Nonlinear Transition Shift in the Combination of Single-layered Perpendicular Recording Medium and Ring Head

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Abstract — Nonlinear transition shifts (NLTS) in the combination of single-layered perpendicular recording media and ring head writing are investigated by read/write experiments employing the fifth harmonic elimination method. The NLTS of single-layered perpendicular recording medium can be kept at the low level at high linear recording density. The NLTS smaller than 10 % is observed at 300 kFCI for a 25 nm thick CoCrPt perpendicular recording medium. Decreasing the medium thickness improves the NLTS.

Key Words : Nonlinear transition shift, single-layered perpendicular magnetic recording medium, ring head

I. INTRODUCTION

The reduction of nonlinearities of recorded states coming from the writing process, such as nonlinear transition shift [1-3] is very important to increase the recording density of hard disk drives. Although the write compensation is useful to extend the usable linear recording density [4], it is desirable to employ the recording system which has small nonlinearities.

Perpendicular magnetic recording has a high potential in increasing the recording density [5,6]. It seems also possible by employing the perpendicular recording to extend the areal density growth while avoiding the thermal fluctuation problem and the excessive coercivities which will limit the attainable recording density with longitudinal recording media [7,8].

The NLTS for the combination of double-layered perpendicular recording medium and single-pole type recording head has been reported to be low at 318 kFCI [9]. On the other hand, the NLTS has not been systematically investigated for the combination of single-layered perpendicular recording medium and ring head recording, though the high potential for increasing the areal density was well studied [10-13].

In the present work, we investigate the NLTS in the combination of single-layered perpendicular recording media and ring head writing by read/write experiments. The NLTS characteristics are compared with those measured for a longitudinal recording medium.

II. EXPERIMENTAL PROCEDURES

The NLTS was measured by fifth harmonic elimination method [14] using two ring heads for writing and a magneto-resistive (MR) head for reading. The track width, the upper pole thickness and the gap length of the one ring

head were 7.0, 3.2 and 0.4 μm , respectively. Those of the other ring head were 3.5, 4.4 and 0.4 μm , respectively. The track width and the gap length of the MR head were 2.6 and 0.35 μm , respectively. The rise-time of the write current for the ring heads was about 10 ns. The dependencies of NLTS on linear recording density were measured for both perpendicular and longitudinal recording media under similar experimental set-up conditions.

Two CoCrPt perpendicular media with the respective magnetic layer thicknesses of 25 and 50 nm were fabricated employing Si substrates and the $\text{CoCr}_{35}/\text{TiCr}_{10}$ dual-underlayers [13]. A CoCrPt longitudinal magnetic recording medium was also prepared for comparison on a NiP/Al substrate with a CrTi/Cr underlayer. The magnetic properties of these media are shown in Table 1. The perpendicular and the longitudinal media are designated as medium A (PM), medium B (PM) and medium C (LM), respectively as shown in the table.

Before measuring the NLTS by fifth harmonic elimination method, it is necessary to check if the reproduced output is represented by the output calculated from the superposition of isolated wave form. The examples of recording density dependencies of reproduced output of the medium A (PM), the medium B (PM) and the medium C (LM) are shown in Fig. 1(a), (b) and (c), respectively. It is clear that the superposed wave form is almost same with the reproduced output for each cases. Thus it is equally possible to measure the NLTS by utilizing the fifth harmonic elimination method for the present recording systems.

III. RESULTS AND DISCUSSION

The dependencies of NLTS at 200 kFCI and overwrite on write current for the ring head measured for the perpendicular recording media A (PM), B (PM) and the longitudinal recording medium C (LM) are shown in Fig. 2 (a), (b) and (c), respectively. The ring head of which the

Table 1. Magnetic properties of media.

	Magnetic layer (nm)	Ms (emu/cm ³)	Hc($\perp$) (Oe)	Hc($\parallel$) (Oe)
A (PM) CoCrPt	50	470	2900	250
B (PM) CoCrPt	25	465	3050	300
C (LM) CoCrPt	18	336	—	2270

Fig. 1. Dependencies of reproduced output on linear recording density.
 (a) Perpendicular medium A (PM).
 (b) Perpendicular medium B (PM).
 (c) Longitudinal medium C (LM).

Fig. 2. Dependencies of NLTS at 200 kFCI and overwrite on write current.
 (a) Perpendicular medium A (PM).
 (b) Perpendicular medium B (PM).
 (c) Longitudinal medium C (LM).

upper pole thickness is 3.2 μm was employed. Here, the overwrite for the media A (PM) and B (PM) is defined as the attenuation of 160 kFCI signal overwritten by 45 kFCI signal. On the other hand, the overwrite for the medium C (LM) is defined as the attenuation of 45 kFCI signal overwritten by 160 kFCI signal. The overwrite better than 30 dB is performed at the write current which gives the lowest NLTS on respective medium.

