PERPENDICULAR RECORDING BY A NARROW TRACK SINGLE POLE HEAD

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Abstract - The feasibility of high track density recording in a perpendicular magnetic recording system has been investigated. The properties of the magnetic field of a single pole type (SPT) head having a narrow track width were studied by using a large scale model of a head and a medium. The y-field gradient of the SPT head near the track edge is steeper than the x-field gradient of a ring head, and it was confirmed by Bitter technique that the recorded track width accurately coincides with the width of the main pole of the SPT head. Perpendicular recording using the SPT head also has superior off-track characteristics and the crosstalk signal is hardly detected even at very narrow track pitches. From a magnetics point of view, no problems exist in narrowing the track width of the SPT head in perpendicular recording. Narrow track recording and reproducing with SPT head of only 6.5 μm in track width could be achieved with sufficient signal to noise ratio in perpendicular flexible disk systems.

1. INTRODUCTION

In perpendicular magnetic recording with a single pole type (SPT) head driven by an auxiliary pole and a double layered medium having a soft magnetic layer underneath a perpendicular anisotropic Co-Cr layer, the recording and reproducing of signals at very high linear densities over 200 kBPI have been achieved [1]. To increase the stored information per unit area of the magnetic recording medium, not only the linear density but also the track density should be increased. From a viewpoint of a simple geometrical strucure of the head, it is expected that a high track density is easy to realize in perpendicular recording using an SPT head.

Recently, a theoretical analysis on the crosstalk in perpendicular recording has been carried out by S.B. Luitjens and A.van Herk [2], and it was reported that perpendicular recording using an SPT head and double layered medium with soft magnetic layer has superior crosstalk properties at high densities.

In this paper, experiments of high track density recording in the perpendicular recording system are described. The profile of the fringing field of a narrow track SPT head has been measured using a large scale model and compared with that of a scaled-up ring head. Moreover, actual SPT heads having track widths from 6.5 μm to 500 μm have been made, and the reproducing sensitivity and the crosstalk of narrow track heads have been measured.

2. MAGNETIC FIELD OF NARROW TRACK HEAD

To investigate the properties of a narrow track SPT head, the magnetic field distribution around the tip of the main pole has been measured using a large scale model. The thickness Tm of the main pole, scaled-up about 10^4 times as thick as that of the actual head, is 10 mm. The track width and length of the main pole are 150 mm x 600 mm for the relatively wide track head and 20 mm x 600 mm for the narrow track head. The material is pure iron. The strength of the magnetic field is measured by a Hall probe whose sensitive element is 3.7 mm x 3.8 mm x 1 mm in size.

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2.1 Magnetic field of SPT head

Figure 1 shows the configuration of the perpendicular field component Hy of the SPT head measured along the center line of the main pole in the transverse (Z) direction at the distance Y of 0.5 times Tm above the top surface. The origin of the coordinates is the center of the edge of the track. The configuration of the longitudinal field component Hx of the ring head which has the same gap length as the main pole thickness of the SPT head is also drawn for comparison. Although Hx of the ring head reaches its maximum at the center of the track, Hy of the SPT head increases near the edge of the track. Moreover, at the outside of the track, the gradient of Hy of the SPT head is steeper than that of Hx of the ring head. The lines of constant Hx of the ring head are spread in both the transverse and longitudinal directions. This result means that the effects of widening the recorded track and phase shift of magnetization in the transverse direction occuring in longitudinal recording [3], become very small in perpendicular recording using the SPT head.

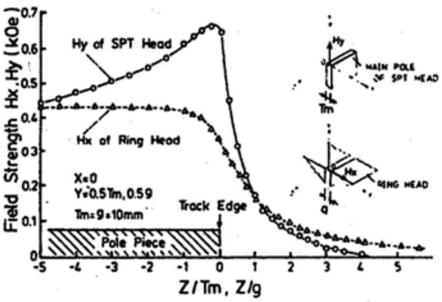


Fig.1. Comparison of magnetic field configuration of Hy for SPT head and Hx for ring head.

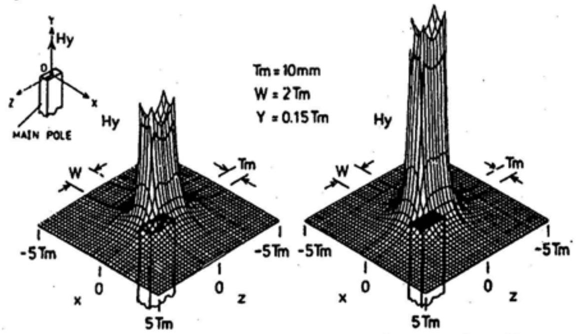
In contrast with a ring head [1], when the track width of the main pole becomes narrower, the intensity of demagnetizing field in the tip of the main pole decreases and the strength of the head field generated from the top surface is enhanced. Therefore the magneto-motive-force per unit record current and the reproduced voltage per unit track width are increased by narrowing the track width.

