# Printed Media Technology for an Effective and Inexpensive Servo Track Writing of HDDs

Tatsuaki Ishida, Keizo Miyata, Taizou Hamada, and Kiyokazu Tohma

*Abstract*-- As an alternative method for the servo track writing of hard disk drives (HDDs), a magnetic contact duplication method by using a lithographically patterned master disk has been proposed and investigated. On the master disk, magnetic film pattern according to the information signal to be printed on slave disks is provided by a lithography technique. In this method, unlike the anhysteretic process of the conventional contact duplication method for magnetic tapes, the master information never disappears when a large external field is applied to the master while printing. This duplication method, as we call the *Printed Media* technology, can provide a very effective and inexpensive lump-sum servo track writing method for HDDs.

*Index Terms*-- Lithographically patterned film, Master disk, Printed media, Servo track writing.

## I. Introduction

As the recording density of HDDs is being rapidly increased, current servo track writing method by using a conventional servo track writer has become more costly and technically difficult. In order to overcome the problem, a magnetic contact duplication method using a lithographically patterned master disk [1] has been proposed and investigated in this work.

## II. Basic Principle and Advantages

Fig. 1 shows a schematic illustration of the duplication method. On the master disk, magnetic film pattern according to the information signal to be printed on slave disks is provided by a lithography technique. After the master disk is faced with a DC erased slave disk, an external field is applied to the master disk. Then, owing to the shielding effect of the individual patterned magnetic film on the master, flux leaks and reverses the initial magnetization on the slave disk at the portion between the neighboring patterned films, and magnetic signal information according to the magnetic film pattern on the master is printed on the slave disk.

Unlike the anhysteretic process of the conventional contact duplication method for magnetic tapes [2], this method can provide a very effective way of printing signals on highly coercive hard disk media. For one reason, since the signal information stored in the master is not a magnetization pattern, but provided as a physical shape pattern of the magnetic films, the master information never disappears when a large external field is applied to the master during the printing process. Also, the magnetic film on the master is not necessarily required to be so coercive as the slave medium, but is allowed to be a more permeable soft magnetic film with higher magnetic moment, thus ensuring the sufficient recording capability.

This duplication method, as we call the *Printed Media* technology, can also provide a very productive and inexpensive way for the servo track writing process of HDDs, because it is essentially the areal lump-sum recording, while the current servo track writing process is the linear recording based on the relative movement between the head and the disk.

## III. Experimental Procedure

For studying basic properties of the printed signal, simple periodic signal with the track width of $300\,\mu m$ and the wavelength at the track center of $3.0\,\mu m$ was printed on hard disks and the reproduced signal was examined on a spin stand.

On the master disk, periodic line and space pattern made of $0.5\,\mu m$ thick cobalt films was provided with a lithography technique by using a photo mask process, so that the pattern create a circular track with the signal feature to be printed on the hard disks.

Printed signal was evaluated by using a conventional MR head with a read track width of $1.7\,\mu m$. Relative head-disk velocity was set at $5.0\,m/s$, where the nominal flying height of the head was about $50\,nm$. In spite of the eccentricity existing between the printed pattern center and the spindle rotation center, the track width of as large as $300\,\mu m$ can still allow the reproduction head to read the printed signal along an entire revolution on a spin stand.

The slave disks used were commercial glass substrate disks with the coercivity of $160\,kA/m$. Fig. 2 shows how the external DC field is applied during the duplication process. First, the slave disk is DC erased along the circumferential direction of the disk by rotating a permanent magnet block on the disk surface. After that, the slave disk and the master disk are aligned and securely faced with each other by evacuating the air between the two disk surfaces through the center hole of the slave disk. Then, the external DC field is applied again in the same manner as in the DC erasing process, but with the opposite polarity.

In the signal printing process, slave-magnet spacing, $D$ affects the magnetic field strength applied to the slave and master disks. In the present study, $D$ was experimentally

Manuscript received October 10, 2000.

The authors are with the HD Development Center, Matsushita Electric Industrial Co., Ltd., 3-1-1 Yagumo-Nakamachi, Moriguchi, Osaka 570-8501 Japan (e-mail: ishida@hdct.ctmo.mei.co.jp).

varied and optimized in view of the reproduced signal quality from the printed track. Slave-magnet distance in the DC erasing process was fixed at 0.5 mm .

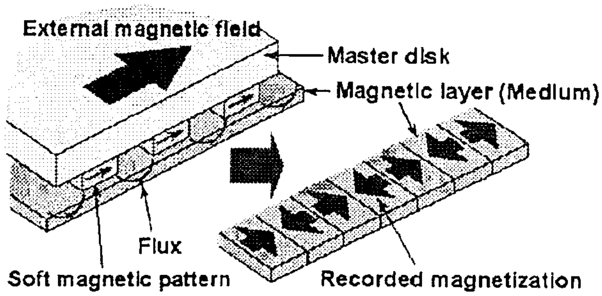


Fig. 1. Schematic illustration of the magnetic duplication method by using a lithographically patterned master disk.

