Journal of Magnetism and Magnetic Materials 320 (2008) 2967–2970

Contents lists available at ScienceDirect

Journal of Magnetism and Magnetic Materials

journal homepage: www.elsevier.com/locate/jmmm

Stepped side shield writer for perpendicular recording

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ARTICLE INFO

Available online 3 August 2008

Keywords:
Perpendicular recording
Side shield head
Fringing field
HDD

ABSTRACT

To increase the track density in hard disk drive (HDD), the write head fringing field should be controlled. The side shield is one of the candidates to reduce the fringing stray field. Although the wrap-around type [K. Nakamoto, et al., IEEE Trans. Magn. 41(10) (2005) 2914] and many other side shield structures [Y. Kanai, et al., IEEE Trans. Magn. 39(4) (2003) 1955; D.T. Wilton, D.J. Mapps, IEEE Trans. Magn. 29 (1993) 4182] were proposed, these side shield structures have a trade-off between the track edge field sharpness and the maximum write field strength on the center track. In this paper, we propose the new side shield writer called the stepped side shield (3S) head. The 3S head satisfies both the on-track write field strength and reduction of the adjacent track stray field. The track edge field sharpness is much improved especially in the high skew angle recording. We studied the 3S head effect by the statistic field simulation.

1. Introduction

To increase the recording track density in the hard disk drive (HDD), the reduction of cross-track write interference is one of the key points. The recording writer design with the write head and the medium soft under-layer affects both track edge field distribution and center track field strength at the same time. Most design methods to reduce the stray field interference to the neighbor track tend also to reduce the maximum field strength in the center of the recording track.

Surely the wrap-around type head [1] and other side shield (SS) structures [2,3] are very effective for the reduction of fringing field. But the field strength on the track gets worse compared the no SS head.

In this paper, the new SS writer called the stepped SS (3S) head is proposed. The 3S head is more effective for the reduction of fringing field on keeping the center track field strength. We studied this effect by statistic magnetic field simulation.

2. The new writer design

The three-dimensional structure of the 3S head near the ABS is shown in Fig. 1. The structure type of the writer is the trailing shielded head, which consists of the main pole (MP) and the write shield yoke (WY). The distance between the MP and the WY is 40 nm on the ABS plane. The SS of '3S head' are positioned at both the adjacent track sides of the MP leading portion. Both SS are separate from the MP and the WY.

The bottom sectional structures facing the ABS of the 3S head are shown in Fig. 2. In this simulation, the physical width (PW) at the trailing edge of the MP and the thickness (PL) of the MP are fixed at 0.14 and 0.3 μm, respectively.

The characteristics soft under-layer (SUL) of the media are shown in Table 1.

3. Magnetic field simulation

The three-dimensional field made from the combination of the writer and SUL is calculated by the FEM simulator. And the effective field (H_{eff}) is calculated from the magnetic field amplitude $|\vec{\mathbf{H}}|$ and the medium switching field (SWF) angle dependence, assuming S-W model medium magnetization reversal as follows:

$$\begin{aligned} H_{eff} &= |\vec{H}|/\mathrm{SWF}(\varphi) \\ &= |\vec{H}|(\cos\,\varphi^{2/3} + \sin\,\varphi^{2/3})^{3/2} \end{aligned} \qquad (1)$$

SWF is the function of the angle φ between the perpendicular direction for the medium plane and the write field. The H_{eff} at each point in the recording layer on the medium is calculated. The example of the trailing shield head is shown in Fig. 3(a).

In the HDD with the rotational actuator, higher skew angle makes worse fringing performance as shown in Fig. 3(a). Both the magnetic write track width (MWW) and the erase width (EW) are calculated at skew 15° position as shown in Fig. 3(b).

In the case that the skew angle is higher than the bevel angle, the maximum effective field position of the side edge (part B) may

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doi:10.1016/j.jmmm.2008.08.006

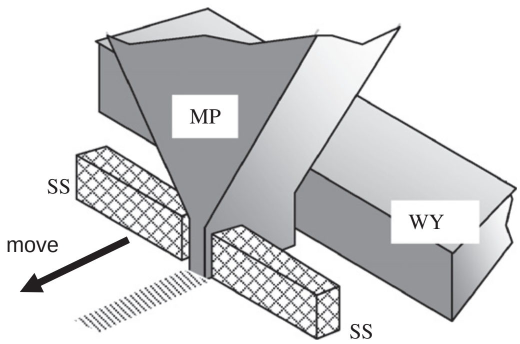

Fig. 1. The three-dimensional structure of the 3S head MP: main pole, WY: write shield yoke, SS: side shield.

