Improvement of Dual-Layer HAMR Recording Conditions Using SMR

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Three-dimensional heat-assisted magnetic recording (3D-HAMR) with dual recording layer (DL-HAMR) aims to achieve high areal density using two conventional recording layers over one disk surface and simultaneous MR head reading. However, in conventional magnetic recording (CMR)-based DL-HAMR, the track width on the bottom layer becomes narrow due to the track width limit on the top recording layer, and the track on the top layer is also limited so as not to erase the information on the bottom layer. To address these issues, this study introduces shingled magnetic recording (SMR) into the DL-HAMR system. A simulation using a FePt granular medium with dual-layer structure was conducted. A two-pass write process with a Gaussian heat source was used, and the magnetization patterns were evaluated. SMR provided patterns close to the ideal track width for both layers. Furthermore, the medium signal-to-noise ratio (SNR) was measured, yielding 10.3 dB for CMR and 14.2 dB for SMR. The results show that the application of SMR improved the recording condition of DL-HAMR compared to the CMR method, and the medium SNR increased by approximately 4 dB.

***Index Terms*—Three-dimensional magnetic recording, Heat-assisted magnetic recording, Shingled magnetic recording, Magnetization pattern.**

I. Introduction

THREE-DIMENSIONAL (3D) magnetic recording is garnering considerable attention as a next-generation magnetic recording method to achieve high areal recording density by utilizing two recording layers on one surface and magneto-resistive (MR) head reading [1]. Heat-assisted magnetic recording with dual recording layer (DL-HAMR), which incorporates HAMR, has been proposed as a promising approach to realize 3D magnetic recording [2]. However, the leakage magnetic field from the bottom (second) recording layer, which is farther from the MR head, is weaker than that from the top (first) recording layer, resulting in a smaller amplitude of the reproduced waveform [3]. Furthermore, in DL-HAMR using conventional magnetic recording (CMR), which requires a guard band, the track widths of both recording layers must remain within the track pitch, making it difficult to maintain wide enough track widths on both layers. Therefore, we propose introducing shingled magnetic recording (SMR) [4] into the DL-HAMR system to mitigate the reduction in track width.

II. DL-HAMR read/write channel model

We simulate a granular medium with non-magnetic grain boundaries employing a discrete Voronoi model [5]. We assume FePt granular medium [2] for the recording layer of the DL-HAMR. The parameters of average grain size, standard deviation of grain size, and average non-magnetic grain boundary are set to 6 nm, 1 nm, and 1 nm, respectively. We assume that each grain has the first and second layers, and the dual recording layer is constructed on one surface of the disk by the grains. Here, the channel bit length and the track pitch are set to 12 and 26 nm, respectively. Thus, the areal recording density of each layer is 2 Tbits/inch^2, and the total areal recording density results in 4 Tbits/inch^2. The head-media structure for DL-HAMR was: Read/Write head / 5 nm Air / 4 nm first recording layer / 1nm Isolation layer / 8 nm second recording layer / Soft-under layer (SUL) [3].

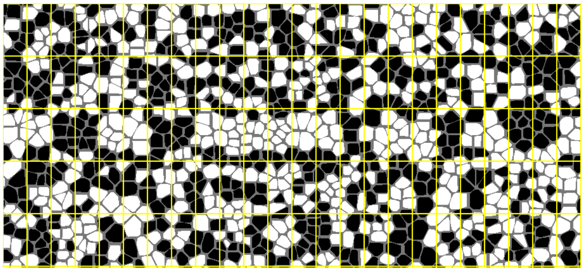
The coercivities of both recording layers are assumed to be 40 kOe at 0 K, and Curie temperatures of the first and second recording layers are also assumed to be $T_{c1} = 520$ K and $T_{c2} = 620$ K, respectively. Moreover, the Curie temperatures of each recording layer fluctuate with a standard deviation of 10 K. The temperature dependence of the media coercivity was calculated using a Curie-Weiss model [6].

In the writing process, we apply the two-pass write method and use the write head field distribution by the split main poles [6]. The heat source is installed between the split main poles. The heat distribution of the medium assumes a two-dimensional Gaussian distribution [3], where the standard deviations in the down-track and cross-track directions are σ_{hx} and σ_{hy}, respectively. Furthermore, we also assume the maximum temperatures in the first and second recording layers to be T_{max1} and T_{max2}. The coercivity of the magnetic grains in the medium was reduced below the write head field strength by heating, and the grains were magnetized in the direction of the writing field according to a recording sequence. The first recording layer was recorded after the second recording layer.

