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Invited paper

Realization of 52.5 Gb/in^2 perpendicular recording

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Abstract

The potential of perpendicular recording system for realizing 52.5 Gb/in^2 was clarified. To realize a recording density of over 50 Gb/in^2, a quarter-micron-track-width perpendicular head consisting of an SPT writer and an advanced GMR reader was developed. A low-noise and thermally stable double-layered medium and a signal processing technique suitable for perpendicular recording channel were also developed. At the same time, high frequency write characteristics at around 60 MB/s as well as the acceptable thermal stability characteristics were also confirmed at a room temperature.

Keywords: SPT writer; Double-layered medium; Signal processing; Thermal stability

1. Introduction

Perpendicular recording was proposed by Prof. Shun-ichi Iwasaki in 1977, and it was verified by using a single-pole-type (SPT) head and a double-layered (DL) medium more than 20 years ago [1,2]. After that, research on perpendicular recording was mainly progressed by Prof. Yoshihisa Nakamura and Dr. Kazuhiro Ouchi to this day [3,4,5]. Meanwhile, a number of trials have been done to make this recording method practical [6,7,8]. However, no hard disk drives using perpendicular recording can be found in the market yet. The motivation behind our study is to review the fundamentals of perpendicular recording using SPT writer and DL medium. Then we want to develop an ultra-high-density-recording using advanced GMR reader and advanced signal processing. Before starting this study, we reviewed the issues concerning perpendicular recording such as signal decay of low-density data, domain stability of soft under-layer, very sensitive to stray field, very sensitive to head-to-medium spacing, as well as very small erase bandwidth. Throughout our study, we become convinced that most of these issues can be tackled, and that the recording density over 50 Gb/in^2 is feasible.

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2. Head and medium

Fig. 1 shows the cross sectional view of a perpendicular head which can write and read the data at recording densities of more than 50 Gb/in^2. The main pole of the SPT head consists of an FeNi film with a saturation magnetization of 16 kG. The thickness of this film is 0.4 μm, and the track width, which was defined by the wafer-level FIB process, was a quarter micron. The auxiliary pole, which serves as an upper shield of the GMR sensor, consists of conventional permalloy. The thickness of this film is 2.5 μm. Track-width of the GMR reader is 0.2 μm and the shield-to-shield separation is 0.08 μm. Very fine lithography using a KrF stepper enables us to fabricate such a narrow track head.

Fig. 2 is a TEM image of the surface of the double layered medium. To fabricate the medium, a crystal-orientation control technique was used for the recording layer, and a high saturation magnetization precipitated fine crystal film was used for the under-layer. As a result, we obtain a medium that produces less noise and better thermal stability. From the image shown in Fig. 2, it can be seen that the recording layer consists of uniform grains with a diameter of about 12 nm. The recording layer has 20-nm-thick CoCrPt with a coecivity of 2.6 kOe, an anisotropy field of 10 kOe, saturation magnetization of 250 emu/cc, and squareness of 0.98. The under-layer has 400-nm-thick FeTaC having a very high saturation magnetization of around 16 kG [9].

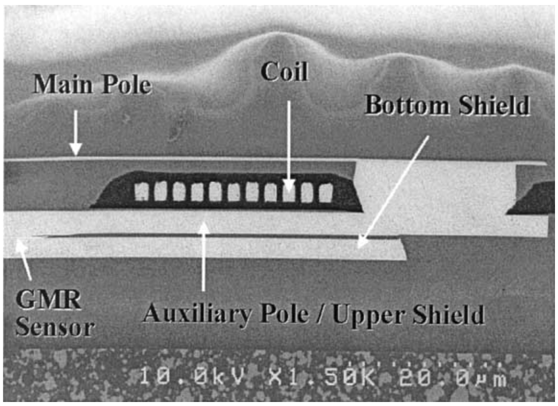

Fig. 1. Cross sectional view of a perpendicular head.

