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A study on magnetic layer thickness effects on magnetic properties of CoCrPt /Ti perpendicular media.

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Abstract

Change of magnetic properties in CoCrPt/Ti perpendicular media with varying CoCrPt films thickness has been studied. As CoCrPt films thickness increases, the Ms(magnetization saturation) drastically increases at thinner thickness and gradually increases with further increase in thickness from 25nm. This Ms behaviour is associated with primarily the formation of "amorphous-like" reacted layer by intermixing of CoCrPt and Ti at CoCrPt/Ti interface and secondarily change of Cr segregation mode with varying the CoCrPt films thickness. Magnetic domain structure distinctively changes with increasing CoCrPt magnetic layer(ML) thickness. Also the strength of exchange coupling measured from the slope in demagnetizing region in M-H loop changes with ML thickness. Details of the above magnetic properties will be discussed. The expansion of lattice parameters a and c at thinner thickness suggests that Cr segregation mode may be connected with the residual stress of the films. Finally, negative nucleation field(Hn) behaviour with the exchange slope will be reported.

1. Introduction

CoCrPt single layered perpendicular media has been considered as one of the potential candidates for extremely high density recording. For high density recording, media should have a high S/N ratio. As it is experimentally known that noise power rapidly increases in higher recording density region in perpendicular recording media, noise reduction is an essential issue. It was reported that the major origin of noise in perpendicular media was d.c.erase noise by the magnetization fluctuations formed inside the recorded bits[1]. Recently micromagnetic simulation studies on CoCrPt single layered media and a ring head combination showed the media with negative nucleation field and appropriate exchange coupling would be essential for higher density recording[2]. Therefore, it is very important to control nucleation field and magnetic properties to improve the S/N characteristics of perpendicular media . A negative nucleation field in CoCrPt/Ti perpendicular media was reported in the previous paper[3]. In the present work, we have studied more systematically effects of the layer thickness on magnetic and structural properties of the CoCrPt films.

2.Experiment

CoCrPt films were deposited on Ti/CoZr/glass or thermally oxidized si wafer substrates by a dc magnetron sputtering method. The thickness of Ti underlayer and CoZr paramagnetic seed layer was fixed at 20nm for all the specimens.

To deposite CoZr and CoCrPt, composite targets were used. Substrate temperature was maintained at 240 °C by resistance heating. Ar pressure was kept at 3 mTorr. Sputtering power density(W/cm^2) was 0.62, 0.46, and 0.37 for CoZr, Ti, and CoCrPt layers, respectively. Background pressure was maintained under 5×10^{-7} Torr. The composition of the films was analyzed by EDS(Energy Dispersive X-Ray Spectroscopy). Magnetic properties of the films were measured by a VSM (vibration Sample Magnetometer) at room temperature. Crystallographic orientation of the films was studied by a XRD (X-Ray Diffractometer) and a GIXRD (Grazing Incidence X-Ray Diffractometer). Cross sectional images were observed by a high resolution TEM. Magnetic domain structures were measured by MFM (Magnetic Force Magnetometer).

3. Results and Discussion

Fig 1 shows the magnetization saturation(Ms) change of $CoCr_{16.3}Pt_{13.6}/Ti/Co_{50}Zr_{50}$ with varying CoCrPt layer thickness. At thinner range Ms drastically increases by 41.6% from 382 emu/cc to 541 emu/cc when the thickness changes from 10nm to 20nm and gradually increases by 2.8% from 572 emu/cc to 588 emu/cc when thickness increases from 30nm to 40nm.

Fig 2 (a) and 2(b) are cross sectional images of the two specimens with two different thicknesses of slightly different compositions. They show the existence of "amorphous-like" reacted layer which was formed by intermixing of Ti and CoCrPt at CoCrPt/Ti interface[4]. Exact magnetic properties of this reacted layer are not known. It must have very low M value. The higher Ms behaviour with the increase of ML thickness is partially associated with the reduced contribution of this reacted layer.

