OPTIMISATION OF CoNi/Pt MULTILAYERS COMPARED WITH Co/Pt MULTILAYERS FOR THERMOMAGNETIC WRITING

Q. Meng, D. M. Donnet, P. J. A. van Schendel, J. C. Lodder and Th. J. A. Popma
MESA Research Institute, University of Twente, P. O. Box 217, 7500 AE, Enschede, The Netherlands

Abstract - The optimisation of sputtered CoNi/Pt multilayers for thermomagnetic writing has been studied with relation to the layer thickness, film structures and sputtering conditions. It was found that the writing was more easily performed in CoNi/Pt multilayers than Co/Pt multilayers because of lower Curie temperature in CoNi/Pt multilayers. The films deposited at a lower Ar pressure displayed sharp magnetisation reversal that results in the sharp domain boundaries around the written domains. The films deposited at a higher Ar pressure showed the undesirable microstructures and unsuitable magnetic properties which result in the worse written domains. The large perpendicular coercivity obtained in the film deposited at higher Ar pressure is attributed to the large voids in the film.

KEYWORDS: THERMOMAGNETIC WRITING, SPUTTERING, CoNi/Pt, Co/Pt, MULTILAYERS, CURIE TEMPERATURE, KERR EFFECTS, WRITTEN DOMAINS, MICROSTRUCTURES, TEM, MFM.

INTRODUCTION

It has been reported that CoNi/Pt multilayers can provide a higher number of write/erase cycles and a higher write sensitivity for magneto-optical recording because of their lower Curie temperature compared with Co/Pt multilayers [1]. Previously, we reported upon the CoNi and Pt layer thickness dependence of magnetic properties, especially the Curie temperature in CoNi/Pt multilayers [2]. The optimum CoNi and Pt layer thicknesses have been determined from an MO application point of view. Effects of Pt seedlayer and Ar sputtering pressure have also been studied [3]. In this paper, the optimisation of CoNi/Pt multilayers for thermomagnetic writing will be determined with regard to the layer thickness and Ar pressure. The magnetic properties and the characteristics of the written domains will be investigated with respect to the film microstructures.

EXPERIMENTAL

CoNi/Pt and Co/Pt multilayers were prepared by magnetron sputtering using Ar gas. The individual layer thicknesses were estimated by the product of the deposition time and the deposition rates which were determined by XRD measurements with the films deposited at different Ar pressures. The magnetic properties were measured using a VSM and a Kerr spectrometer. The samples used for thermomagnetic writing and TEM measurements were deposited on Si$_3$N$_4$ membrane windows (40 nm) which were prepared using the method as reported in [4].

Thermomagnetic writing was carried out using the laser power modulation method as reported in [5]. The laser beam (λ = 780 nm) was focused on the film through the Si$_3$N$_4$ window. A permanent magnet was placed behind the film providing a constant magnetic field. The written domains were imaged by Lorentz microscopy and MFM.

RESULTS AND DISCUSSION

Fig. 1 shows a cross sectional TEM image of a Co$_{0.5}$Ni$_{0.5}$/Pt multilayer that was deposited on Si substrate at Ar pressure, $P_{Ar}=1.6 \times 10^{-2}$ mbar. It clearly shows the individual layers which are parallel to the substrate surface. At the bottom, the layers are smooth and flat due to the smooth and flat surfaces of the substrate and Pt seedlayer. However, as the film was growing, the curvature of the layers and columnar structures were formed. Such layer curvature and columnar structures are important to dominate the magnetic properties of the film, which are even pronounced in the films deposited at the relatively higher Ar pressures [6].

Fig. 1. A cross sectional TEM picture of a Co$_{0.5}$Ni$_{0.5}$/Pt multilayer with a composition of Si/11 nm Pt/[26.3 Å CoNi/16.5 Å Pt]×11, deposited at $P_{Ar}=1.6 \times 10^{-2}$ mbar.

As an example, Fig. 2 (a) shows the written domains in a Co$_{0.5}$Ni$_{0.5}$/Pt multilayer (sample I) which were written by different laser powers from 2.5 mW to 10 mW. As expected, the domain size decreases with decreasing the laser power [5]. However, in a high resolution MFM image (Fig. 2 (b)), the subdomains are clearly observed outside and inside the written domains. The subdomains were formed due to a type
of domain nucleation process [7] because of numerous domain nucleation centres in this particular film that was deposited at a higher Ar pressure of $4.0 \times 10^2$ mbar. Such type of domain nucleation process results in a typical magnetisation hysteresis loop as shown in Fig. 2 (c). The reversal curve reveals that the domains reversed slowly and hardly with increasing the magnetic field that results in a poor squareness ratio, i.e. $M_r/M_s<1$ and a large saturation field, $H_s$. During the thermomagnetic writing, the subdomains were not completely reversed due to its high saturation field $H_s$ even though under a higher temperature and a higher magnetic field (50 kA/m). Thus, the subdomains remained inside the written domain and caused the irregular domain boundary around the written domain. Such irregularity of domain structures will cause the readout noise, which is not desirable for MO application. Therefore, a 100% squareness ratio i.e. $M_r/M_s=1$ and a lower $H_s$ are required in order to avoid the existence of subdomains. As previously reported [2, 3], the films deposited at lower Ar pressure showed the improved squareness but the coercivity, $H_c$ is lower. The coercivity can be increased with thinner individual Pt layers and a thicker Pt seedlayer. However, Pt seedlayer should be not too thick because the writing and TEM measurements are performed through the Si$_3$N$_4$ window and Pt seedlayer. Furthermore, by lowering number of bilayers, $H_s$ can be lowered so that the rectangular ratio, $H_s/H_c$ of the hysteresis loop can be improved [8]. Thus, by taking into account all those factors, a sample of Co$_{0.8}$Ni$_{0.6}$/Pt multilayer (sample II) with a composition of [6Å CoNi/5Å Pt]$\times 10$ was prepared at $P_A=1.6 \times 10^2$ mbar and on a Pt seedlayer of 10 nm. This film exhibits a desired magnetisation hysteresis loop with $M_r/M_s=1$, and $H_s/H_c\sim 1$ as shown in Fig. 3 (a), which results in a homogeneously written domain with a sharper boundary as shown in Fig. 3 (b). The sharp magnetisation reversal is attributed to the rapid propagation of domain walls which formed at a few domain nucleation centres [7-9]. On the other hand, it is worthy to be noted that a small magnetic field of 15 kA/m was applied to get such good written domains. Such a low magnetic field is important to realise the direct overwriting with the magnetic field modulation recording mode, which is important to achieve a high data transfer rate for the practical MO application [10].
For a comparison, a Co$_{0.4}$Ni$_{0.6}$/Pt multilayer (sample III) with the same composition as Sample II, was deposited at $P_A=4.0 \times 10^{-2}$ mbar. As shown in Fig. 4, the shape of the hysteresis loop of this film is completely different from that of Sample II, but quite similar to that of Sample I. The written domains can be expected to be similar to the domain as shown in Fig. 2 (b). The difference in magnetic properties between the samples II and III is attributed to the difference in microstructures, which will be discussed later. The higher $H_e$ and $H_u$ in sample III compared with the sample I are attributed to the thinner Pt individual layers and the thicker Pt seedlayer [2, 3].

