Thin Film Head For VCR

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Abstract —A thin film magnetic head has been expected to be applied to high density recordings. However, the practical use of the head for video recordings is not yet realized because of its problems regarding head contact reliability, impedance noise and low frequency transmission characteristics. In order to overcome such problems, authors have developed a new thin film magnetic head for video recording applications, which is made solely of high heat resistant inorganic materials, the coil resistance of which is lowered. The developed head is evaluated by using a metal evaporated tape (ME tape) and a metal particulate tape (MP tape). The head of innovative structure is proved to be highly reliable both in the normal and level-different wear characteristics, and to have a superior low frequency transmission characteristic and a high carrier-to-noise ratio. And having a gap depth of 5 μm , the newly developed head has sufficient performance for VCR.

1. INTRODUCTION

Downsizing and upgrading picture quality are always demanded on VCR, which lead to wide frequency band and digitized signal processing for the VCR. For this reason, a high performance magnetic head capable of high density and frequency recordings is strongly required for the VCR application. In this regard, use of thin film magnetic heads already available for HDD is conceivable for the purpose. However, various problems as follows have to be solved of the head primarily designed for HDD, when application of such to VCR is attempted:

1) the gap depth must be long enough for wear as the head physically contacts the tape in the VCR use;

2) d.c. resistance of the head must be reduced for adequate low frequency signal transmission through a rotary transformer which is generally required in the VCR application. Reduction of the d.c. resistance is also an important factor for lowering impedance noise of the head;

3) in order to secure a steady head to tape contact for smooth tape running, a protective substrate is adhered to the head element, and glass bonding is necessary for better reliability, which requires the head element made of high heat resistant materials.

This paper reports on the thin film magnetic head for VCR, the problems of which discussed above are solved by the new structure of the head, further, recording and reproducing characteristics and wear characteristics for various types of tapes are evaluated as well.

2. STRUCTURE OF THE HEAD

Fig. 1 shows a cross section of the head element cut through the center. It is fabricated in the manner that a core and a coil are embedded into an inorganic insulating film and polished by lapping, and such is laminated 4 times to form the head element. High precision core forming is made possible without causing magnetic response degradation since it is processed on the flat substrate. The coil is made by

forming grooves in the insulating film by dry etching, then copper material is embedded in the grooves. Wear characteristic greatly depends on the material of substrate. In this regard, $\text{Al}_2\text{O}_3\text{-TiC}$ and the like materials are good against normal wear, however, they are apt to cause an level-different wear i.e. producing a step from the magnetic core by running a tape. This invites a spacing loss of short-wavelength signals. In consideration of this problem, CaTiO_3 which is excellent against both the normal and level-different wear, is employed as the substrate material. As the insulating film, TiO_2 which is easy to be dry etched and has a large thermal expansion coefficient, is employed, and the core material is a CoNbZr amorphous film having a saturation magnetic flux density of 1.2T. Gap depth of approximately 1 μm is common to heads for HDD [1], but a mere increase of the gap depth for a VCR application would cause a saturation easily in the magnetic flux path of the head and be incapable of recording sufficiently. In order to better the situation, the core thickness is made to 10 μm and the gap depth is varied from 5 to 20 μm . Besides on the HDD heads, the d.c. resistance of the coil is generally 1 Ω per turn, however in this head for VCR, 0.28 Ω per turn is realized by increasing the coil thickness.

Fig. 1 Cross section of the head element

3. READ - WRITE CHARACTERISTICS

3-1 Measurement conditions

Measurements are mainly conducted by a drum tester, and the C/N measurement is performed on the open-reel

type deck through its rotary transformer. The head reproduced output is measured as such that a sinusoidal signal is recorded first then the amplitude of fundamental component of the reproduced signal is measured by a spectrum analyzer. Table 1 shows the measurement conditions, Table 2 indicates specifications of the evaluated typical head.

Relative velocity	10.1m/sec
Drum tester	Outer contact type
Deck	Drum diameter 120mm 9000rpm
Tape	1/4in. Metal tape ME : $H_c=127\text{kA/m}$, $B_r=0.4\text{Wb/m}^2$ MP : $H_c=195\text{kA/m}$, $B_r=0.3\text{Wb/m}^2$

Table 1 Measurement conditions

Tack width	14 μm
Gap length	0.18 μm
Gap depth	5 μm
Coil turns	20turns
Inductance	0.4 μH
Q value	2.2
d.c. resistance	5.6 Ω
Azimuth	20°

Table 2 Head specifications

3-2 Input-output characteristics

Input-output characteristics of the typical thin film head (gap depth : 5 μm) at frequencies of 1,10.5 and 21 MHz are shown in Fig. 2.

Fig.2 Input-output characteristics

The reproduced output frequency response is shown in Fig. 3, as indicated, the output of both the ME and MP tapes saturates in the low frequency range, however, recording is considered feasible in practical use as the response over 5 MHz exhibits a moderate hill shape. Although the output level in the low frequency range is low of both the taps due to their thin magnetic layer, the

demagnetization in recording is less because of their high H_c property and the output response extends well into the high frequency range indicating a superior short-wavelength characteristics.

Fig.3 The reproduced output frequency response

3-3 Gap depth dependency of head output

Gap depth dependency of head output is examined on the head having a core thickness of 10 μm using an ME tape. The result when optimum recordings are made at respective frequencies, is shown in Fig. 4. As indicated, the recording-reproducing output reduces as the gap depth increases, that is, 1.5 dB down for an increase from 5 to 10 μm , and 3 dB for a 5 to 15 μm increase.

