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Effects of Magnetic Layer Thickness on Magnetic Properties of CoCrPt/Ti/CoZr Perpendicular Media

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Change of magnetic properties in CoCrPt/Ti perpendicular media with varying CoCrPt film thickness has been studied. As the CoCrPt film thickness increases from 25 nm, the Ms (saturation magnetization) increases rapidly at first and then more gradually. This Ms behavior is associated primarily with the formation of an "amorphous-like" reacted layer created by intermixing of CoCrPt and Ti at the CoCrPt/Ti interface and secondarily with a change of the Cr segregation mode with varying CoCrPt film thickness. Magnetic domain structure distinctively changes with increasing CoCrPt magnetic layer (ML) thickness. Also the strength of exchange coupling measured from the slope in the demagnetizing region of the M-H loop changes with ML thickness. The expansion of lattice parameters a and c at smaller film thickness suggests that the Cr segregation mode may be connected with the residual stress of the films. Finally, the negative nucleation field (*Hn*) shows a unique behavior with the change of strength of the exchange interaction.

1. Introduction

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

2. Experiment

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

To deposit 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 (Vibrating Sample Magnetometer) at room temperature. Crystallographic orientation of the films was studied by XRD (X-Ray Diffraction) and GIXRD (Grazing Incidence X-Ray Diffraction). Cross sectional images were observed in a high resolution TEM. Magnetic domain structures were measured by MFM (Magnetic Force Magnetometer).

3. Results and Discussion

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

Fig. 2(a) and 2(b) are cross sectional images of two specimens with different thicknesses and slightly different com-

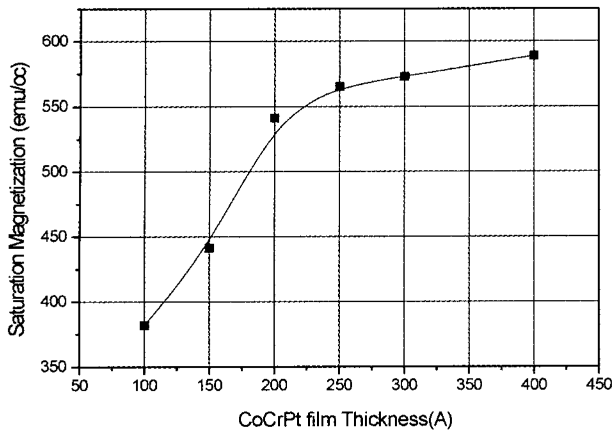


Fig. 1. Saturation Magnetization (Ms) of $CoCr_{16.3}Pt_{13.6}/Ti/Co_{50}Zr_{50}$ as a function of CoCrPt layer thickness.

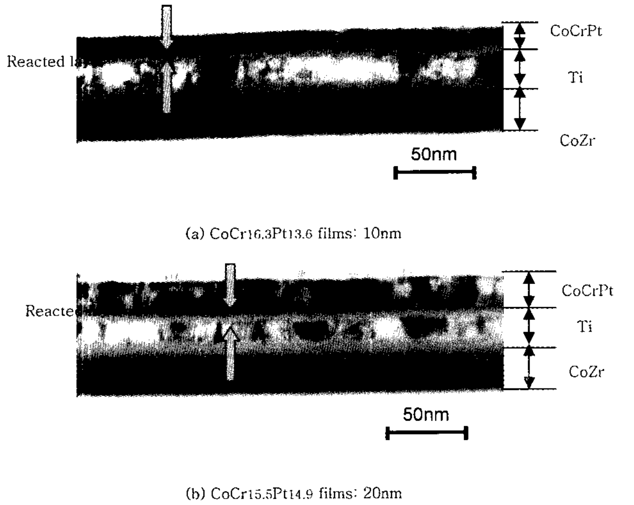


Fig. 2. Cross sectional TEM iamges of the two thin film-sCoCrPt/Ti(20 nm)/CoZr(20 nm)/glass.

positions. They show the existence of an "amorphous-like" reacted layer which was formed by intermixing of Ti and CoCrPt at the CoCrPt/Ti interface [4]. Exact magnetic properties of this reacted layer are not known. It must have a very low magnetization value. The higher *Ms* behavior with the increase of ML thickness is partially associated with the reduced contribution of this reacted layer.