Fig3(a) and 3(b) are the magnetic domain structures of $CoCr_{16.3}Pt_{13.6}/Ti/Co_{50}Zr_{50}$ at ac erased states measured by MFM. As the ML thickness increases from 10nm to 20nm, domain patterns clearly change and domain size drastically decreases from 0.625 μm to 0.125μm. Sometimes, domain structure at 10nm thickness showed a typical serpentine domain. This change of observed domain structure is connected with the change of Cr segregation mode in CoCrPt films. The change of Cr segregation mode also agrees with exchange slope in M-H loop as seen in the followings. The enhancement of Cr segregation with the increase of the CoCrPt thickness has secondary effect on the Ms increase in the thicker magnetic layers.

Fig 4 shows the change of exchange slope with the ML thickness. The exchange slope is defined as 4π Ms/(Hc-Hn) and represents the strength of exchange coupling between adjacent grains in the perpendicular CoCrPt films. The exchange slope drastically decreases with the increase of ML thickness in the films with the two Pt compositions. As Pt content is higher, the exchange slope becomes larger. The reason for this may be lower Cr concentration in higher Pt films as we have used a composite target mode with Pt chips on $CoCr_{19}$ alloy target. The lower exchange slope at thicker magnetic layer is due to the enhancement of Cr segregation as the magnetic layer thickness increases.

X-Ray diffraction characteristics of CoCrPt films of the two different thickness (10nm, 20nm) were studied. The variation of CoCrPt lattice parameters, c and a with Pt content is shown in Fig 5. Fig 5 (a) and Fig5 (b) are measured by a conventional XRD and a GIXRD (Grazing Incidence X-Ray Diffractometer, λ =1.631A, α =0.74), respectively. As shown in fig 5 , lattice parameter c and a are expanding with increasing Pt contents. This is a well known fact. Also, an interesting thing is the lattice parameters of the thinner film are always larger than that of the thicker film. When the lattice parameters have been expanded, there was no Cr segregation and when lattice parameters were reduced, there was Cr segregation.

This result suggests that Cr segregation mode of CoCrPt films may be associated with residual stress by lattice expansion .

At CoCrPt/Ti/CoZr system, all the sample specimens have squareness (Mr/Ms)of 1. Fig 6 and Fig 7 represent the trend of coercivity(Hc) and nucleation field(Hn) with ML thickness, respectively. Nucleation (Hn) is defined as the critical applied field to reverse magnetization in a medium after saturation and means a shoulder point of a MH loop. The two magnetic properties show the similar trends, parabolic curve shape.

The thickness of the ML which shows the maximum nucleation field is always thinner than that of the ML which shows maximum coercivity.

This may be due to the following reason. As the ML increases, exchange interaction decreases. As the exchange interaction decreases, the magnitude of nucleation field slightly decreases and exchange slope rapidiy decreases. Therefore, coercivity could

increase up to certain thickness.
It should be pointed out that roundness of shoulder points in MH loop must be associated with existence of small grains which are affected by thermal agitation at room temperature.
Read/Write characteristics of media with various nucleation fields and exchange slopes will be studied to improve S/N ratio in ultra high density recording region.

4.Conclusion

As ML thickness increases, the Ms drastically increases at thinner thickness and gradually increases with further increase in thickness from 25nm. This Ms increase behaviour is connected with the reduced contribution of amorphous-like reacted layer by intermixing between CoCrPt and Ti at a CoCrPt /Ti interface and the enhancement of Cr segregation in CoCrPt films with the increase of ML thickness.
Also, it was found that change of Cr segregation mode may be linked with the residual stress by the expansion of lattice parameter a and c.
Finally, magnitude of the exchange coupling which is correlated with the change of Cr segregation mode with ML thickness is one of the important parameters that determine the magnitude of the nucleation field at room temperature.

