THE STUDY OF CoCr/FeNi DOUBLE LAYERS FOR PERPENDICULAR MAGNETIC RECORDING

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Abstracts— Both FeNi and CoCr/FeNi films were prepared by a DC planar magnetron sputtering system. This paper describes the effects of sputtering conditions of FeNi films on the magnetic characteristics and structure of FeNi films and CoCr/FeNi films. It was found that the FeNi film is sensitive to the deposition conditions, the sputtering parameters have great influences on the (111) preferred orientation and the magnetic properties of the FCC FeNi films, satisfactory soft magnetic properties of FeNi films can be obtained by decreasing the argon pressure and the film thickness and/or raising the substrate temperature. The degree of C-axis preferred orientation of CoCr films deposited onto the FeNi films is strongly dependent on the degree of (111) plane orientation of FeNi films, this may be the result of the epitaxial growth of CoCr film with its (0002) plane parallel to the (111) plane of FeNi film. Some experimental results show the magnetic properties of CoCr/FeNi double layers is related to that of the FeNi film. It is pointed out that a FeNi underlayer with satisfactory properties is the prerequisite condition for obtaining CoCr/FeNi double layers with desired properties.

INTRODUCTION

Recently, much efforts have been made to study CoCr/FeNi double layers as high density recording media^[1]. The surface layer is CoCr film used as a perpendicular magnetization medium^[2], while the underlayer is FeNi film used to magnify the signal output level and to decrease the recording current. Many deposition parameters such as the argon pressure, the substrate bias voltage and the substrate temperature, etc, will affect the growth of FeNi films, and this will, in turn, influence the double layers.

This work presents the effects of varying the sputtering conditions of FeNi films on the magnetic characteristics and structures of both the FeNi underlayer and the CoCr/FeNi double layers.

EXPERIMENTAL

A series of FeNi (20at%Fe-80at%Ni) thin films with 500nm thick was deposited by planar magnetron sputtering using high purity alloy targets, and CoCr (80at%Co-20at%Cr) thin films with 400nm thick deposited onto FeNi films immediately. The deposition conditions for CoCr films were such that the argon pressure was kept at 0.46Pa and deposition rate was as high as 200nm/min. The substrate temperature can be set at any desired value by heating, ranging from 50 to about 400° C. The substrate used for thin film deposition were well cleaned glass slides(0.8mm thick).

X-ray diffraction method with CuK α radiation (intensity versus 2θ scanning, rocking curve) were used to identify qualitatively the preferred orientation of the FeNi and CoCr films with respect to the specimen surface. A vibrating sample magnetometer (VSM) was used to measure the magnetic properties.

RESULTS

1. The preferred orientation and the magnetic properties.

FIG. 1 gives X-ray diffraction pattern of CoCr/FeNi films deposited onto glass without heating substrate, two peaks are observed; one at 44.16° corresponding to FeNi (111) diffraction, the other at 44.56° corresponding to CoCr (0002) diffraction. The hysteresis loop (M-H curve) is shown in FIG. 2, which is typical for this CoCr film and indicates a low coercivity of about 200Oe in the normal direction of the film surface.

FIG. 1 X-Ray diffraction pattern of CoCr/FeNi film

FIG. 2 M-H curve of CoCr/FeNi film obtained with unheated substrate

2. The effects of the deposition conditions on the preferred orientation and properties of the thin films.

a. Argon Pressure

Table. 1 The influence of argon pressure on FeNi and CoCr/FeNi films

Argon Pressure (Pa)	FeNi films		CoCr/FeNi films		
	$\Delta\theta_{50}$	$H_{c//}$ (Oe)	$\Delta\theta_{50}$	$H_{c\perp}$ (Oe)	$H_{c//}$
0.26	8.8°	6.5	7.0°	127	36
0.53	8.5°	6.4	7.2°	127	36
1.06	9.4°	4.3	7.1°	91	36

The effect of argon pressure is shown in Table. 1. From the table it is shown that with the increase of the argon pressure, the FeNi (111) plane becomes more and more scattered and both the in-plane coercivity $H_{c//}$ of the FeNi film and the vertical coercivity $H_{c\perp}$ of the double layers decrease. However, the (0002) preferred orientation of double layers is not significantly influenced by the argon pressure.

b. The Thickness of FeNi Films

FIG. 3a $\Delta\theta_{50}$ of FeNi and CoCr/FeNi versus the thickness of FeNi films.

FIG. 3b H_c of FeNi and CoCr/FeNi films versus the thickness of FeNi films.