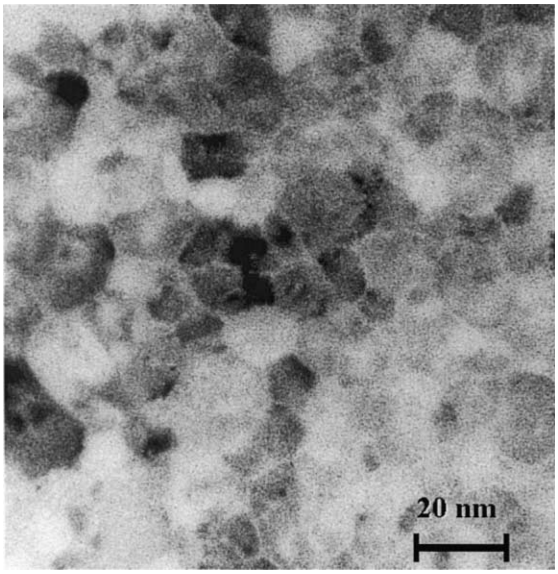

Fig. 2. TEM image of the surface of the double-layered medium.

3. Recording characteristics

The recording conditions were as follows. Magnetic spacing, which means the distance between the head surface and the surface of the recording layer, was fixed at 20 nm. The highest frequency was fixed at 250 MHz. The magneto-motive force was set at 0.5 AT_{o-p} and overwrite values exceeding 40 dB were obtained under this condition. Fig. 3 shows the roll-off characteristics. Here, the signal amplitude of the isolated pulse was 620 μV_{p-p} and the resolution is 10% at a linear density of 500 kBPI. The resolution at a linear density of 600 kBPI was about 6%. The waveforms are also shown in this figure, and deformed square waves can be seen at a linear density of 20 kBPI. The slope seen at the DC region is due to the frequency response of the pre-amplifier. On the other hand, a sine-wave with no distortion is seen at the linear density of 200 kBPI.

4. BER estimation

The bit-error-rate characteristics were estimated by computer simulation. In our study, rate 32/33

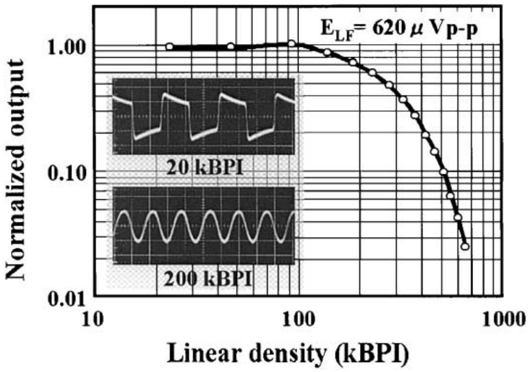

Fig. 3. Roll-off characteristics and waveforms.

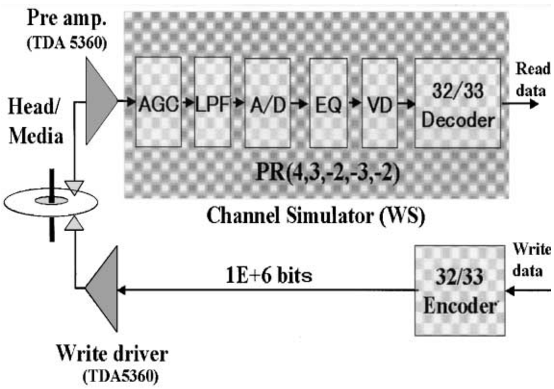

Fig. 4. Diagram of BER estimation system.

coded data was written by using a spin stand. The read signal was detected by a digital oscilloscope, and the bit-error-rate was evaluated by a channel simulator with 13-tap equalizer and a 16-state ML detector. Noise whitening equalization denoted by the target response shown in Fig. 4 were used. The number of bits used for this simulation were one million, and write pre-compensation was not used. Fig. 5 shows the result of BER estimation, and no error occurs at the density lower than 590 kBPI.

5. Off-track capability

Fig. 6 shows the micro-track profile of the GMR reader used in the BER analysis. The track width defined as the half pulse width is 0.2 μm. Based on the micro track profile shown in Fig. 6 and the information about the write track width including erase bandwidth, 747-curve was estimated as shown in Fig. 7 [10]. The reference levels of the bit error rate were fixed as 1E-5 and 1E-4. The intercept between the 747-curve (@1E-5) and the

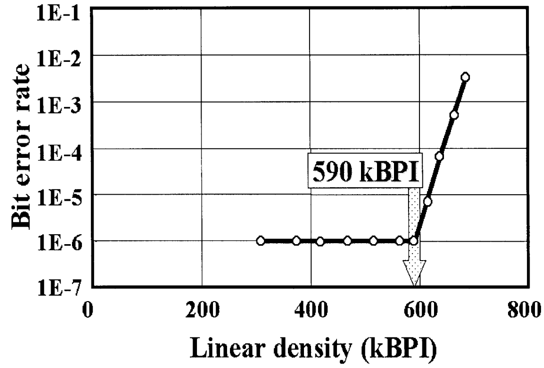

Fig. 5. Estimated BER performance.

