RECORDING CHARACTERISTICS OF LOW FLYING SINGLE POLE HEAD

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Abstract---A single pole head with slider characterized by low flying height (less than 500Å) was investigated to improve recording performance in perpendicular recording. The low flying height was obtained by using a head with cross-cut rail. A Co-Cr-Pt/Ni-Fe double layer medium was used for evaluation of these heads. As a result, the decrease of flying height was very effective to improve the recording and reproducing efficiency. A sharp isolation waveform and high linear recording density were obtained on the low flying height. In conclusion, it was necessary to obtain the low-flying condition to get a useful perpendicular magnetic recording head.

INTRODUCTION

Perpendicular magnetic recording is the most suitable method for high areal recording density [1]. It is important to maintain the strong magnetic interaction between a head and a medium.

That is, a head and a medium spacing seriously affects the read/write characteristics. Therefore, to realize perpendicular recording, it needs to realize a stable low flying height condition. We have previously reported a contact perpendicular magnetic recording head and disk, a CN ratio of 41dB and over-write of -30dB at 100KFCI using a $0.2\mu\text{m}$ main pole thickness [3]. The purpose of the present work is to make a useful head for HDD under low-flying condition. In this paper, we describe the flying characteristics of the head slider with cross cut rail [4,5] and the read/write characteristics.

FABRICATION OF THIN FILM HEAD

Fig.1 shows a cross section diagram and SEM image of single pole thin film head with a one sided core. The head parameters are shown in Table 2. Ni-Zn ferrite was used as the material of the

Fig. 1 Cross section diagram and SEM photo of cross section of 30 turns single pole thin film head.

TABLE 1. Head dimensions

Main pole material:	$\text{Co}_{0.8}\text{Zr}_{0.5}\text{Nb}_{0.3}\text{Mo}_{0.2}\text{O}$
Thickness of main pole:	$0.2\mu\text{m}$
Track width(Tw):	$9\mu\text{m}$
Number of turns:	30 turns
Gap length(Gl):	$10\mu\text{m}$
Gap depth(Gd):	$5\mu\text{m}$

TABLE 2. Medium parameters

Soft magnetic layer: Ni-Fe	
Thickness	: 5000A
Coercivity	: 1 Oe
Perpendicular magnetic layer	Co-Cr-Pt
Thickness	: 1000A
Coercivity	: 560 Oe
Ms	: 700emu/cc
$\Delta\theta 50$	: 10°
Protect film	: Carbon
Thickness	: 200A

auxiliary magnetic pole , and the gap between main pole and auxiliary magnetic pole is filled with Al_2O_3 . Gap length is about $10\mu\text{m}$. The coil structure is three-layer, Cr/Cu/Cr construction and is made using a dry process. The number of coil turns is 30(16 turns in the lower layer and 14 turns in the upper layer of two-layer construction). A polyimide resinoid was used as the insulation between film layers , and the main pole was fabricated from a

Fig. 2 Low flying slider with cross-cut.

Fig. 3 The cross section of the double layered medium.

CoZrNbMo amorphous film prepared by sputtering. The magnetic main pole was heat-treated at 300°C for 30 minutes in a static magnetic field of 9K0e , subsequently at 260°C for 10 minutes in a rotating magnetic field of 2K0e in Ar atmosphere. The composition of the main pole was $\text{Co}_{0.8}\text{Zr}_{0.5}\text{Nb}_{0.3}\text{Mo}_{0.2}\text{O}(\text{at}\%)$. The magnetic properties were $\text{HK}=5\text{ Oe}$, $\mu > 2000$ at 5MHz and $4\pi\text{ Ms} = 11.7\text{KG}$. Using the above mentioned processes . Several heads with main pole thickness of $0.2\mu\text{m}$

Fig. 4. The dependence of flying height on velocity at various cross-cut length.

and $9\text{ }\mu\text{m}$ track width were fabricated in order to investigate the dependence of recording characteristics on flying height. Fig. 2 shows the construction of the low flying height slider with cross-cut rail.

EXPERIMENT

The 3.5 inches hard disk with Co-Cr-Pt/NiFe double layer medium was prepared by sputtering process. This double layer medium was made on a GGA(Glass Glazed Alumina) substrate, and the medium surface was protected by a sputtered carbon thin film. The thickness of the carbon film was 200Å. Perfluoro-polyether lubricant, thickness of 15Å, was coated on the surface. Fig. 3 shows the construction of the double layer medium. The medium parameters are shown in Table 2. The read/write characteristics were evaluated with low flying height head condition.

Fig. 5 The dependence of reproduced voltage on flying height

The loading force was 6gf. The head to medium velocity was 7.5m/sec. The rotational speed of disk was 3600rpm. Over-write property was measured at 40KFCI and 100KFCI. The flying height was measured by a laser interference fringes flying tester under the laser wave length of 633nm. By using this system, flying height can be measured a accuracy of $\pm 0.003\text{ }\mu\text{m}$ with measurement limit of $0.03\text{ }\mu\text{m}$. The CN ratio was measured by a spectrum analyzer under the conditions of RBW(Resolution band width) 10KHz and VBW(Video band width) 100Hz. CSS property was measured by CSS drive tester and measuring point was 80mm(D), the loading force was 6 gf and CSS drive test cycles was up to 60 thousands.

RESULTS AND DISCUSSIONS

(1) The relationship between the velocity and flying height at various cross-cut length(L).