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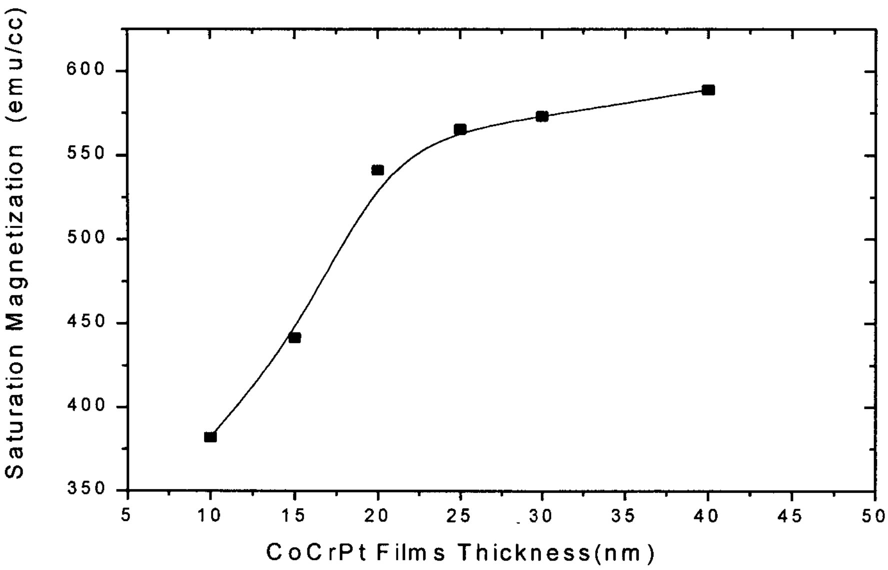
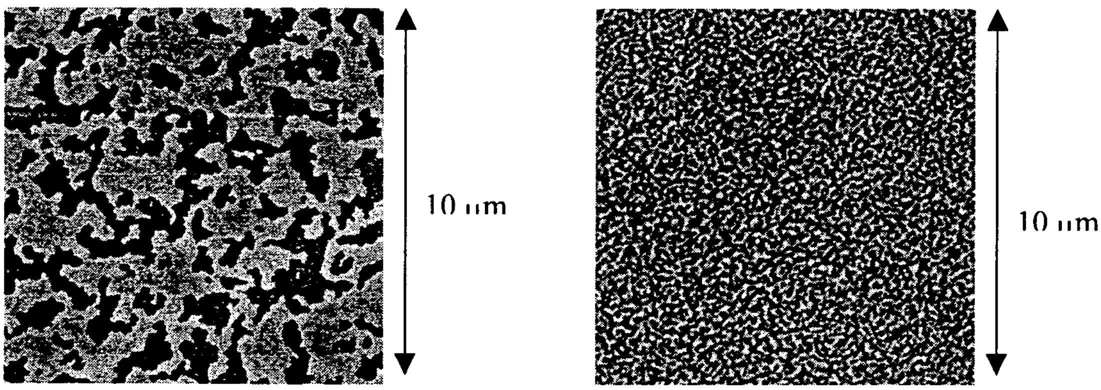


Fig.1.Saturation Magnetization(Ms) of $CoCr_{16.3}Pt_{13.6}/Ti/Co_{50}Zr_{50}$ as a function of CoCrPt layer thickness



(a) CoCrPt :10nm d = 0.625 μm

(b) CoCrPt :20nm d = 0.125μm

Fig.3 Magnetic domain structures of CoCr16.3Pt13.6/Ti(20nm)/Co50Zr50(20nm) measured by MFM . Scan size : 10 μm×10 μm