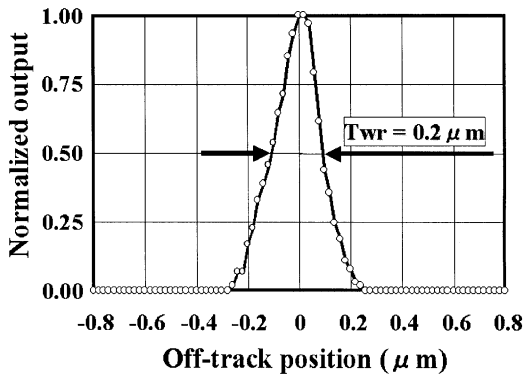

Fig. 6. Micro track profile of GMR head.

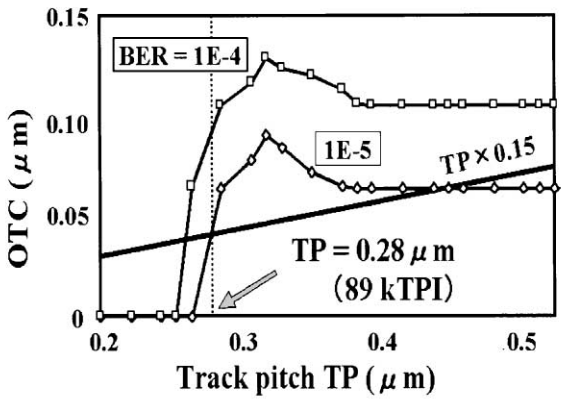

Fig. 7. Analyzed 747-curves.

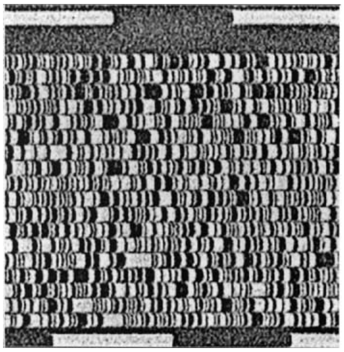

Fig. 8. MFM image of the recorded pattern.

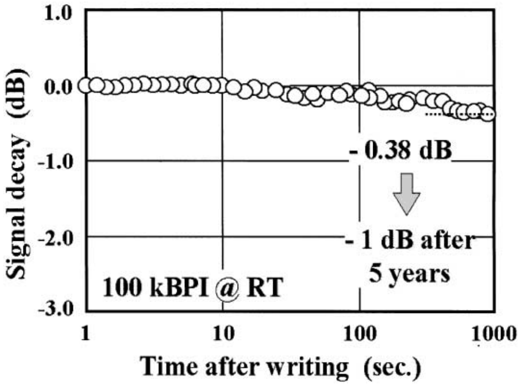

Fig. 9. Signal decay characteristics.

15% track pitch line gives the lowest track pitch that the system allows. In this case, the maximum linear density is 590 kBPI and at this linear density, the minimum track pitch that meets the first criterion is 0.28 μm. This yields an areal density of 52.5 Gb/in^2. Fig. 8 exhibits an MFM image of the recorded pattern. Here, the random pattern was written at a track pitch of 0.28 μm. From this result, we can see that each track was separated very clearly.

6. Thermal stability

Perpendicular recording is in contrast to longitudinal recording, and its lower density signal tends to decrease with time. So, we fixed the linear density at 100 kBPI and measured the stability of the signal at the room temperature. As shown in Fig. 9, signal decay at 1000 s after writing is -0.38 dB. If we extrapolate this decay characteristic up to five years, the signal decay is considered to be -1 dB. The experimental condition was not sufficient, however, these decay characteristics are not so far from the practical use.

7. Summary

To realize a recording density of over 50 Gb/in^2, a quarter-micron-track-width perpendicular head consisting of an SPT writer and an advanced GMR reader was developed. A low-noise and thermally stable double-layered medium and a signal processing technique suitable for perpendicular recording channel were also developed. From the results of this study, the potential of perpendicular recording for realizing 52.5 Gb/in^2 was clarified. At the same time, high frequency write characteristics at around 60 MB/s as well as the acceptable thermal stability characteristics were also confirmed.

Acknowledgements

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