Abstract

With the increase in recording density and capacity of hard-disk drives (HDD), high speed, high precision and low cost servo writing method has become an issue in HDD industry. The magnetic printing was proposed as the ultimate solution for this issue [1] [2] [3]. There are two types of magnetic printing methods, which are ‘Bit Printing (BP)’ and ‘Edge Printing (EP)’. BP method is conducted by applying external field whose direction is vertical to the plane of both master disk (Master) and perpendicular magnetic recording (PMR) media (Slave). On the other hand, EP method is conducted by applying external field toward down track direction of both master and slave. In BP for bit length shorter than 100 nm, the SNR of perpendicular anisotropic master was higher than isotropic master. And the SNR of EP for the bit length shorter than 50 nm was demonstrated.

Keywords: Hard disk drive; magnetic printing; servo track writing; perpendicular magnetic recording media

1. Introduction

With the increase in recording density and capacity of HDD, high speed, high precision and low cost servo writing method has become an issue in HDD industry. The magnetic printing was proposed as the ultimate solution for this issue [1] [2] [3]. There are two types of magnetic printing methods, which are BP and EP. BP method is conducted by applying external field whose direction is vertical to the plane of both master and slave. On the other hand, EP method is conducted by applying external field toward down track direction of both master and slave. Sheeda et al. reported that the peak-to-peak value of MFM of the magnetic printed media using CoPt (Pt 20 at.% )
perpendicular magnetic anisotropic master was larger than the one using FeCo isotropic master in the bit length range of wider than 100 nm [4]. However, the experiment of BP for tens nm of bit length which is an essential requirement for servo signal to support 500 Gbit/in² could not be found. In this paper, BP characteristics for bit length shorter than 100 nm using masters with the perpendicular magnetic anisotropy and EP characteristics for the bit length shorter than 50 nm are discussed.

2. Experimental

Fig. 1 shows the schematic diagram of cross section of a master. A master with line and space pattern was fabricated by sputtering of magnetic layer on a nickel substrate. In this study, BP used CoPt (Pt 10 at.%) and FeCo (Co 30 at.%) as the master magnetic layer material. Fig. 2 shows the schematic diagram of perpendicular hysteresis loops of CoPt and FeCo. The optimum external field intensity of BP is generally around the coercivity of the slave [5]. In case that the coercivity of slave is about 5000 Oe, magnetic printing characteristic is improved by using CoPt because the magnetization value of CoPt is larger than that of FeCo. The bit length ranged from 52 nm to 100 nm.

And EP used FeCo (Co 30 at.%) as the master magnetic layer material because the direction of external field is parallel to the plane of both master and slave. CoPt is not suitable for EP, because the saturation magnetization of CoPt is lower than that of FeCo and its perpendicular magnetic anisotropy prevents its magnetic saturation toward in-plane direction. The bit length was less than 50 nm. Fig. 3 shows schematic diagram of BP process. The slave initialization was done applying external field (Hi) of 10000 Oe (a). In the subsequent printing process, a slave was contacted with a master and 4000 to 5900 Oe of magnetic field (Ha) was applied (b). Magnetization reversal occurs at the line portion of the master by the Ha (upper arrow). Fig. 4 shows schematic diagram of EP process. In EP, initialization process can be skipped. A slave was contacted with a master same as BP and 7000 to 9000 Oe of Ha was applied. The magnetic patterns with both polarities are printed at the same time by the Ha.
3. Results and discussion

Fig. 5 shows signal to noise ratio (SNR) of BP for 55 nm bit length pattern as a function of Ha. The maximum SNR for CoPt and FeCo master was 11.7 dB at Ha 4400 Oe and 9.3 dB at Ha 5600 Oe respectively. In case that the intensity of Ha was lower than optimum Ha, the SNR was decreased by the lack of magnetic flux at the line portion of master. On the other hand, in case that the intensity of Ha was higher than optimum Ha, the SNR was also decreased by the leakage of magnetic flux from the space portion of the master. The SNR of CoPt was 2.4 dB higher than FeCo and the optimum Ha was lower than FeCo by 1200 Oe. This is caused by magnetic flux concentration on the master line portion due to the perpendicular magnetic anisotropy of the CoPt magnetic layer. Fig. 6 shows SNR as a function of bit length for CoPt and FeCo master at each optimum Ha. The SNR of CoPt was higher than FeCo through all the range of bit length and the SNR delta between CoPt and FeCo became larger in the shorter bit length below 60 nm. The recording field gradient at the edge of the line portion of the CoPt master was larger than that of FeCo [6]. This is probably due to the difference of the recording field gradient between CoPt and FeCo. The master with perpendicular magnetic anisotropic layer is essential to the good SNR on BP with the bit length below 60 nm.
While the waveform of BP is compatible with head write waveform, EP waveform is incompatible and drive side special care for servo signal demodulation is needed. EP has a merit that it does not require anisotropic magnetic layer on master and can obtain better SNR than BP even in the bit length range shorter than 50 nm.

Fig. 7 shows SNR of EP for 48 nm bit length pattern as a function of Ha. The SNR is insensitive in this range of Ha. The result was probably due to that the magnetization of slave was saturated even at Ha 7000 Oe. Fig. 8 shows the SNR of EP (FeCo) in the 40～65 nm bit length range with BP (CoPt) reference data used in Fig. 5. The reason why the SNR of EP was higher than the extrapolation curve of BP is that in-plane Ha generates the same level of very sharp perpendicular magnetization at the edge of the line and prints the different polarities of signal at the same time [7]. The SNR value over 13 dB was obtained up to 44 nm bit length.

4. Summary

In this study, BP characteristics of CoPt master with perpendicular magnetic anisotropy and FeCo conventional isotropy master were compared. The optimal printing field of CoPt was lower than FeCo and 2.4 dB high SNR obtained on CoPt master. The SNR capability of EP with the bit length shorter than 50 nm was demonstrated and it was found that distinct magnetic printing was obtained even at the 40 nm bit length.

References