IMPROVEMENT IN MAGNETIC PROPERTIES OF CoZrNb THIN FILMS FOR A SINGLE POLE TYPE HEAD

Hiroshi YOKOTA, Ichiro KUDAKA, Masami YAMASHITA and Terutoshi SUENAGA

Research Center, Denki Kagaku Kogyo K.K.
3-5-1 Asahicho, Machidashi, Tokyo 194, Japan

Abstract—The read/write performance of a single pole type head was greatly advanced by increasing the magnetic circuit efficiency. These developments have enabled recording densities of 530 Mb/in² without MR and PRML technology. In order to achieve higher recording density, we have investigated CoZrNb films deposited by ion beam sputtering. It is confirmed that an increase of the amount of incident particles with a large incident angle leads to improve the magnetic properties of CoZrNb films in the thickness range less than 2000 Å.

Keywords; Perpendicular magnetic recording, Contact recording, Single pole type head, CoZrNb film

1. INTRODUCTION

In the earlier work, we reported a contact single pole type head, of which the fundamental concept is employed in the original Salanx Head. However, its signal amplitude at 100 kfc i was only 80 nV_{pp} / μm/turn/m/s which is too low for practical application [1]. The low amplitude seemed to be caused by the low reproducing efficiency of its transducers.

We tried to improve the efficiency this time. The geometry of the transducers such as the return stud(R.S.) or the back gap(B.G.) was analyzed using a micromagnetic calculation software(JMAG) first.

As the R.S. functions only to gather the return flux up, area(thickness) of the R.S. facing toward the recording media should be large(wide). Our calculation results also suggested this trend. However, the amplitude increase is saturated when the thickness is over 40 μm. The B.G. thickness(length between the main pole and the R.S.) seems to influence the reproducing efficiency because the B.G. induces an electric current in a coil by magnetic flux change. The calculation results say that the signal amplitude increases with the decrease of the B.G. thickness, but that a peak-shift occurs when the B.G. is too thin and then the desirable thickness of the B.G. is 25 to 30 μm.

In order to confirm the calculation result, transducers of the Salanx Head were refabricated as shown in Table 1, and read/write characteristics were examined. A CoZrNb film for the main pole and NiFe films for the R.S. and the B.G. were deposited on the same condition as our previous work. The read/write characteristics were measured with a double layered medium composed of a 700 Å thick CoCrTa(Hc:2700 Oe) and a 7 μm thick NiFe.

Fig.1 shows its results. The signal amplitude of the new Salanx Head is 250 nV_{pp} / μm/turn/m/s at 100 kfc i and Pw₅₀ is 12 μm. Considering 5 μm track width and a necessary guardband, track density reaches 4000 TPI and the new Salanx Head can actualize 530 Mb/in² recording

density with conventional peak detection at a linear velocity of 4m/s.

Table 1 Specification of Salanx Head

	Old design	New design
Pole material	Co ₈₂ Zr ₅ Nb ₁₃	←
Pole thickness	0.2 μm	0.18 μm
Track width	5.0 μm	←
Number of coil turns	40	←
R.S. thickness	10 μm	40 μm
B.G. thickness	15 μm	25 μm

Fig.1 Recording density of the New Salanx Head

We confirmed that much of this advance in the read/write characteristics was obtained by increasing the magnetic circuit efficiency. However, in order to achieve higher density recording, over 1Gb/in², it is necessary to obtain high read-sensitivity with a thinner main pole film and a narrow track head. [2] To realize it, amorphous CoZrNb films which are deposited by ion beam sputtering were introduced as the material of main pole films.

However, magnetic properties of Co(Zr,Nb,Ta,Mo) films are severely influenced by the film thickness, especially the coercivity increases with the decreasing of

film thickness [3,4] . Therefore , it is difficult to obtain a thin main pole film with low coercivity . On the other hand , a closure domain areas tend to increase with narrowing track width [5] , and then it is difficult to control the domain structures .

We investigated the soft magnetic properties of CoZrNb films deposited by ion beam sputtering in the thickness range 500 ~ 2000 Å in order to use them as very thin main pole heads . We present here relationships among sputtering conditions , magnetic properties , domain configuration , and microstructure of those films .

2. IMPROVEMENT IN CoZrNb MAGNETIC PROPERTIES

A. EXPERIMENTAL

An ion beam sputtering system is shown schematically in Fig.2 . In order to obtain high rate deposition , a substrate is usually held parallel to the target . Since it is well known through some experimental results that magnetic properties are severely influenced by the substrate tilt angle . Therefore , 500 ~ 2000 Å thick CoZrNb films were deposited on glass substrates with different tilt angles. The deposition was carried out in a 300 Oe field which is parallel to the substrate to induce uniaxial anisotropy in the films . The sputtering conditions are shown in Table 2 . The coercivities of the CoZrNb films were measured with a B-H curve tracer . The magnetostriction coefficient were measured by applying stress in parallel to the hard axis of the films . Chemical compositions of these films were analyzed with E.D.X. Internal stress of the films was measured by monitoring the change of curvature of the substrate before and after film deposition .