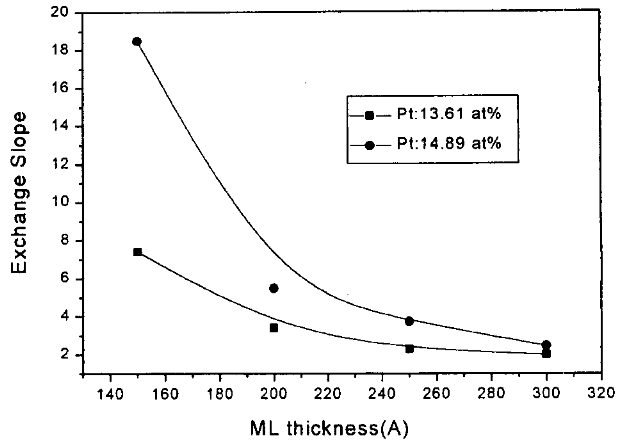


Fig. 4. Change of exchange slope with ML thickness. Exchange slope is defined as 4 $\pi Ms/(Hc\text{-}Hn)$.

Fig. 3(a) and 3(b) are the magnetic domain structures of $CoCr_{16.3}Pt_{13.6}/Ti/Co_{50}Zr_{50}$ in the ac erased state measured by MFM. As the ML thickness increases from 10 nm to 20 nm, domain patterns clearly change and domain size drastically decreases from 0.625 mm to 0.125 mm. Sometimes, the 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 the exchange slope in M-H loop as seen in the following. The enhancement of Cr segregation with the increase of the CoCrPt thickness has a 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 $4\pi\ Ms/(Hc\text{-}Hn)$ and represents the strength of the exchange coupling between adjacent grains in perpendicular CoCrPt films. The exchange slope drastically decreases with the increase of ML thickness in the films with the two Pt compositions. As the 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 a $CoCr_{19}$ alloy target. The lower exchange slope at larger thicker magnetic layer thickness is due to the

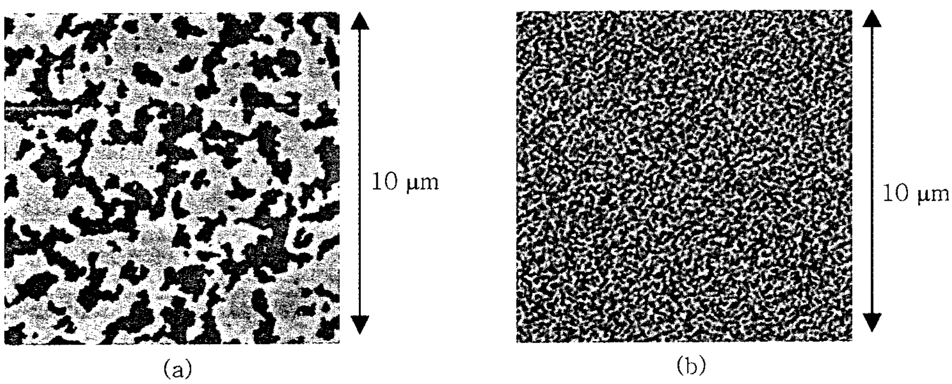
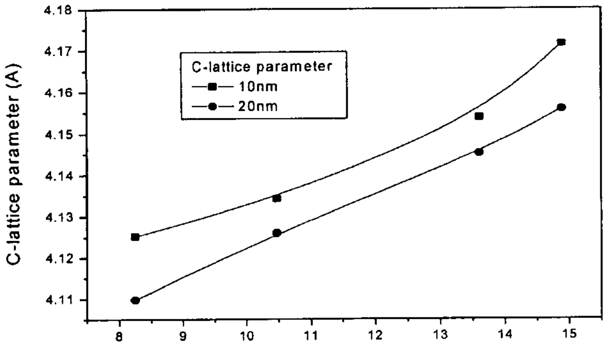
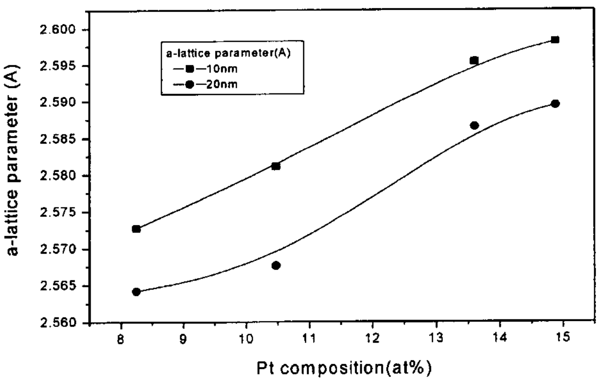


Fig. 3. Magnetic domain structures of $CoCr_{16.3}Pt_{13.6}/Ti(20\ nm)/Co_{50}Zr_{50}(20\ nm)$ measured by MFM. Scan size : $10\ \mu m \times 10\ \mu m$.