2.2 Influence of recording medium

It was expected that, in the SPT head, the interaction between the main pole and the recording medium is quite substantial in understanding the properties of perpendicular recording [1].

When the medium approaches the main pole, the field strength is increased by the magnetic interaction between the main pole and the medium as shown in figure 2 (b). In this measurement, a model medium which is almost the same scale up factor as the head is used. The columnar structure of a Co-Cr layer possessing perpendicular anisotropy is modeled by sticks of Fe-Co-Ni-Cr alloy (1 mm in diameter and 10 mm in length) which are packed and oriented perpendicularly to the surface of the medium.

Figure 2 (a) and (b) are the profiles of Hy of the SPT head in the absence and presence of the medium at a head-to-medium spacing of 0.2 times Tm (Y=0.2 Tm), respectively. The field from the magnetized medium acts to remarkably weaken the demagnetizing field in the tip of the main pole, and hence the main pole is strongly magnetized. Since such a magnetic interaction is restricted within the region facing the top surface of the main pole, the field distribution becomes much steeper as shown in figure 2 (b) and very sharp transitions of the magnetization in the medium can be realized in both the longitudinal and transverse directions. When the double layered medium having the soft magnetic layer underneath the Co-Cr layer is used, this tendency is enhanced and the recording and reproducing sensitivities are increased by about 10 times [5].



(a) Absence of medium (b) Presence of medium

Fig.2. Magnetic field profiles of narrow track SPT head.

2.3 Bitter pattern of actual narrow track recording

To observe the magnetizing state in narrow track perpendicular recording, the Bitter technique was used. Figure 3 is the Bitter pattern on the surface of the double layered medium after recording of NRZI all 1's signals with the auxiliary pole driven multi-track SPT head having the track pitch of 10 μm and the track width of 6.5 μm. The medium has been previously magnetized by DC field in the perpendicular derection with a wide track SPT head.

As shown in the figure, the colloidal particles adhere to both the track edge and the bit transition at almost the same concentration. The region oppositely magnetized by the narrow track head is clearly observed by a rectangle of bit length and track width. The width of the recorded track accurately coincides with the main pole width and the recorded track does not interfere with the neighboring tracks even at very narrow track pitches. This fact proves that the magnetization transition at the track edge is as sharp as that of a bit transition, as expected from the field measurement of the large scale SPT head.

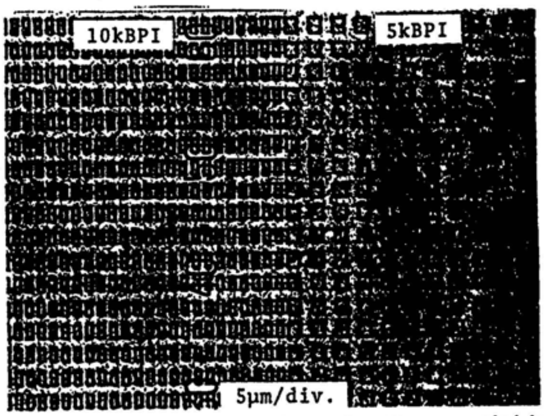


Fig.3 Bitter pattern on surface of medium recorded by SPT head having track width of 6.5μm and track pitch of 10μm.

3. REPRODUCTION WITH NARROW TRACK SPT HEAD

It was confirmed by the above results that very high track density is achievable in perpendicular recording using an SPT head. The practical limitation will be given by the signal to noise ratio in the reproducing process. It is presupposed that the amplitude of the reproduced signal decreases approximately in proportional to the track width of the head and that the crosstalk from the adjacent tracks will increase at very narrow track pitches. Therefore, the reproducing sensitivity of narrow SPT head and the off-track characteristics have been investigated.

3.1 Reproducing sensitivity

The effect of the track width on reproduced voltage has been measured over a wide range (6.5 μm ~ 500 μm) by using auxiliary pole driven SPT heads and double layered perpendicular flexible disks.

Figure 4 shows the reproduced voltage per turn of the coil wound on an auxiliary pole versus the track width of a main pole. The decrease of reproduced voltage accompanied by the decrease of the track width is more gradual than the decrease of the track width (broken line). Therefore, the narrowing of the main pole width results in an increase of the reproducing sensitivity. This fact is interpreted by the decrease of the demagnetizing field in the main pole tip, as shown by the large scale model experiments. In the figure, black circles represent the reproduced voltage of the highly sensitive main pole which is made of high permeable Co-Zr amorphous film [1],[6]. It is experimentally observed that the recording and reproducing sensitivity of the SPT head can be increased by improving the magnetic property of the soft magnetic film and the structure of the main pole.

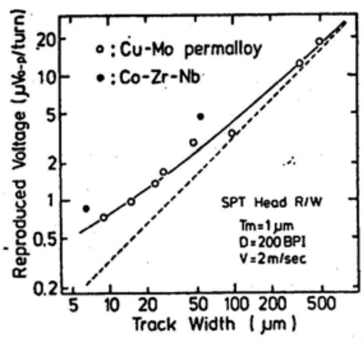


Fig.4. Reproduced voltage versus track width of main pole.