Fig. 6 The dependence of reproduced voltage on recording current.

Fig. 4 shows the dependence of the flying height on velocity at various cross-cut length. From these results, as the cross-cut length increase, flying height decrease. A flying height is below $0.05 \mu\text{m}$ at cross-cut length of above 1.0mm (10m/sec). Furthermore, compared with conventional type slider ($L=0$), the flying height is relatively flat, almost affecting velocity. As a result of above mention fact, the low flying height seem to be explained by interaction of negative pressure at the shape of this head and slider surface decrease. In this respect, this slider is fit to use for low flying.

(2) The relationship between the flying height and the recording characteristics.

Fig.5 shows the dependence of reproduced voltage and D50 on flying height. From these results, as flying height decrease, reproduced voltage increase and D50 increase. D50 was 110KFCI at flying height of $0.04 \mu\text{m}$.

Fig. 7 The dependence of reproduced voltage on linear recording density.

Fig. 8 Measured noise spectrum and C/N ratio.

From the above mentioned results, it was found that the head having $0.04 \mu\text{m}$ flying height has good recording characteristics. (3) The recording characteristics of single pole thin film head with 1.0mm length cross-cut.

(a) 3.4KFCI

(b) 68KFCI

(c) 100KFCI

(d) Envelope (at 100KFCI)

Fig. 9 The reproduced waveform and envelope.

The following shows the recording characteristics of these heads.

Fig. 6 shows the saturation current characteristics at 40KFCI and 100KFCI, and the over-write property. Saturation magnetic recording is obtained at relatively low write current of $8\text{mA}_{\text{O-P}}$.

Fig. 7 shows the relationship between the linear recording density and the normalized output voltage of $0.04\text{ }\mu\text{m}$ flying height. A high normalized output voltage was obtained and D50 was 110KFCI.

Fig. 8 shows the C/N ratio 36db at a recording density of 100KFCI, and it has a low noise value.

Fig. 9 (a) (b) (c) (d) show the reproducing wave forms and envelope using this head. Fig. 9 (a) shows the reproduced waveform at the a recording density of 3.4KFCI.

There remains some distortion at the end of the each pulse, and wave form is asymmetrical. This may be due to the influence of the edge of the ferrite auxiliary pole, but the details are not clear. In Fig. 9 (b) (c) are shown the reproduced wave forms at 68KFCI and 100KFCI, respectively. Judging from these wave forms, there is no longer an asymmetry in the reproduced waveform.

In Fig. 9 (d) is shown the reproduced envelope at 100KFCI. Judging from this envelope, there is relatively flat. Therefore relative flat envelope can be obtained by using slider head with cross-cut rail.

(4) The relationship between the coefficient of friction and CSS drive test cycles.

It is necessary not to increase the coefficient of friction on CSS drive test cycles. Fig. 10 shows the dependence of the coefficient of friction on CSS drive test cycles. From these results, as the

Fig. 10 The dependence of coefficient of friction on CSS drive test cycles.

CSS drive test cycles increase, the coefficient of friction increase and the coefficient of friction was 0.8 at 25K CSS drive cycles, therefore CSS characteristics is not enough yet. We think that this phenomena is due to the sputtering conditions of protective carbon and texturing condition of disk.

Here after, we intend to study in detail sputtering conditions of protective carbon and micro texturing condition.

CONCLUSION

In a study of the relationship between the flying height and cross-cut length, the following results were obtained.

(1) A flying height could be controlled by changing cross-cut length. Especially, a flying height of $0.04\mu\text{m}$ was obtained at cross-cut length of 1.0mm and velocity of 7.5m/sec.

(2) A flying height is relatively flat with respect to velocity.

And by using a slider as mentioned above, the read/write characteristics of single pole head with $9\mu\text{m}$ track width and 30 turns-winding was evaluated at $0.04\mu\text{m}$ flying height. And the following results were obtained.

(1) A normalized reproduced voltage higher than $60\text{nV}_{\text{O-P}}/\mu\text{m}\cdot\text{t}\cdot\text{m}/\text{sec}$ (at low frequency) was obtained.

(2) The D50 was 110KFCI.

(3) The C/N ratio was 36dB and over-write was -30dB at 40KFCI/100KFCI.

(4) The reproduced envelope was flat.

Moreover, according to the relationship between the coefficient of friction and CSS drive test cycles, the following results were obtained.

(1) A Coefficient of friction was 0.8 at 25K CSS drive cycles.

REFERENCES

- [1] S.Iwasaki and Y.Nakamura, IEEE Trans. Magn. MAG-13,5,1272,1977.
- [2] K.Kobayashi, J. Magn.Soc. Japan, 10(1),23,1988
- [3] M.Yamashita and T.Wada, J.Mag.Soc. Japan, Vol 15, 175, 1991
- [4] S.Fuluichi, Japan Patent, 57-82249, 1982
- [5] G.Clifford et al., IEEE Trans. Mag. Vol 25(5), 1989 PP.3713 ~ 3715
- [6] S.Yamamoto, Y.Nakamura, S.Iwasaki, The 4th Joint MMM-Intermag Conference, July 1988
- [7] K.Yamakawa and Y.Nakamura, J.ECE.J Tech. Rep., MR-8428,1984
- [8] K.Ouchi and S.Iwasaki, J. Inst Elec. Eng. Japan, MR87-5, pp.1-8,1987.