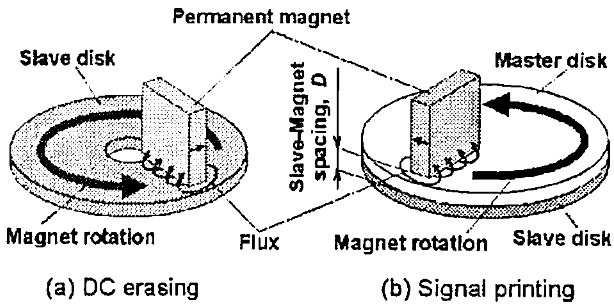


Fig. 2. Schematic illustrations of (a) DC erasing process and (b) signal printing process.

## IV. Experimental Results and Discussions

Fig. 3 shows the reproduced signal from the printed track. In this case, optimum slave-magnet spacing, $D$ of 3.0 mm was used. It is found that the reproduced waveform is very sharp, and the envelope is rather flat and smooth indicating that the evacuation of the air can ensure the very small variation in slave-master spacing during the printing process.

Fig.4 shows the slave-magnet spacing, $D$ dependence of (a) signal output and noise, and (b) signal to noise ratio, $S/N$ . The signal to noise ratio, $S/N$ was measured with 22 MHz band width. For comparison, values for the signal written by a conventional inductive head with an optimum recording current are also shown. Signal output from the printed track shows maximum value at $D$ of 3.0 mm , which is only 1.5 dB lower than the signal output from the track written by the inductive head. However the noise from the printed track is found considerably higher than that from the track written by the inductive head. The maximum signal to noise ratio, $S/N$ from the printed track is as high as 31dB, but still lower than that with the inductive head writing by more than 6 dB .

Possible noise factors in the printed track are listed and considered to be (a) amplitude modulation, (b) jitter, (c) transition noise caused by the zig-zag wall at the magnetic transition region, and (d) domain noise caused by the locally reversed domain, as illustrated in Fig. 5.

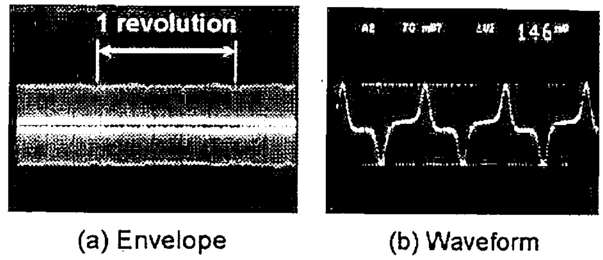


Fig. 3. Reproduced signal (a) envelope and (b) waveform from the printed track by using an MR head.

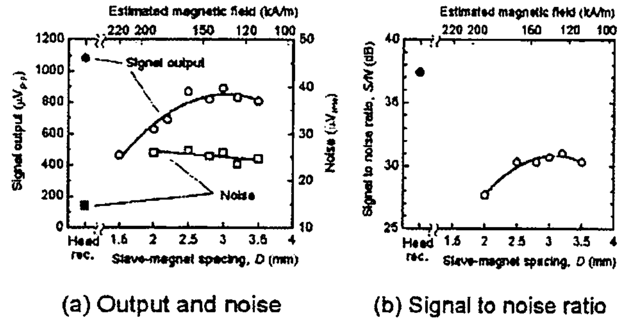


Fig. 4. Dependence on slave-magnet spacing of (a) signal output and noise, and (b) signal to noise ratio, $S/N$ . Signal to noise ratio, $S/N$ was evaluated with 22 MHz band width.

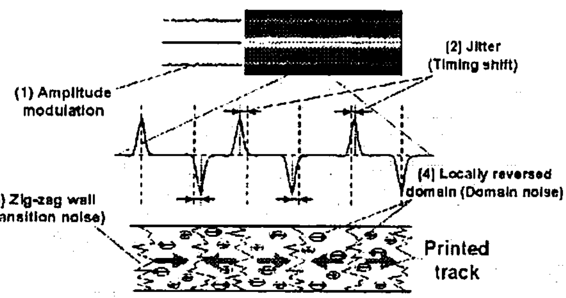


Fig. 5. Schematic illustration on the possible noise factors in the reproduced signal from the magnetically printed track.

In order to study which of these factors dominates the noise from the printed track, in comparison with that from the inductive head writing, both the printed track and the track written by the inductive head were observed with an magnetic force microscope (MFM). Fig. 6 shows the MFM image of the printed track and the track with the inductive head writing. For this observation, a portion of the 300 $\mu$m wide printed track was over-written by a 2.4 $\mu$m wide inductive writer at the same linear density as the printed track. As far as the MFM observation result shown in Fig. 6 is concerned, any significant difference between the printed track and the track written by the inductive head is not to be seen in view of the zig-zag wall and locally reversed domain features. So, either the transition noise or the domain noise doesn't seem to be the main noise factor observed in the printed track.