Table 2 Sputtering conditions

Target(wt%)	Co ₈₅ Zr ₅ Nb ₁₀ , Co ₉₃ Zr ₄ Nb ₃
Accelerative voltage	1 kV
Background pressure	less than 7×10^{-7} Torr
Ar pressure	2.2×10^{-4} Torr
Substrate temperature	15 °C
Substrate tilt angle	33 , 43 and 57 deg.

The domain structures of the CoZrNb films , patterned as a main pole shape of 3 ~ 25 μm track width after at 180 °C in a 1 kOe rotating field annealing and at 240 °C in a 1.4 kOe static field annealing , were observed by Bitter method .

B. RESULTS

1. Soft magnetic properties

The film coercivity of the hard axis in as a function of the tilt angle is shown in Fig.3 , while Fig.4 shows B-H

curves of sheet films deposited at 57 ° and 33 ° .

These data show that the coercivity of CoZrNb films prepared using both of targets Co₈₅Zr₅Nb₁₀ and Co₉₃Zr₄Nb₃ can be reduced by increasing the tilt angle from 33 ° to 57 ° . However , the deposition rate decreases when the tilt angle becomes larger .

Fig.2 Ion beam sputtering machine for deposition

Fig.3 Coercivity as a function of the substrate tilt angle

Tilt angle : 57 deg. Tilt angle : 33 deg.
Fig.4 B-H curve of as deposited Co₉₃Zr₄Nb₃ films

Fig.5 Coercivity dependence on CoZrNb thickness

Fig.5 shows the relationship coercivity and thickness of CoZrNb which were deposited at 33° and 57°. The data show the coercivity decreases as the film becomes thinner. However, the coercivity of films deposited at 57° increases less than those of deposited at 33°.

Fig.6 shows the magnetostriction coefficients as a function of the substrate tilt angle. The magnetostriction coefficient shifts from positive to negative when the angle becomes larger. However, the values deposited at 43° and 57° are within the order of 10^{-7} .

Fig.6 Saturate magnetostriction

2. Domain structure

Fig.7 shows a relationship between the effective track width [5] and the patterned track width. The effective track width with negative magnetostriction is wider than that with positive magnetostriction when the track width is less than approximately 10 μm in spite of the same anisotropy field of 12 Oe.

Fig.7 Dependence of the effective track width on the pattern width

C. DISCUSSION

Improvement in soft magnetic properties

In this experiment, we succeeded in preparing a 1000 Å thick CoZrNb film with a low coercivity of 1 Oe, and confirmed that the deposition rate of CoZrNb films decreased when the substrate tilt angle are large. Then it seems that such good magnetic properties have been attained by the low deposition rate. In order to confirm this effect, we have also investigated the relationship between the magnetic properties and deposition rate.

However, we could not obtain any low coercivity CoZrNb films of 1 Oe or less by deposition at 33°, although it was done at the same low rate of 1.25 Å/sec as the deposition at 57° by adjusting the ion current to the target during deposition.

Another possibility is that the low coercivity CoZrNb films may have been obtained by oblique incidence deposition. In order to confirm this hypothesis, cross sections of CoZrNb films were observed.

Fig.8 shows a T.E.M. images of the films deposited at 57° and 33° of substrate tilt angle. The film at 57° has a columnar structure, and while the film at 33° does not exhibit any microstructure.

On the other hand, it was found that the internal stress of the film deposited at 57° is lower than that of at 33° as shown in Fig.9.

According to these results, the CoZrNb film of the columnar structure seems to be caused by the oblique incidence of sputtering particles. It appears that the columnar structure is attribute to stress relaxation of the CoZrNb film.

(a) Tilt angle : 57°

(b) Tilt angle : 33°

Fig.8 T.E.M. photographs for CoZrNb films

Fig.9 Dependence of the internal stress on CoZrNb thickness

The work of Kersten shows that the coercivity of Ni decreases as the internal stress of Ni decreases. [6] The similar result is described by Naoe et.al about sputtered Fe film. [7]

According to these results, in this study the oblique incidence deposition is attributed to stress relaxation of the CoZrNb film, as a result, the low coercivity CoZrNb film may be obtained. However, the exact reason for relationship between internal stress and film thickness is not clear.

D. CONCLUSION

An increase in the amount of the high angle incident particles leads to improve magnetic properties of ion beam sputtered CoZrNb films with thickness than 2000 Å. And good domain structure with negative magnetostriction in a narrow track of 3 μm can be expected.

3. ACKNOWLEDGEMENT

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