Figure 5 shows the wave form of the reproduced signal at the density of 20 kBPI by using the SPT head of 6.5 μm track width. A carrier to noise ratio of about 40 dB has been obtained even with such a narrow track [1].

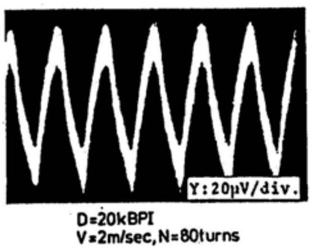


Fig.5. Reproduced wave form of SPT head of 6.5 μm track width.

3.2 Off-track characteristics

It is expected from the model experiment that perpendicular recording using the SPT head has superior off-track characteristics.

Figure 6 is the off-track characteristics for a digital signal in both perpendicular and longitudinal recordings measured with a double layered and a conventional (γ-Fe_2O_3) flexible disk. In the figure, the amplitude of the reproduced voltage is plotted for the displacement of the head in the transverse direction of the track. In longitudinal recording using a ring head, a relatively large crosstalk signal is observed at low desities as plotted by white circles in the figure. For example, when the head has been shifted off to the position at the edge of the recorded track, the crosstalk level is -26 dB below at the density of 100 BPI. The decrease of the reproduced signal due to the head displacement in perpendicular recording is quite large as compared with that of longitudinal recording, and is almost independent of the recording density. This off-track characteristics can be approximately expressed by equation (1).

$$\frac{E(d/W)}{E_0} = 1 - \frac{d}{W} \qquad (1)$$

where: $E(d/W)$ is the amplitude of reproduce voltage at the head displacement d/W
: E_0 is that of on-track.

This equation means that the crosstalk signal in perpendicular recording is smaller than that in longitudinal recording [7].

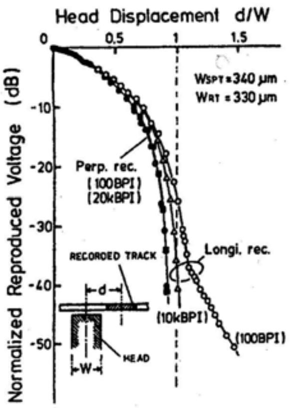
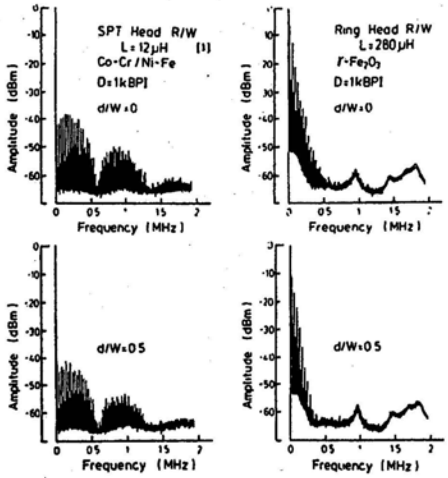


Fig.6. Comparison of off-track characteristics of perpendicular recording and longitudinal recording.

To clarify the difference in the off-track characteristics, the frequency spectra of the reproduced signal at 1 kBPI have been measured for (a) perpendicular and (b) longitudinal recordings. As shown in figure 7 (a), the higher harmonics are very large in perpendicular recording, and they exist in the region over 0.6 MHz corresponding to the wavelength which is equal to the thickness of the main pole (1 µm). Although the displacement d is increased, the spectrum amplitude of the higher harmonics still remains sufficiently high as shown in the bottom figure. On the contrary, in longitudinal recording, the amplitude of the fundamental component is much larger than that of the harmonics, as shown in figure 7 (b). This means that the off-track characteristics is determined by the long wavelength components of signal in longitudinal recording. Theoretical calculations show that long wavelength components of signal do not rapidly diminish with increasing displacement [2].



(a) Perpendicular rec. (b) Longitudinal rec.

Fig.7. Frequency spectra of reproduced signal for displacement d/W=0 (top) and 0.5 (bottom)

4. CONCLUSIONS

An increase of the track density in perpendicular recording has been investigated experimentally. Since the gradient of the perpendicular field of an SPT head is very large in the transverse direction near the track edge, narrow track recording can be realized with superior crosstalk characteristics. It has also been ascertained that reproducing sensitivity per unit width of the SPT head is improved by narrowing the width of the main pole. These properties are closely related with the behavior of magnetic interaction between the main pole and the recording medium with perpendicular anisotropy. At present the reproduction by the SPT head of only 6.5 µm in track width has been made with sufficient signal to noise ratio.

Hence, an increase of the track density as well as the linear density would become a powerful method to attain the high areal density of recorded signal in perpendicular recording. It is expected that an areal storage density over 10^8bits/inch^2 is achievable just at present, even in a flexible disk system, if a high-accuracy head-positioning technique is developed.

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