Magnetic properties and crystal texture of Co alloy thin films prepared on double bias Cr

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A double layer Cr film structure has been prepared by sputter depositing Cr on single crystal Si substrates first without substrate bias and then with various substrate bias voltages. Without substrate bias, Cr{200} texture grows on Si at room temperature; thus the first Cr layer acts like a seed Cr layer with the {200} texture, and the second Cr layer, prepared with substrate bias, tends to replicate the {200} texture epitaxially. CoCrTa and CoNiCr films prepared on these double Cr underlayers, therefore, tend to have a $\{11\bar{2}0\}$ texture with their *c*-axes oriented in the plane of the film. At the same time, the bias sputtering of the second Cr layer increases the coercivity of the subsequently deposited magnetic films significantly. Comparison studies of δM curves show that the use of the double Cr underlayers reduces the intergranular exchange interactions. The films prepared on the Si substrates have been compared with the films prepared on canasite and glass substrates. It has also been found that the magnetic properties are similar for films on canasite and on glass.

I. INTRODUCTION

It has been argued that the crystallographic orientation of Co alloy thin films plays an important role in media noise and trackedge writing.[1–3] Tsai and his co-workers have found that Co with $\{11\bar{2}0\}$ texture formed on Cr{200} texture is preferred in order to obtain low noise recording media.[1] While the Cr{200} texture is usually obtained by heating the substrate prior to and during the Cr deposition,[4,5] in our recent paper,[6] we reported that at room temperature Cr underlayers easily formed with a {200} crystallographic texture on single crystal Si substrates. This resulted in the polycrystalline magnetic CoNiCr films having their *c*-axes oriented in the plane of the film. When rf bias was applied to the Si substrate during the Cr deposition, however, the Cr underlayers exhibited an extremely strong {110} texture, and the magnetic CoNiCr films prepared on these Cr underlayers tended to have a strong $\{10\bar{1}1\}$ texture and a lower coercivity. Films simultaneously sputtered under the same conditions on glass substrates showed weaker Cr{110} and CoNiCr $\{10\bar{1}1\}$ textures and an increased coercivity. In this article, we describe a new technique that can be used to increase the film coercivity by taking advantage of bias sputtering while preserving the {200} texture in the Cr underlayer formed on the Si substrate. The technique is to sequentially sputter two Cr underlayers on Si substrates using different processing conditions. The first Cr layer in this double Cr underlayer is deposited onto a well-cleaned Si substrate using a zero bias potential, which defines the crystallographic texture to be {200}. The second Cr layer is bias sputtered in order to enhance the film coercivity while maintaining the Cr{200} texture. Our technique eliminates the need to heat the substrate to increase in-plane orientation and coercivity.

II. EXPERIMENTAL

$Co_{82.8}Cr_{14.6}Ta_{2.6}/Cr$ and $Co_{62.5}Ni_{30}Cr_{7.5}/Cr$ thin films were prepared by rf diode sputtering in a Leybold–Heraeus *Z*-400 sputtering system with a background pressure of 7×10^{-7} Torr and an Ar sputtering pressure of 10 mTorr. (100) single crystal Si, Corning 7059 glass, and Corning canasite substrates were used. The film deposition rate was in the range of 30–120 Å/min. The substrates were cleaned with organic solvents and then rinsed in deionized water. The Si substrate was dipped in a 10% HF solution for 45 s in order to remove the surface oxide, and then blow dried without a water rinse. Prior to the film deposition, a low power *in situ* plasma etching was performed to remove the residual surface contaminants and to improve film-substrate adhesion. Magnetic properties and structural characteristics were studied by vibrating sample magnetometry and by x-ray diffraction using Cu K_α radiation.

