Low Temperature Sputter-Deposition of Ni-Zn Ferrite Thin-Films
Using Electron-Cyclotron-Resonance Microwave Plasma

Soft Magnetic Backlayer for Spinel Ferrite Thin-Film
Perpendicular Magnetic Recording Media

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Abstract

A novel reactive sputtering method using an Electron-Cyclotron-Resonance (ECR) microwave plasma was used to deposit Ni-Zn ferrite thin-films for a soft magnetic backlayer of Co-containing spinel ferrite thin-film perpendicular magnetic recording media. To achieve high deposition rate, configuration of sputtering target, position of oxygen gas inlet and processing parameters such as microwave input power, target voltage, oxygen partial pressure were carefully optimized. Ni-Zn spinel ferrite thin-films with preferential orientation of (400) and relatively low coercivity of 15 Oe were obtained at a high deposition rate of 14 nm/min and at a temperatures lower than 200 degrees C. The reactive ECR sputtering is one of the most suitable preparation methods of ferrite thin-films applicable to the perpendicular magnetic recording media.

Keyword Ni-Zn ferrite thin-films, Reactive ECR sputtering, Perpendicular recording, Recording media
1. Introduction

We have already reported on Co-Cr thin-film deposition by a novel sputtering method using an Electron-Cyclotron-Resonance (ECR) microwave plasma, in short, ECR sputtering [1,2]. The ECR sputtering method has advantages over conventional diode or magnetron sputtering method: Firstly, independent process control with respect to plasma generation, sputtering and film deposition. Secondly, the ECR sputtering is predicted to be suitable for low temperature deposition of oxide or nitride thin-films which need chemical reaction during film growth because the ECR microwave plasma is dense and contains many energetically excited ions. We have already proved that the Co-containing spinel ferrite thin-films with a high coercivity of 3000 Oe for magnetic recording media application can be deposited at a temperature lower than 200 degrees C using the reactive ECR sputtering method [3].

To apply soft magnetic ferrite thin-films to advanced magnetic devices such as backlayer of PMR media, MMIC (Monolithic Microwave Integrated Circuit), thin-film isolator and circulator, acceptable highest deposition temperature is at most 300 degrees C, and high deposition rate is necessary to meet the demand of relatively large film thickness over micrometer.

In this study, the high rate and low temperature deposition of soft magnetic Ni-Zn spinel ferrite thin-films was investigated using the reactive ECR sputtering method.

2. Experimental

Figure 1 shows the configuration of the ECR sputtering apparatus used in this experiment [4]. Plasma was generated by the combination of 2.45 GHz microwave and 875 Gauss magnetic field which satisfied ECR condition. The process gas was introduced in the following two ways. Firstly, argon and oxygen mixture gas was introduced in the plasma generation chamber. Secondly, argon gas and oxygen gas were separately introduced in the plasma generation chamber and in the near space of the substrate in the film deposition chamber, respectively. Ni-Zn ferrite thin-films were deposited without substrate heating. The substrate temperature rose up to 200 degree C during film deposition. Three Ni-Zn-Fe alloy platelet targets were placed in the vicinity of plasma extraction window, and the angles between the sputtering targets and substrate was tuned to form so-called “in-axis configuration” to achieved high deposition rate.

3. Results and Discussions

At first, 200 nm thick Ni-Zn ferrite thin-films were deposited at a microwave input power of 500 W, target-voltage of -300 V, with varying oxygen partial pressure from 0 to 10%. The oxygen partial pressure was defined as the percentage of oxygen pressure to total gas (argon and oxygen).

As shown in figure 2, the saturation magnetization of the deposited film gradually decreased with increasing oxygen partial pressure and dropped suddenly at a oxygen partial pressure of 4%. However, high deposition rate over 10 nm/min was still maintained up to oxygen partial pressure of 7%. XRD diagrams of the deposited films in
As shown in figure 4, in condition I, the minimum coercivity of 65 Oe was obtained at a target voltage of -300 V. In condition II, the minimum coercivity of 67 Oe was obtained at a target voltage of -400 V. In condition III, the minimum coercivity of 15 Oe was obtained at a target voltage of -350 V.