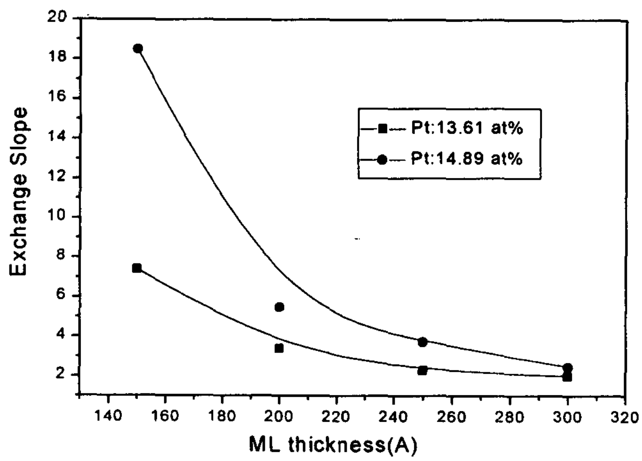
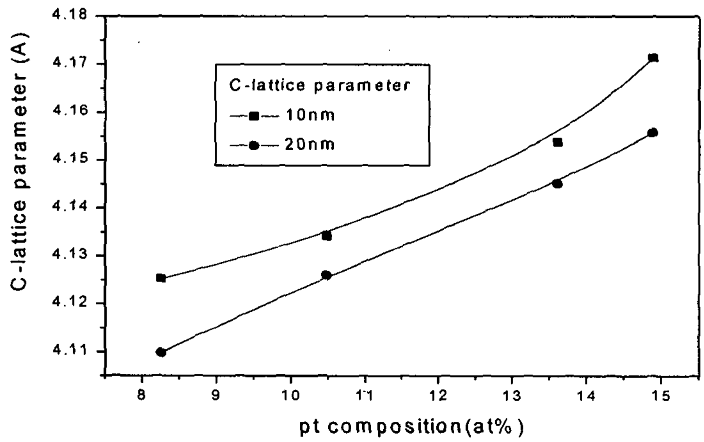
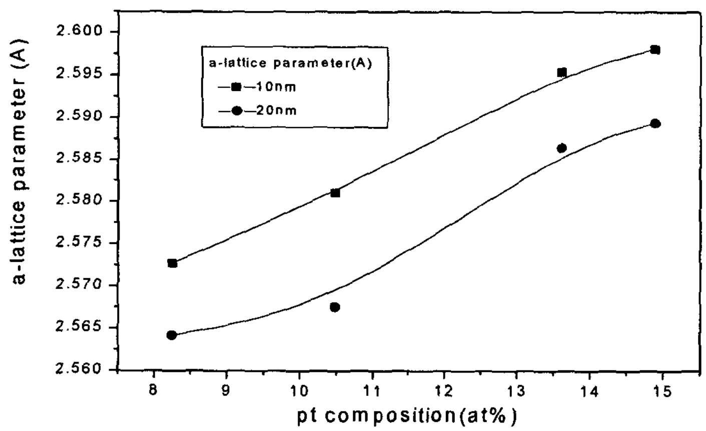


Fig.4. Change of exchange slope with the ML thickness.

Exchange slope is defined as $4\pi Ms/(Hc\text{-}Hn)$.



(a) lattice parameter c



(b) lattice parameter a

Fig.5. Variation of CoCrPt lattice parameters c and a with Pt content.

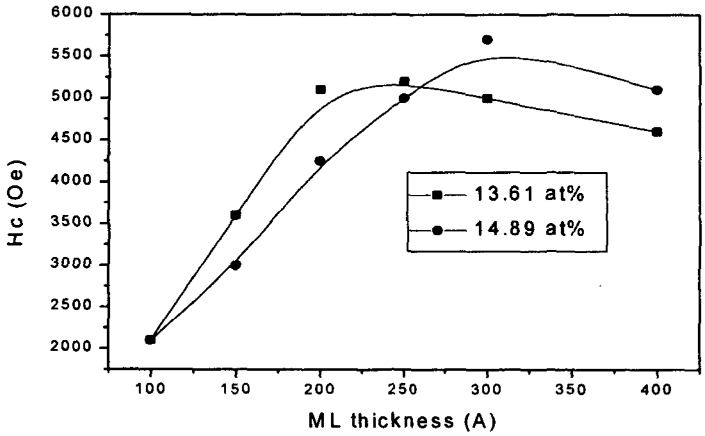


Fig.6. Change of coercivity (Hc) with the ML thickness for two Pt compositions(13.61at%,14.89at%)

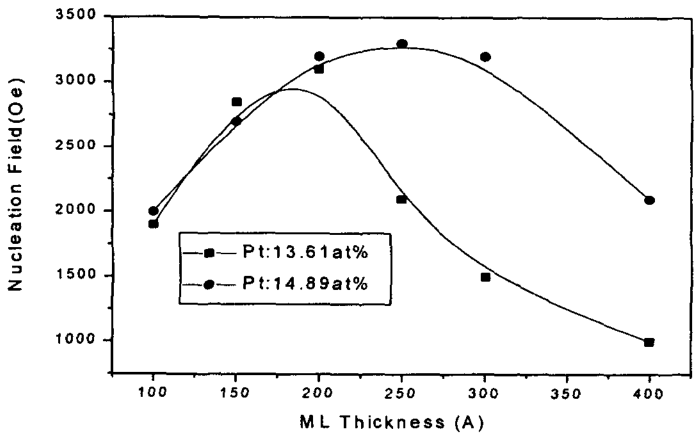


Fig.7. Change of nucleation field (Hn) with the ML thickness for two Pt compositions(13.61at%,14.89at%)