The thickness of thin films can be controlled by adjusting sputtering time. There is a relationship between the thickness of FeNi film and the FeNi (111) and CoCr (0002) preferred orientations as shown in FIG. 3a, it can be seen that the increasing of the underlayers thickness improves the orientation of not only FeNi (111) plane but also CoCr (0002) plane. FIG. 3b show the magnetic properties of both FeNi film and CoCr/FeNi double layers as a function of the thickness of the underlayer FeNi. It can be seen from the figure that with the increasing of the underlayer thickness, the in-plane coercivity $H_{c//}$ of the FeNi films increases, while both the vertical and in-plane coercivity ($H_{c\perp}$, $H_{c//}$) of the double layers decrease. These results above show that the thickness of the underlayer must be controlled at some adequate value to ensure the films with satisfactory properties.

FIG. 4a $\Delta\theta_{50}$ of FeNi and CoCr/FeNi films versus bias voltage given on deposition of FeNi films.

FIG. 4b H_c of FeNi and CoCr/FeNi films versus bias voltage (on FeNi).

c. The Substrate Bias Voltage

The bias voltage also has some effect on the structure of the films. As shown in FIG. 4a, with the decrease of bias voltage, the preferred orientation of FeNi films becomes more perfectly, while that of the double layer remains unchanged. FIG. 4b shows the properties of sublayer and the double layers as a function of the bias voltage applied during the deposition of FeNi films. It can be seen from the figure that the coercivity deposited without the application of bias voltage is greater than those deposited under bias voltage of $-50V$, $-100V$, $-150V$ and $-200V$'s. In these voltage range, the H_c values are almost independent of the applied bias voltage.

d. The Substrate Temperature

FIG. 5 The Coercivity of FeNi and CoCr/FeNi film versus the substrate temperature.

The films mentioned above were prepared with unheated substrate. In this case the $H_{c\perp}$ of the double layers are quite low. To study the effect of the substrate temperature, some films were prepared at varying substrate temperature, FIG. 5 shows the dependence of the coercivity of the underlayer and the double layers on the substrate temperature. The figure indicates that raising the substrate temperature will lead to decrease of $H_{c\parallel}$ of underlayers and increase of the $H_{c\perp}$ of double layers, meanwhile, it has no effect on the $H_{c\parallel}$ of double layer. This result shows that the substrate temperature is an important factor for improving the magnetic characteristics of the underlayers and the double layers.

DISCUSSIONS

Based on the experimental results above, we can see that the (111) preferred orientation and the magnetic properties of the FeNi underlayers are sensitive to the deposition conditions. In particular, the underlayer has great influence on the CoCr/FeNi double layers in the following aspects.

a. The Epitaxial Growth Mechanism

FIG. 6 The dependence of $\Delta\theta_0$ of CoCr/FeNi(0002) on $\Delta\theta_0$ of FeNi(111).

FIG. 6 shows the relationship between the FeNi (111) preferred orientation and the CoCr (0002) preferred orientation. It is obvious from the figure that the C-axis preferred orientation of the surface layer deposited onto the underlayers is highly affected by the (111) preferred orientation of the under-

layers. The higher the degree of the FeNi (111) preferred orientation, the higher the degree of the CoCr (0002) preferred orientation. On the other hand, the interatomic distance in the FeNi (111) plane ($2.518 \text{ \AA}$) is approximately equal to that in the CoCr (0002) plane ($2.523 \text{ \AA}$). From all those features above, the epitaxial growth mechanism—CoCr (0002) plane is epitaxial growth parallel to the FeNi (111) plane—can be confirmed. Some literatures^{[3][4][5]} also have given this result.

b. The Relationship Between Magnetic Properties.

FIG. 7 The dependence of the coercivity of CoCr/FeNi films($H_{c\perp}$) on the coercivity of FeNi($H_{c\parallel}$) films.

The magnetic properties of FeNi films have some effects on that of double layers as shown in FIG. 7. The figure shows that the $H_{c\perp}$ of CoCr/FeNi films decreases with the increasing of $H_{c\parallel}$ of FeNi films, this indicates that good soft properties of underlayer is closely related to the magnetic properties of double layers.

CONCLUSIONS

The results show that the underlayer FeNi films are sensitive to the deposition conditions. By decreasing the argon pressure and the film thickness and/or by raising the substrate temperature, one can obtain FeNi films with satisfactory soft magnetic properties. There is a close interrelationship between the C-axis preferred orientation of the CoCr

film and the (111) preferred orientation of the FeNi film. This may confirm the epitaxial growth mechanism of the CoCr film with its (0002) plane parallel to the (111) plane of the FeNi film. Since the magnetic properties of CoCr/FeNi double layers is related to that of the FeNi films as found in our experiment, it is concluded that a FeNi underlayer with satisfactory soft properties is the prerequisite condition for obtaining CoCr/FeNi double layers with desired properties.

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