As for a comparison between CoNi/Pt and Co/Pt multilayers, Co/Pt multilayers were prepared using the same sputtering system under the same conditions. Fig. 5 shows Kerr loops of two Co/Pt multilayers (samples IV and V) which were deposited at $P_A=1.6 \times 10^{-2}$ and $4.0 \times 10^{-2}$ mbar, respectively. Their layer thicknesses were designed to be the same as CoNi/Pt multilayers (samples II and III). These two Co/Pt multilayers exhibit larger coercivity than that of CoNi/Pt multilayers, which is attributed to the large perpendicular anisotropy in Co/Pt multilayers as measured by a torque magnetometer.

The writing performance on these two Co/Pt multilayers has been tested. However, no significant written domains can be observed. It seems that the writing power used for CoNi/Pt multilayers, e.g. 10 mW, is not high enough for Co/Pt multilayers because they have higher Curie temperatures as shown in Fig. 6. When a higher power, e.g. 15 mW was used, the Co/Pt specimen seems to be melted as observed by an optical microscope. This implies that the writing temperature was too high when the laser power is higher than 15 mW. Therefore, it is important to have a lower Curie temperature to be suitable for a lower laser power writing.

As for a study on the correlation between grain and domain structures, the grain structure was observed by TEM. Fig. 7 shows the grain structure of Co/Pt multilayers (samples IV and V). The film deposited at the lower Ar pressure (Sample IV) shows a dense grain structure, whilst the film (Sample V) deposited at the higher pressure shows large voids (indicated by an arrow as an example) between the grains. Such different structural characteristics dominate the difference in the magnetic properties (see Fig. 5). The inhomogeneity, especially the voids in the film act as the domain nucleation centres or domain wall pinning centres. Thus, when there are a large amount of such nucleation centres in the film, the nucleation process mainly dominates the slow and hard magnetisation reversal so that a large coercivity was obtained [11]. However, the film with numerous voids is not desirable for MO recording because the voids contribute to the media noise [11]. The formation of large voids at high Ar pressure is attributed to the lower mobility and the shadow effect of the oblique incidence deposition of sputtered atoms due to the large number of collision [12]. The lower mobility of deposited atoms on the substrate surface at higher Ar pressures could be also caused by lower energy.
bombardment of reflected Ar neutrals which energy was reduced due to the large number of collision [12].

It is worthy to be remarked that Sample V shows an extremely large perpendicular coercivity, as much as 424 kA/m (see Fig. 5 (b)), which is one of the important parameters for the perpendicular magnetic recording. On the other hand, it also provides a possibility to obtain a large coercivity for the longitudinal magnetic recording. That is to prepare the magnetic thin films at a relatively higher Ar pressure to achieve a magnetically decoupled grains.

In addition, the Kerr spectra of the samples II, III, IV and V are shown in Fig. 8. The magnitude of Kerr rotation of the Co/Pt multilayers is larger than that of CoNi/Pt multilayers due to the higher magnetisation in Co/Pt multilayers. The Kerr rotation of the films deposited at the lower Ar pressure is larger than that of the films deposited at the higher Ar pressure. This difference is attributed to the changes of the polarisation of Pt due to the changes in the microstructures, such as the formation of voids and alloying layers at the interfaces between Co(Ni) and Pt layers [13]. On the other hand, the reflection from the Si substrate could contribute to such difference because the films in Fig. 8 are thinner than the Kerr information depth [14].

CONCLUSION

Thermomagnetic writing can be more easily performed in CoNi/Pt multilayers due to their lower Curie temperature. A 100% squaringness ratio, a sufficiently large coercive field and a small saturation field are required to achieve the regularly written domains with sharp domain boundaries and high stability. The films deposited at higher Ar pressure were not desirable for MO recording because they showed the less dense grain structure that results in the poor quality of written domains although their magnetic coercive fields are larger.

ACKNOWLEDGEMENT

The authors thank S. Porthun and L. Abelmann for their MFM measurements, and M. A. M. Haast for his work on the sample preparation and Kerr measurements.

REFERENCES