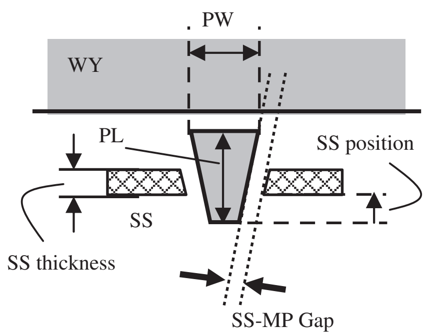

Fig. 2. The bottom sectional view faced on ABS of the 3S head PW = 0.14 μm, PL = 0.3 μm, B_s (MP) = 2.1 T, Bevel angle = 9°.

Table 1
SUL characteristics

Parameters	Value
Thickness	50 nm
B_s	14 kG
SUL-ABS distance	60 nm

exceed 8000 Oe as shown in Fig. 3(b). However, the maximum field position is far from the trailing gap and the field peak ridge angles are quite different from the trailing gap line. This side edge field does not contribute to readable transition in the track because of the degradation of the field gradient. In this paper, to neglect this side writing effect to the write track, the calculated MWW is defined as the only cross-track width where the effective field strength is over 8000 Oe [$\sim H_{c0}$, H_{c0}: fast speed coercivity of medium] at the trailing portion under the MP (part A). The calculated EW is defined as cross-track width in which the effective write field is over H_{c0}. Erase band (EB) is the value obtained by subtracting MWW from EW. The write ability of each writer is discussed by these parameters.

The writer design that reduces the EB by keeping the sufficient write field strength is very effective for higher track density. In this paper, we judged the effect of writer design for higher track densities by comparing the correlation between EB and the maximum effective field with some different writer structures.

4. Result

4.1. SS position robustness

The effective position of SS parts of the 3S head was studied. The thickness of SS parts is fixed at 0.1 μm. The SS position (shown in Fig. 2), the distance of the SS leading edges from the MP leading edge, is an important parameter for discussing the optimum design of the 3S head.

The comparison of the EB and the write ability between the 3S head and no SS head is shown in Fig. 4(a). H_{eff}_max is the maximum effective field strength. In this figure, the solid line shows the correlation between EB and H_{eff}_max of the no SS head. Compared with the solid line, the left side points show the advantage for the reduction of fringing, because EB decreases by keeping the write ability. The square points (■) show the 3S head simulation results with the different positions of SS parts. Some points are in the left side from the solid line. We define this reduction width of EB on the same H_{eff}_max from the no SS head line as the 'EB improvement,' which is shown in Fig. 4(a). The negative 'EB improvement' means the smaller EB with the same write ability, which realizes higher track densities.

Fig. 4(b) describes the optimum SS position of the 3S head using the correlation between the SS position and the 'EB improvement'. The negative 'EB improvement' shows some fringe reduction. The positive 'EB improvement' shows the poor write ability with the same EB width compared with the no SS head. In this figure, the SS position that shows the minimum effective fringe value is about 0 μm where it is the same as the leading position of the MP. This means that the narrower distance between the SS and the WY causes the poor write ability and is not effective. And the wider distance between the SS and the WY does not affect the reduction of fringing.

4.2. Comparison of some writers

4.2.1. MP–SS gap and SS thickness dependence

The MP–SS gap (shown in Fig. 2), which is the distance between MP and SS parts, is also an important parameter for discussing the optimum design of the 3S head. Fig. 5(a) shows the MP–SS gap dependence of EB. All the points were calculated at SS position = 0 μm. The points (*) show the case of MP–SS gap = 20 nm, and the triangle points (△) show the case of MP–SS gap = 50 nm. The different points at each MP–SS gap conditions describe the change with different SS thicknesses. The SS thickness conditions are changed from 0.06 to 0.16 μm. The solid line is the EB–H_{eff}_max correlation of the no SS head that changes PW or PL, etc. as in Fig 4(a). Each result of 3S head shows the effective reduction of EB, compared with the case of the no SS head.

The circle point (○) in Fig. 5(a) shows the case of the full SS head. The fringing width of the full SS is narrow, but the write ability is also poor. In the 3S head, the write ability loss is small and EB reduction is large.

Fig. 5(b) shows the SS thickness dependences of the EB improvement in MP–SS gap = 20 and 50 nm. In MP–SS gap 20 nm, the 'EB improvement' gradually increases up to SS thickness = 0.16 μm. In MP–SS gap 50 nm, the 'EB improvement' increases up to 0.12 μm, and decreases up to SS thickness 0.16 μm.

The impact of 'EB improvement' in the case of MP–SS gap 20 nm is larger than that in the case of MP–SS gap 50 nm. The narrower MP–SS gap is more effective for the reduction of fringing.

Based on these results, the narrower MP–SS gap is more effective for the reduction of EB, and the more effective SS thickness is around 0.12 μm considering the balance of fringing and write ability.

4.3. Comparison with the 3S head and the full SS head

The full SS head [1] has been proposed as the effective fringing characteristics. We compare the full SS head and the 3S head in the view of both fringing and the write ability.