III. RESULTS AND DISCUSSIONS

Figure 1 shows the coercivity dependence on Cr deposition bias voltage for the CoCrTa/Cr films. For these films, the CoCrTa was prepared without substrate bias. The CoCrTa film is 300 Å thick and the total thickness of the Cr underlayer is 1000 Å. When only one Cr underlayer is used, rf substrate bias applied during its deposition increases coercivity for the films prepared either on glass or on canasite. On Si, however, the substrate bias has less effect on the film coercivity. When double Cr underlayers (the first and second Cr underlayers are 100 and 900 Å thick, respectively) are used, the coercivity dependence on bias voltage for the films on Si changes dramatically. We can see that the film coercivity in this case increases with the bias voltage applied during the second Cr underlayer

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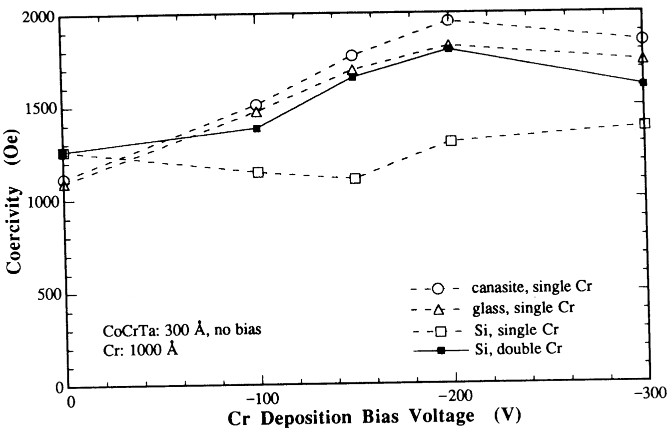

FIG. 1. Coercivity dependence on Cr deposition bias voltage for CoCrTa/Cr films prepared on Si, canasite, and glass substrates. The dashed curves are for a single 1000 Å bias sputtered Cr underlayer. The solid curve is for the double Cr underlayers. Here, the first 100 Å was prepared without bias and second 900 Å was bias sputtered.

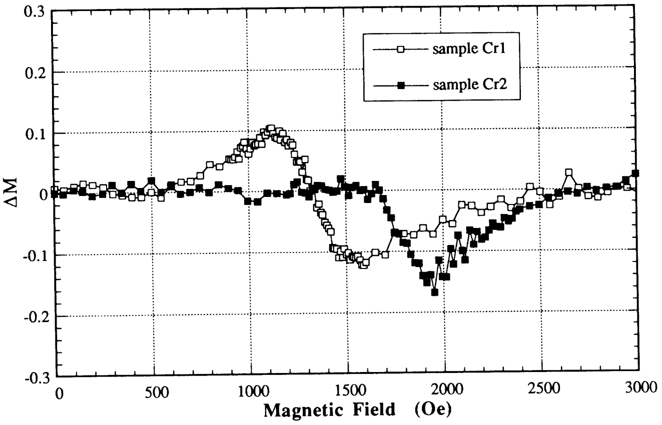

FIG. 3. ΔM curves showing less intergranular exchange interactions in the double-Cr-underlayer sample, Cr2.

deposition and is similar to those for canasite or glass substrates with only one Cr underlayer (bias sputtered). It has also been observed in our experiments that, when the double Cr underlayers are used, Si, glass, and canasite substrates are virtually the same in terms of the film coercivity behavior (for simplicity, the characteristics of the double Cr underlayers prepared on canasite and glass substrates have not been shown in Fig. 1). We have studied the same film construction for CoNiCr/Cr films, and found the results to be similar.