In figure 5, coercivity of the Ni-Zn ferrite thin-film deposited in condition I, II and III was plotted against their saturation magnetization. It was found that the coercivity has a relationship with saturation magnetization, and that low coercivity was achieved at the saturation magnetization of about 150-350 emu/cc. Saturation magnetization of ferrite decreases as the oxidation of the film is enhanced. This experimental result shows that the precise control of oxidation is

figure 3 shows that the Ni-Zn spinel ferrite thin-films with preferential orientation of (400) were obtained at oxygen partial pressure ranging from 5 to 7%, where spinel ferrite films were achieved although the target operated in "metal mode", and high deposition rate was achieved.

From several experiments as described above, it was found that the microwave input power is a primal factor determining the deposition rate because plasma density is proportional to the microwave input power, and that, at higher microwave input power, optimum value of oxygen partial pressure shifts upward, because the more oxygen atoms are needed to oxidize sufficiently when the number of atom is increased.

The following three deposition condition was selected, and deposition of 400 nm thick Ni-Zn ferrite thin-films was carried out to investigate the influence of target-voltage: One is a microwave input power of 500 W and oxygen partial pressure of 5%. This experimental condition is expressed as "Condition I". The other (Condition II) is a microwave input power of 600 W and oxygen partial pressure of 8%. In these two conditions, oxygen gas was introduced in the plasma generation chamber. In Condition II, microwave input power and oxygen partial pressure were increased as compared with that in Condition I. The last one (Condition III) is a microwave input power of 500 W, oxygen partial pressure of 5%, oxygen gas was introduced in the vicinity of the substrate in the film deposition chamber not to easily oxidized the sputtering target. Target voltage was varied from 200 V to 700 V.
necessary to achieve low coercivity Ni-Zn ferrite thin-films.

Figure 7 shows the XRD diagrams for the Ni-Zn ferrite thin-films. The highest diffraction peak from (400) plane was observed for the Ni-Zn film deposited in condition III. The result proves that superior crystallinity was achieved in this film.

The deposition rate was proportional to the target voltage as shown in figure 6. This results means that the target voltage is secondary factor to determine the deposition rate in this ECR sputtering method. In this system, target voltage plays a role only to collect and accelerate argon ions to the target from the plasma flow. In a conventional sputtering system, target voltage concerns to both plasma generation and collection of argon ions. The maximum deposition rate reached to 33 nm/min at a target voltage of -700 V in Condition II. This value is about 20 times larger than that obtained using our prototype ECR sputtering apparatus [4].

At the best condition where minimum coercivity was obtained, the deposition rate was 12.3 nm/min., 18.1 nm/min. and 13.8 nm/min. in Condition I, II and III, respectively.

In table 1, magnetic properties, grain size, average surface roughness (Rₙ), and deposition rate of the Ni-Zn films deposited under the above described minimum coercivity condition are summarized. The ferrite thin films deposited in condition I and II had a small grain size and a smooth surface. This supposed to be due to small plasma radiation during film growth. The residual stress of the Ni-Zn thin-films is less than 1×10¹⁰ dyne/cm² is relatively. This is convenient in deposition of thick ferrite films because this ensures the difficulty in peeling off from the substrate.

**4. Results and Discussions**

A novel reactive sputtering method using an Electron-Cyclotron-Resonance (ECR) microwave plasma was used to deposit Ni-Zn ferrite thin-films. The Ni-Zn spinel ferrite thin-films with preferential orientation of (400) and relatively low coercivity less than

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**Table 1 Magnetic properties, surface roughness and deposition of Ni-Zn ferrite thin-films**

![Fig. 6 Target-voltage dependence of deposition.](image)

![Fig. 7 X-ray diffraction diagram of Ni-Zn ferrite films.](image)
15 Oe were obtained at a high deposition rate of 14 nm/min. and at a temperatures lower than 200 degrees C. The reactive ECR sputtering is one of the most suitable reparation methods of ferrite thin-films applicable to the backlayer of ferrite thin-film perpendicular magnetic recording media.

References