The dependencies of NLTS on linear recording density measured for the perpendicular media A (PM), B (PM) and the longitudinal medium C (LM) are shown in Fig. 3. The write currents for the ring head were set at the optimum values which gave the lowest NLTSs at 200 kFCI for these media. The head-medium relative velocity and the head-medium magnetic spacing were 4 m/s and 65 nm, respectively. The NLTSs of the media A (PM) and B (PM) are lower than that of the medium C (LM) at high linear recording densities greater than 180 kFCI, though the medium A (PM) is far thicker than the medium C (LM). When the NLTS of perpendicular medium is compared between A (PM) and B (PM), the NLTS of the medium B (PM) of which thickness is one half of that of medium A (PM) is lower than that of the thicker medium A (PM). This is probably because that the gradient of write head magnetic field effectively becomes sharper for the thinner perpendicular medium B (PM).

Then, the NLTS is compared between the perpendicular recording medium B (PM) and the longitudinal recording medium C (LM) for the linear recording densities up to 300 kFCI. Here, the ring head with the upper pole thickness of 4.4 μm was employed and the head-medium magnetic spacing was reduced down to 40 nm by setting the head-medium relative velocity to be 2.5 m/s. The dependencies of NLTS at 200 kFCI and overwrite on write current of ring head measured for the perpendicular recording medium B (PM) and the longitudinal recording medium C (LM) are shown in Fig. 4 (a) and (b), respectively. Good overwrite properties are assured for the currents which give the lowest NLTS.

Fig. 3. Dependencies of NLTS on linear recording density.

Fig. 4. Dependencies of NLTS at 200 kFCI and overwrite on write current.

(a) Perpendicular medium B (PM).
(b) Longitudinal medium C (LM).

Fig. 5. Dependencies of NLTS on linear recording density.

Figure 5 shows the recording density dependencies of NLTS. The head-medium magnetic spacing was set at 40 nm by setting the head-medium relative velocity at 2.5 m/s. The NLTS of medium B (PM) is kept below 10 % at the recording density region investigated for the experimental condition. The NLTS of medium C (LM) at 200 kFCI decreased from 11 to 4 % by employing the write head with the thicker upper pole and by decreasing the head-medium spacing from 65 to 40 nm, as can be seen by comparing the data shown in Fig. 3 and 5. Although it is difficult to separate the contributions of the gap length reduction, the magnetic spacing reduction and the head-medium relative velocity reduction on the decrease of NLTS from these results, the drastic decrease in NLTS is possibly due to the increase in the magnetic field gradient of write head. However when the linear recording density was increased from 200 to 300 kFCI, the NLTS of medium C (LM) increased drastically up to 18 % even at the reduced spacing of 40 nm.

On the other hand, when the linear recording density is increased from 200 to 300 kFCI, the NLTS of medium B (PM) does not increase so much as the case of medium C (LM). The reason why the NLTS dependence on linear recording density is low for the perpendicular medium compared with the case of longitudinal recording medium could be related to the effect of demagnetization operating between the neighboring recorded bits which increases for the longitudinal recording as the linear recording density increases. This behavior of perpendicular recording seems to be favorable to keep the NLTS at a low level at high linear densities.

Though the perpendicular component of magnetic field distribution of ring head is not so sharp as that of single-pole type head combined with a double-layered perpendicular medium, the low NLTS values observed for the single-layered perpendicular medium at high linear recording densities were confirmed for the single-layered perpendicular medium and ring head writing combination. Thus, the combination is considered to be suitable for high density recording applications from the NLTS viewpoint, though a further research is necessary to clarify the mechanism of magneto static interaction, the detailed relationship between the rise-time of write current and NLTS, and the influence of other factors such as partial erasure [15].

IV. CONCLUSIONS

Nonlinear transition shifts (NLTS) in the combination of single-layered perpendicular recording media and ring head writing has been investigated by read/write experiments. The NLTS of this combination can be kept at levels smaller than 10 % at 300 kFCI. The increase in NLTS with increasing linear recording density has been shown to be far lower than the case with a longitudinal

recording medium. Decreasing the magnetic layer thickness of perpendicular medium to some extent is effective to decrease the NLTS.

These results show that the single-layered perpendicular recording medium and ring head writing combination is suitable for the application of high density magnetic recording.

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