Figures 2 and 3 are comparison studies of x-ray diffraction and δM curves for the single- and double-Cr-underlayer structures on the selected samples described in Table I. Clearly, the double Cr underlayer changes the film's crystallographic texture. For sample Cr1, the 1000-Å-thick Cr was bias sputtered at -200 V on Si and has an extremely strong {110} texture. It has been conjectured that the Cr{110} texture results from the Ar ion bombardment during bias sputtering.[6] At the same time the CoCrTa film exhibits an epitaxially preferred {10$\bar{1}$1} texture.[7] The double-Cr-underlayer sample, Cr2, however, has a much weaker Cr{110} texture than sample Cr1. Furthermore, the Cr{200} texture is produced and thus the CoCrTa{11$\bar{2}$0} texture develops in sample Cr2. Since the {200} Cr grows on Si without any substrate bias at room temperature, the first Cr underlayer (100 Å) is {200} textured. Apparently, in spite of the bias sputtering the second Cr underlayer tends to grow epitaxially, having the same {200} texture. The Cr{200} epitaxial growth is, however, degraded by the bias sputtering (-200 V), which usually promotes the Cr{110} texture; therefore, some portion of Cr{110} and Co{10$\bar{1}$1} textures also exist in sample Cr2. The dramatic change in the film texture of samples Cr1 and Cr2 indicates clearly that, on a substrate seeded with Cr{200} texture, rf bias sputtering has a minimal effect in converting the Cr texture to {110}.

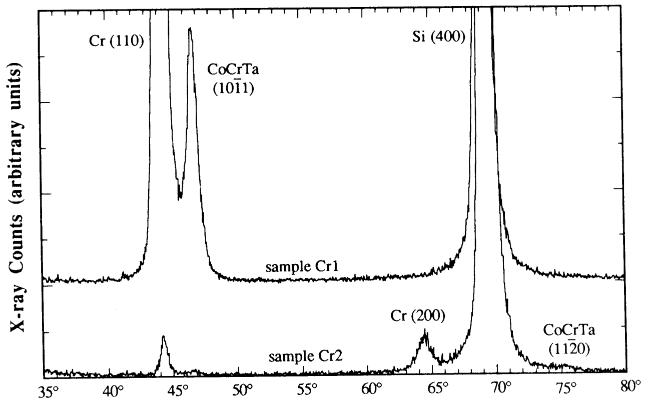

FIG. 2. X-ray diffraction spectra for samples Cr1 and Cr2. The Cr{200} texture remains in the double Cr underlayer of sample Cr2. The Cr{110} texture of Cr2 is weak compared to the anomalously strong {110} texture of the single Cr sample, Cr1.

As shown in Fig. 2, the Cr{110} texture in sample Cr1 is extremely strong. This might be a symptom of the formation of morphologically continuous and dense films. Morphologically continuous films can form if the Cr atoms have a high atomic mobility.[8] Unlike the glass or canasite surface, the Si surface is nearly oxide-free and thus provides fewer oxide sites for the Cr atoms to be trapped. When bias is applied to a Si substrate, the energy transferred from the Ar ion bombardment could dramatically increase the atomic mobility of the Cr atoms. A continuous Cr underlayer will cause the subsequently deposited Co alloy film to have poor grain isolation and large intergranular exchange interactions. The large intergranular ex-

TABLE I. Film parameters and magnetic properties of selected samples.

Sample	Cr1	Cr2
CoCrTa layer	300 Å	300 Å
# of Cr underlayers	1	2
1st Cr *w*/no bias	0 Å	100 Å
2nd Cr *w*/-200 V bias	1000 Å	900 Å
H_c (Oe)/S^*	1302/0.80	1800/0.79

change interaction would cause the film coercivity to decrease.[9] Consistent with this interpretation, Fig. 3 shows that sample Cr1, which has a lower coercivity, has a higher positive portion in the δM curve than sample Cr2, implying that sample Cr1 has larger intergranular exchange interactions.

IV. CONCLUSIONS

The double-Cr-underlayer technique has been developed to increase the coercivity of the CoCrTa/Cr and CoNiCr/Cr films prepared on Si substrates. Along with the increase in the film coercivity, some Cr{200} texture has been obtained and maintained; thus the Co alloy films have some $\{11\bar{2}0\}$ texture with their *c*-axes oriented in the plane of the film. The increase in the film coercivity has been attributed to the reduction in intergranular exchange interactions. It appears that the double-Cr-underlayer structure offers an approach to controlling Cr atomic mobility against bias sputtering effects, and could suppress the growth of continuous films on Si substrates, thereby promoting the formation of high coercivity, low noise magnetic films.

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