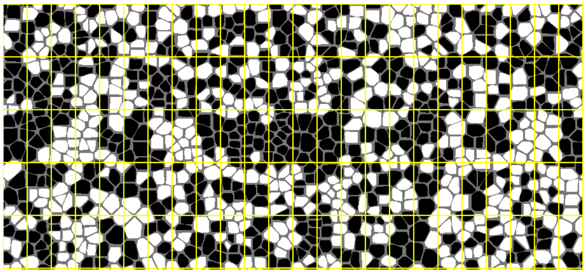
In the reading process, the reproduced waveforms for each layer were obtained by convolving the magnetization pattern with the MR head sensitivity function [3] for each recording layer. Finally, the simultaneous reading waveform was obtained by linearly adding the reproduced waveforms from the first and second recording layers, assuming no MR non-linearity.

III. Magnetization pattern

Figure 1 shows the CMR magnetization pattern recorded from left to right on the third track. (a) and (b) show the magnetization patterns for the first and second recording layers, respectively. The yellow lines represent the ideal bit boundaries,

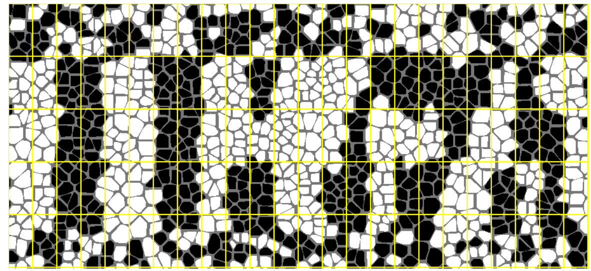


(a) First recording layer.

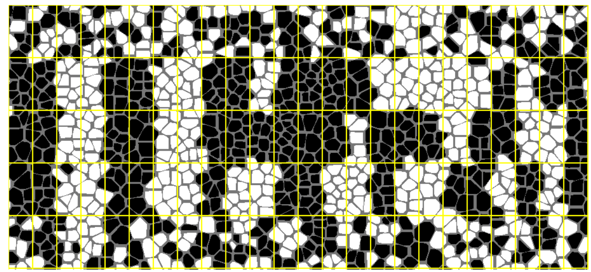


(b) Second recording layer.

Fig. 1. Magnetization patterns for CMR ($\sigma_{hx} = 6$ nm, $\sigma_{hy} = 12$ nm, $T_{max1} = 570$ K, $T_{max2} = 730$ K).



(a) First recording layer.



(b) Second recording layer.

Fig. 2. Magnetization patterns for SMR ($\sigma_{hx} = 6$ nm, $\sigma_{hy} = 22$ nm, $T_{max1} = 570$ K, $T_{max2} = 670$ K).

where the white and black polygons represent magnetic grains for the recorded data "0" and "1", respectively. The heat source properties are set to $\sigma_{hx} = 6$ nm, $\sigma_{hy} = 12$ nm, $T_{max1} = 570$ K, and $T_{max2} = 730$ K. In addition, opposite recording patterns are used for the first and second recording layers. As can be seen from the figures, the track width of the second recording layer is approximately equal to the ideal track width. However, on the first recording layer, information to be written on the first layer is not recorded near the track boundaries, and magnetization from the second recording layer remains in those regions.

Figure 2 shows the SMR magnetization pattern across three tracks, representing an SMR data set. The recording direction for all tracks is from left to right, as in the CMR case. In SMR, the second, third, and fourth tracks from the top are recorded sequentially in that order. The heat source properties are the same as in Fig. 1, except $\sigma_{hy} = 22$ nm and $T_{max2} = 670$ K. Also, the recorded data in the third track is the same as that in Fig. 1. As can be seen from the figures, by applying SMR, magnetization patterns nearly identical to those with the ideal track width are obtained for both recording layers. Therefore, the medium signal-to-noise ratio (SNR_M) was measured by comparing the dual-layer simultaneous reproduced waveform from an ideal recording medium divided into rectangles with that from a granular medium. The results were SNR_M= 10.3 dB for CMR and SNR_M = 14.2 dB for SMR, indicating that the adoption of SMR resulted in an SNR improvement of approximately 4 dB.

IV. Conclusion

We have proposed introduction SMR into the DL-HAMR system to mitigate the reduction in track width. The results show that the application of SMR improved the recording condition of DL-HAMR compared to the CMR method, and the medium SNR was increased by approximately 4 dB.

Acknowledgements

This work was supported by JST, CREST Grant Number JPMJCR22C3, Japan and the Advanced Storage Research Consortium (ASRC), Japan.

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