When the gap depth is 20 μm , the recording is not adequately performed due to a recording efficiency degradation. However in the range below 15 μm where no recording differences are present, it is considered that increase of the recording efficiency contributes straight to the output increase.

Fig.4 Gap depth dependency of head output

3-4 Carrier-to-noise ratio

C/N is an important parameter for the S/N in the analog recording and the error rate in the digital recording. Fig. 5 shows spectrum of the reproduced signal and noise from the typical head, with which an optimum recording is made at a carrier frequency of 21 MHz.

Output of the reproduction amplifier is measured with a spectrum analyzer being set to RBW = 30 kHz, VBW = 1 KHz and a band-width of 0 - 40 MHz. The lower curve indicates the system noise when the tape deck is in the stop mode, the upper curve indicates the noise upon signal reproduction.

The system noise is a sum of the head impedance noise and the amplifier noise, and as can be seen from Fig. 5, the head impedance noise is not significantly contributing. Here, a C/N of 55 dB is derived from the ratio of carrier amplitude and the averaged noise level at frequencies of 18.6 MHz and 23.25 MHz.

Fig. 5 Noise Spectrum

3-5 Transmission characteristics

In digital magnetic recordings, when a d.c. resistance of the magnetic head is large, a low cutoff frequency of the recording system is shifted up, this causes an error rate increase due to a generation of sag (wave form distortion of slant top of square wave) in the signal wave form developed in the recording operation.

Fig. 6 Equivalent circuit of rotary transformer

Fig. 6 is an equivalent circuit of rotary transformer (RT), in which:

- a ; turn ratio of the rotary transformer(RT) : 2
- k ; coupling coefficient of the RT : 0.95
- L_H ; inductance of the head

- R_H ; d.c. resistance of the head
- R_P ; d.c. resistance of the RT in the rotor
- L_P ; mutual inductance observed from the rotor
- R_S ; d.c. resistance in the stator
- L_S ; mutual inductance observed from the stator
- E_i ; electromotive force of the head
- E_o ; actual voltage appearing at the stator

The change of the low cutoff frequency " f_c " due to the d.c. resistance of the head is calculated by the following equation.

$$f_c = \frac{R_H + R_P}{2\pi(L_H + L_P)}$$

From the equation, where $R_P = 1.5 \Omega$, $L_H = 0.42 \mu H$, and $L_P = 6 \mu H$, the relation between the low cutoff frequency and the d.c. resistance is shown in Fig. 7. As can be seen from Fig. 7, 188 kHz is obtained as a low cutoff frequency at a d.c. resistance of 5.6Ω , and 165 kHz was actually obtained as a measured value.

Fig.7 The relation between low-cutoff frequency and d.c. resistance

4. RUNNING RELIABILITY

4-1 Conditions of tape running tests

In order to verify the tape running reliability of the thin film magnetic head, an amount of normal and level-different head wear are evaluated. The measurements are taken at the initial state, 100 hours-run, 300 hours-run and 500 hours-run of both the MP and ME tapes. The conditions of this running tests are shown in Table 3.

Head surface width	60 μ m
Head protrusion	15 μ m
Atmosphere	25°C. 50%RH

Table 3 Running conditions

4-2 Head wear

Fig. 8 shows an amount of head wear at each state of the above tape running hour. The amount of the head wear

is obtained by measuring a value of head protrusion from a surface of the rotary drum. Both with ME tapes and with MP tapes, the amounts of the head wear increases in a range up to the 100 hours, but after that, the increase is minor. Accordingly, a fairly good result, for instance, approximately 1 to 1.5 μm wear after 500 hours-run, is obtained.

Fig.8 Abrasion vs. running time

4-3 Level-different head wear

The tape-running surface of the thin film magnetic head is formed as such that magnetic cores are embedded in insulation layers which are further interposed between a pair of non magnetic substrates as shown in Fig. 9. When a step between the magnetic cores and the substrate develops, in other words, level-different head wear is caused, this invites not only a decrease of a reproduction output due to a spacing loss, but also invites signal dropouts due to contamination accumulated in the step portion. Thus, it is desirable to minimize the level-different head wear as small as possible in a stable condition. Level-differences of the heads are measured of the tape-running surface of the heads in the direction of arrow shown in Fig. 9 by using a surface texture measuring equipment.

Fig. 10 shows level-differences of the head at each of the tape running hours with ME and MP tapes.

Fig. 9 Tape-running surface of the head.

By the way the level difference between the substrate and the insulation layer is barely present. Therefore as can be seen from Fig. 10, it may be said that in a range up to 500 hours-run, the tape-running surface holds a good

condition having level-different head wear of 15 to 20 nm without a change. It is also verified that the reproducing characteristics are not degraded in this state.

Fig.10 Level difference vs. running time

5. CONCLUSION

Thin film magnetic head composed of all inorganic materials in order to enhance heat resistance of the head, is developed. Specifically, a prototype thin film head for video tape recorder applications is fabricated, in which a protective substrate is welded to the head element by glass bonding, and a d.c. resistance of the head is decreased by enlarging the cross section of the coil. The recording and reproducing characteristics and the head wear characteristics of the head are evaluated by using both MP and ME tapes.

Results include:

- (1) Thin film magnetic head for video tape recorders having a high tape running reliability on both ME and MP tapes, is obtained.
- (2) By decreasing the head impedance, a C/N of 55 dB at a frequency of 21 MHz from the head with a gap depth of 5 μm is obtained.
- (3) Low cutoff frequency of the head is reduced to 165 kHz by decreasing the resistance of the thin film coils to 5.6 Ω /20 turns.

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7. REFERENCES

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