(a) lattice parameter c



(b) lattice parameter a

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

enhancement of Cr segregation as the magnetic layer thickness increases.

X-Ray diffraction characteristics of CoCrPt films of two different thickness (10 nm, 20 nm) were studied. The variation of CoCrPt lattice parameters c and a with Pt content is shown in Fig. 5. Fig. 5(a) and Fig. 5(b) are measured by a conventional XRD and a GIXRD (Grazing Incidence X-Ray Diffractometer, λ=1.631 A, α=0.74), respectively. As shown in Fig. 5, lattice parameters c and a are expanding with increasing Pt content.

This is a well known fact [5]. Also, 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 the Cr segregation mode of CoCrPt films may be associated with residual stress by lattice expansion.

In the 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 thick-ness, respectively. Nucleation field (*Hn*) is defined as the critical applied field to reverse magnetization in a medium after saturation and means the shoulder point of an M-H loop. The two magnetic properties show similar trends with parabolic curve shape.

The thickness of the ML which shows the maximum nucleation field is always less than that of the ML which shows

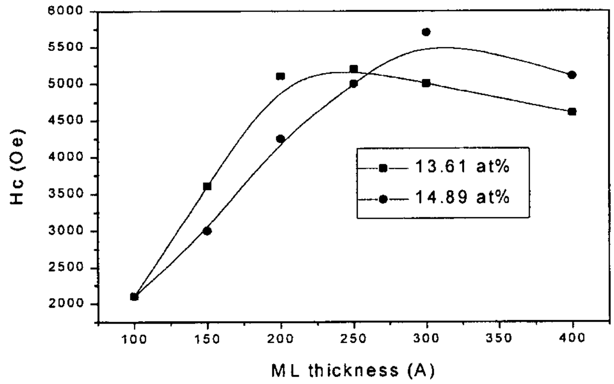


Fig. 6. Change of coercivity (Hc) with ML thickness for two Pt compositions (13.61 at%, 14.89 at%)

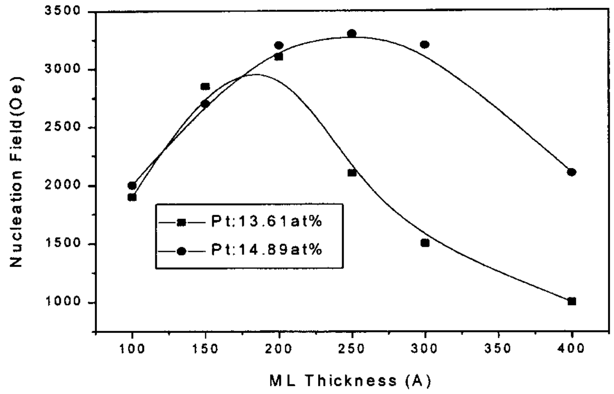


Fig. 7. Change of nucleation field (*Hn*) with ML thickness for two Pt compositions (13.61 at%, 14.89 at%).

maximum coercivity. This may be for the following reason: As the ML increases, the exchange interaction decreases. As the exchange interaction decreases, the magnitude of the nucleation field slightly decreases and exchange slope rapidly decreases. Therefore, coercivity can increase up to a certain thickness.

It should be pointed out that roundness of the shoulder points in the M-H loops must be associated with the existence of small grains which are affected by thermal agitation at room temperature.

4. Conclusion

As ML thickness increases from 25 nm, *Ms* at first drastically increases and then gradually increases with further increase in thickness. This *Ms* increase behavior is connected with the reduced contribution of an amorphous-like reacted layer caused by intermixing between CoCrPt and Ti at the CoCrPt/Ti interface, and by the enhancement of Cr segregation in CoCrPt films with increasing ML thickness.

Also, it was found that change of Cr segregation mode may be linked with the residual stress by the expansion of lattice parameters a and c.

Finally, the 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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