On the other hand, it should be noted that the noise spectrum reproduced from the printed track shows marked noise increase at the vicinity of the printed signal frequency and higher harmonic frequencies, as shown in Fig. 7, which is likely to be influenced by the signal amplitude modulation and the pulse jitter.

Although the signal envelope reproduced from the printed track is rather flat and smooth, the amplitude modulation with shorter period is still observed as is seen in Fig. 3 (a), and it is certainly found larger than that with the inductive head writing.

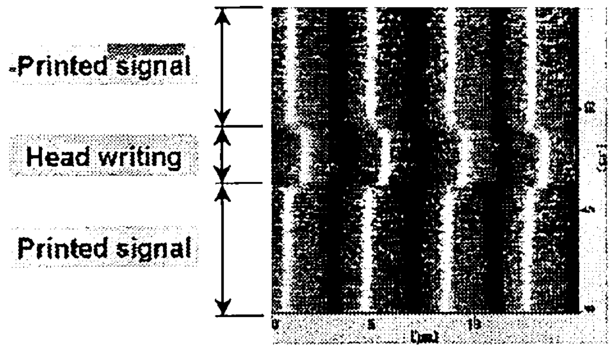


Fig. 6. MFM image of the track magnetically printed by the lithographically patterned master disk and the track written by a conventional inductive head. First a very wide track was printed and a portion of the printed track was over-written by the inductive writer at the same linear density.

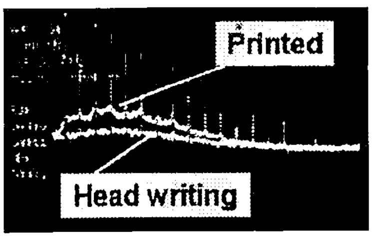


Fig. 7. Noise spectrum reproduced from the printed track. For comparison, noise spectrum reproduced from the track written by an inductive head is also shown.

Fig. 8. Typical jittering waveform frequently observed in the reproduced signal from the printed tracks. When positive pulses are triggered, considerable peak shift variation is observed in the negative pulses.

Also, in the signal reproduced from the printed track, jittering waveform, typically shown in Fig. 8, is frequently observed. When positive pulses are triggered with an oscilloscope, considerable peak shift variation is observed in the negative pulses.

This kind of jittering waveform is supposed to be caused by the following two reasons. One is that, in reproducing the printed signal on a spin stand, a certain amount of eccentricity between the printed signal pattern center and the spindle rotation center cannot be avoided, resulting in the considerable variation of the reproduced pulse interval in a disk revolution. Introducing a drive system for actively compensating the eccentricity would give a solution for this issue.

The other is the line and space length variation in the magnetic film pattern on the master disk, which may originate from the insufficient resolution or the dimension inaccuracy in the lithography process.

In view of the servo signal density used in current HDDs, the experimental feature size used in this work was extremely relaxed just for studying basic properties of the printed signal. However, it is apparently considered that this technology can be developed and turned scalable to current and future track densities by using a more sophisticated lithography technique, such as an electron beam lithography system with higher resolution and accuracy. Master disk productivity and cost with such an expensive system would not be a serious subject, as the master disk is durable enough to print millions of disks.

## V. SUMMARY

The magnetic contact duplication method by using a lithographically patterned master disk has been investigated, and the following outcomes were obtained.

Recording capability of the presented magnetic duplication method seems to be superior to that in the anhysteretic process of the prior contact duplication method for magnetic tapes, with the reproduced signal output amplitude equivalent to that from the track written by an inductive head. However, the noise from the printed track is found considerably higher than that with the inductive head writing.

The noise from the printed track is supposed to originates from the signal amplitude modulation and the pulse jitter, although the influence of the transition noise and the domain noise cannot be denied at this stage.

Controlling the printed pattern eccentricity with respect to the spindle rotation center, and introducing a more sophisticated lithography process with higher resolution and accuracy would be the key issues for practical implementation.

The presented magnetic duplication method, as we call the *Printed Media* technology, can provide a very effective and inexpensive lump-sum recording method for the servo track writing of high density HDDs, which can dispense with expensive servo track writers for precisely controlling the head position. So, the *Printed Media* technology is supposed to be a promising technological candidate for realizing the productive and cost effective mass production process of HDDs.

## REFERENCES

[1] W. R. Bernard and W. S. Buslik, "Magnetic pattern recording," U. S. Patent 3,869,711, 1975.

[2] C. D. Mee and E. D. Daniel, Magnetic storage handbook, Second edition, 5.67 (McGraw-Hill, 1996).