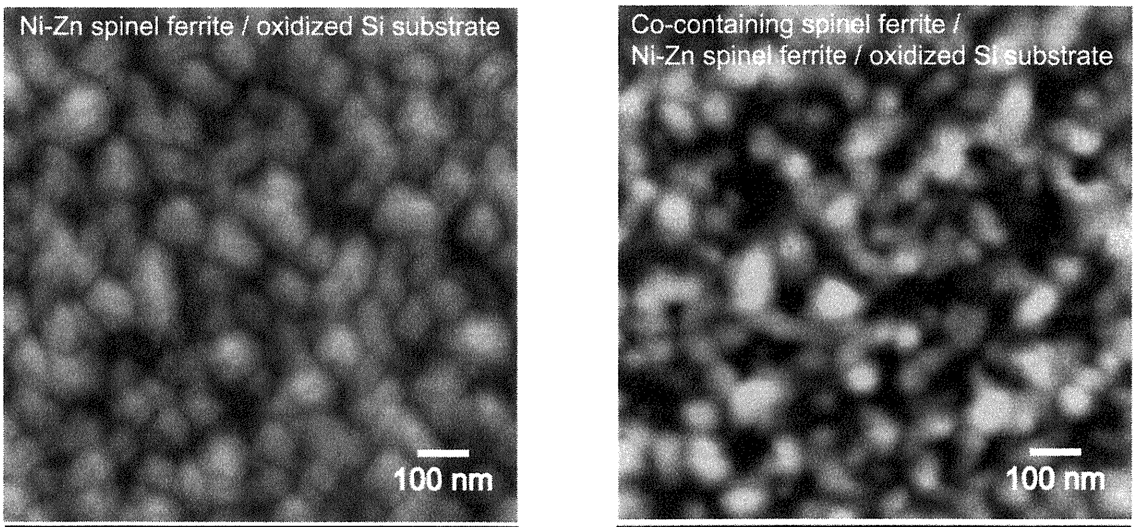


(a) Crystal orientation of Co-containing ferrite and Ni-Zn ferrite thin-films.



(b) Hetero-epitaxial growth of Co-containing ferrite thin-film.

Fig.3 X-ray diffraction diagrams of ferrite thin-films deposited onto oxidized Si substrate.



	Ni-Zn spinel ferrite / oxidized Si substrate	Co-containing spinel ferrite / Ni-Zn spinel ferrite / oxidized Si substrate
Grain size	42.9 nm	70.3 nm
Surface roughness (R_a)	1.36 nm	3.00 nm

Fig.4 AFM surface images of Ni-Zn ferrite single-layer thin-film and Co-containing ferrite / Ni-Zn ferrite double-layer thin-film.

X-ray diffraction diagrams of Ni-Zn spinel ferrite thin-film, Co-containing spinel ferrite single-layer thin-film and Co-containing spinel ferrite / Ni-Zn spinel ferrite double-layer thin-film were shown in Fig.3. In the Ni-Zn ferrite thin-film, X-ray diffraction peak only from (400) plane was observed. In the Co-containing ferrite thin-film single-layer, the peak only from (311) plane of Co-containing ferrite was observed. However, the Co-containing ferrite thin-film deposited on the (400) oriented Ni-Zn spinel ferrite backlayer showed (400) preferential orientation showing the hetero-epitaxial growth.

Fig.4 shows the AFM surface images of the Ni-Zn ferrite single-layer film and Co-containing ferrite / Ni-Zn ferrite double-layer film on the surface oxidized Si substrate. The Ni-Zn ferrite thin-film has a grain size of 42.9 nm and a surface roughness (R_a) of 1.36 nm. Co-containing ferrite single-layer film had a small grain size of 14.9 nm and smooth surface roughness R_a of 0.60 nm. However, the Co-containing ferrite / Ni-Zn ferrite double-layer film had a large grain size of 70.3 nm and large Ra of 3.00 nm. In the double-layer medium, the grains in Co-containing ferrite thin-film grew and resulted in the considerable increase in surface roughness. From the practical viewpoint, reduction of grain size and surface roughness is necessary.

4. CONCLUSIONS

The following results were obtained.

(1) The Ni-Zn spinel ferrite thin-films prepared by reactive ECR sputtering method at temperature lower than 200 degrees Celsius had (400) spinel preferential orientation, relatively low coercivity of 2.4 Oe, relative initial permeability of 46, and same composition as the sputtering target.

(2) The Co-containing spinel ferrite thin-films prepared by reactive ECR sputtering method onto the Ni-Zn spinel ferrite backlayer showed (400) preferential orientation. The Co-containing spinel ferrite thin-films grew onto the Ni-Zn spinel ferrite backlayer in hetero-epitaxial manner.

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