DOMAIN OBSERVATION OF Co-Cr FILM FOR PERPENDICULAR MAGNETIC RECORDING

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Abstracts--- Transmission electron microscopy in Lorentz mode was employed to observe the domains of Co-Cr films which were prepared by magnetron sputtering. The variation of domain structures with thickness, composition and magnetization history of the films has been studied. It is found that the domain structure of Co-20% Cr(at) film is very closely related to the thickness of films. The Lorentz micrograph of the film with thickness of 20 nm shows a feather-like domain, and the 100 nm thick film has a typical dotted pattern. The difference in domain structure of films is caused by the c-axis orientation. The domain structures of Co-Cr film vary greatly with the chromium content. It is observed that the domain size at remnance is affected by its magnetization history. For same magnetization history the domain pattern of Co-4.9% Cr film is different from that of Co-20% Cr film.

INTRODUCTION

The Co-Cr film is still the first candidate for the perpendicular magnetic recording media.¹⁾ The Co-Cr film has recently been shown to have the capability of ultra high density recording over 600 KFRPI.²⁾ A lot of effort have been put into the studying of the practical application of Co-Cr films, though the reason why the Co-Cr medium itself has such dramatically high recording resolution still remains unclear. The reversal mechanism of magnetization in sputtered Co-Cr film for perpendicular recording has not been completely clarified yet. Studying the domain configuration may contribute to the solution of these problems.³⁾ There are only few papers which indicated the complicated domain structures in Co-Cr films. The reported structures of this high density recording medium may have several types, such as feather-like structure, stripe domain, dotted contrast type, ripple type and so on.^{4,5)} The purpose of this study is to correlate the magnetic do-

main structure with the composition, the magnetization history and the crystallographic orientation of the films with varying thickness. The preliminary results of our work on domain observation of Co-Cr films were summarized in this paper.

EXPERIMENT

The films were deposited on carbon-coated copper grids or rock-salt pieces in a DC plane magnetron sputtering system JCK-500. The magnetron target is 120 mm wide and 240 mm long, it is composed of 8 pieces of target plates, the 6 upper plates are made of Co-22% Cr alloy while the 2 lower plates are pure cobalt. So at the different position of the substrate, the films with different Cr content can be obtained, as shown in Fig.1.

The deposition conditions were kept approximately constant as follows: the background pressure was $(2.7-5.3) \times 10^{-4}$ Pa, the Ar pressure during sputtering was 4×10^{-1} Pa, the input power was 500Vx3A, the exciting current for magnetron target was

5A, the distance from substrate to target was 5 cm and the deposition rate was about 200 nm/min at room temperature.

Fig.1 Target and substrate

The composition of films was analysed by the electron probe of scanning electron microscope S450, the dispersion of c-axis orientation, $\Delta\theta_{50}$, was measured by rocking curve using a x-ray diffractometer BD-84, and the domain structures were investigated in Lorentz mode using a transmission electron microscope Philips EM-400 at 120 KV.

RESULTS AND DISCUSSION

A) The effect of thickness of films

Some experiments were made for studying Co-Cr films with different thickness. Co-Cr films with the most desirable c-axis orientation were obtained and characterized. It is shown from the convergent beam electron diffraction (CBED) pattern (see Fig.2) that a satisfactory c-axis orientation occurred in a film with thickness of 80 nm. A relationship between c-axis orientation dispersion, $\Delta\theta_{50}$, and the thickness of the films has been established as shown in Fig.3. It can be seen from that figure that a well orientation occurred in 80 nm thick film is about 8° .

The domain structures of Co-Cr film with a thickness of 20 nm and 100 nm are shown in Fig.4a and 4b respectively. The micrograph of 20 nm thick film (Fig.4a) reveals a feather-like domain structure and some white/black dots, while in 100 nm thick film shown in Fig.4b the feather

-like domain disappears completely and is replaced by dotted contrast and maze domain. Lorentz micrographs have shown the

Fig.2 CBED pattern of Co-Cr film

Fig.3 The relationship between $\Delta\theta_{50}$ and thickness

close relationship between the domain structure and the thickness of film which is originated from the c-axis orientation. This conclusion is in good agreement with that presented by J.W.Lee et al.⁶⁾ K.Ouchi et al has reported that the maze domain is due to an in-plane magnetization component where the film consisted of columnar grains.⁷⁾ The dotted contrast has been suggested to originated from in-plane magnetization curling surrounding a perpendicular domain where one column contained an assembly of equiaxed grains.^{4,8)}

a. 20 nm thick 400X b. 100 nm thick 2200X2X

Fig.4 Domain structure of Co-Cr film

B) The effect of the Cr content

With varying of chromium content, Co-Cr films exhibit very different characters, such as c-axis orientation, magnetic properties etc. It seemed from our research that the more the Cr content, the smaller the $\Delta\theta_{50}$. The relationship between the magnetic properties and Cr content are very complicated. These problems will not be discussed here.

a. 4.9% Cr 1350X b. 19.8% Cr 2200X

c. 21.8% Cr 1700X

Fig.5 Domain structure of Co-Cr film with different Cr content

Some domain patterns with different Cr contents are given in Fig.5, the pattern with 4.9% Cr (fig.5a) shows a typical Bloch domain wall, while 19.8% Cr pattern a ripple domain (Fig.5b) and 21.8% Cr pattern a typical cross-tie wall (Fig.5c). It is seen that the domain in Fig.5c is more narrow than that in Fig.5a, but no explanation of the effect of Cr content on domain structure has been made.

C) The effect of technical magnetization

In order to understand the magnetization behavior of Co-Cr films, a DC magnetic field either parallel or perpendicular to the film plane was applied on the Co-Cr films by a CGX-1 magnetic-optical equipment. After removal of the magnetic field the film was examined under electron microscope. The results are shown in Fig.6a and 6b which indicate that it is easier to magnetize the Co-20% Cr films in parallel direction than in vertical direction. This leads us to the conclusion on that the in-plane magnetic component is greater than the perpendicular

a. 20% Cr 1350X $H_{\perp}=100$ Oe b. 20% Cr 1050X $H_{\parallel}=100$ Oe

c. 20% Cr 1050X $H_{\parallel}=2$ K Oe d. 4.9% Cr 1050X $H_{\parallel}=2$ K Oe

Fig.6 Domain structure of Co-Cr film at remnance

one. Furthermore, it can be seen that the displacement of walls is the dominant mechanism in Fig.6a and the rotational mode occurred in Fig.6c. With Co-4.9% Cr films, however, the situation is quite different as shown in Fig.6d. It can be seen that in contrast to the domain pattern in Fig.6c the pattern in Fig.6d could not turn into dotted domain under the same magnetization history. That means the exchange coupling between the columns in Co-4.9% Cr films is so strong that the dotted pattern could not be observed.

CONCLUSION

It is well known that chromium is important to the Co-Cr films used for perpendicular magnetic recording. This study once more confirms the widespread viewpoint that the chromium and its segregation at grain boundaries between columns have very significant effect not only on c-axis orientation but also on domain structure.

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