Write current control based on THMap in HAMR

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Both laser and write currents have large impact on write-ability, areal density capability (ADC), and reliability in heat assisted magnetic recording (HAMR). We utilized THMap for two objectives, to obtain laser and write currents condition which saturates magnetization switching of grains, and to calculate write current dependence of write temperature (T_w). ADC was maximized at higher laser and write currents than those to saturate magnetization switching. It indicates that laser and write currents for magnetization saturation are requirements to maximize ADC. To achieve both maximization of ADC and reliability, we considered an approach to reducing laser current with increased write current. From the comparison of two different design heads, write current dependence of T_w was well matched to that of magnetic write width. The approach to keep high ADC with reduced laser current and increased write current succeeded with the head which could reduce T_w by increase of write current.

***Index Terms*—heat assisted magnetic recording (HAMR), laser current, write current, THMap.**

I. Introduction

In heat assisted magnetic recording (HAMR) of hard disk drives (HDDs), heat power and magnetic field strength are adjusted by laser and write currents, respectively, with the aim of maximizing areal density capability (ADC) and reducing write stress for reliability [1]-[3], which contradict each other. High probability of magnetization switching with sufficient laser and write currents is required to obtain good bit error rate [4]. However, the relation between probability of magnetization switching and ADC is still unknown. In the point of view of reliability, increase of head temperature is a dominant factor of write quality degradation in long-run test [5]. The reduction of laser current is crucial to reliability of HAMR. First, we discussed laser and write currents dependence of ADC and its relation to saturate magnetization switching probability. Next, write current dependence of write temperature (T_w) was discussed to explore the approach to reducing laser current with increasing write current.

II. Experimental method

All measurements were conducted using HAMR drives in temperature controlled chamber at 35 °C. We used THMap [6] to evaluate magnetization switching probability of media grains as a function laser and write currents. THMap measured noise power after reversed DC write, which is assumed to be related to the magnetization switching probability.

To compare with THMap, ADC of conventional magnetic recording (CMR) system was measured under multiple laser and write currents conditions. In the measurement, we used the industry standard method [7] with 6 times write in each adjacent track, and track density (TPI) was relaxed by 10 % from track pitch which satisfies 50 % sector failure rate.

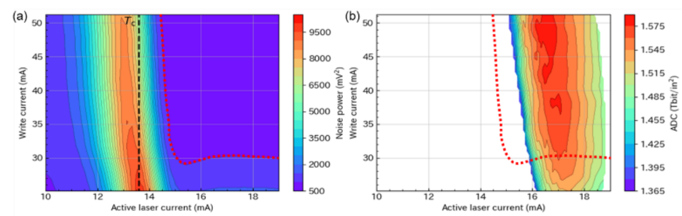

Fig. 1. (a) A THMap, noise power as a function of active laser current which is laser current above lasing threshold, and write current. Region boundary of noise power saturation is shown in red dotted line. Active laser current 13.6 mA corresponds to T_c where noise power reached peak under minimum write current, 1.8 mA. (b) A 2-D ADC map. The region boundary from (a) is shown in red dotted line.

III. Results and discussion

Fig. 1 (a) shows a THMap. We considered that media temperature reached Curie temperature (T_c) at active laser current 13.6 mA where noise power was maximized under minimum write current, 1.8 mA. Media temperature needs to be higher than T_c to reach the saturation region, whose boundary is shown in red dashed line, because actual T_c for each grain has distribution. As well as the temperature requirement, saturation recording requires sufficiently high write current, approximately 30mA in Fig.1 (b), in order to overcome thermal agitation [8]. Fig.1 (b) shows a 2-D map of ADC as a function of active laser and write currents. Additionally, the same region boundary of noise power saturation is overlayed in red dashed line. Higher laser current than the boundary condition is required to maximize ADC. On the other hand, maximum ADC along laser current-axis almost saturated within the saturation region, and dropped if write current is below the boundary condition. In Fig.1 (b), overshoot amplitude of write current (OSA) and its duration were set to 50.8 mA and 268 psec, respectively. In addition to the condition shown in Fig.1 (b) with OSA 50.8 mA, ADC was measured with multiple OSA conditions from 42.3 mA to 93.1 mA. In all OSA conditions, ADC was maximized with higher write current than that of noise power saturation. It suggests that laser and write currents

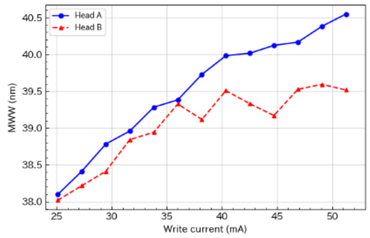

Fig. 2. Write current dependences of MWW for two head designs. Fixed active laser current 18.4 mA, and 15.3 mA were selected where MWW is around 38 nm at write current 25 mA, respectively.

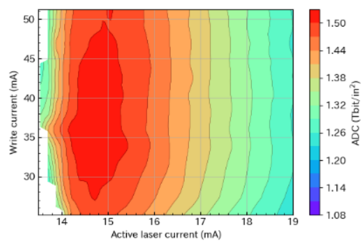

Fig. 3. A 2-D ADC map of head B. Compared with Fig.1 (b), it is less sensitive to write current.

for noise power saturation could be utilized as a necessary condition to maximize ADC. From the point of view of reliability, Fig. 1(b) also suggests the approach to reducing laser current while maintaining high ADC by increased write current.

Fig. 2 shows write current dependence of magnetic write width (MWW) under fixed laser current. Two heads with different designs, head A and head B, were tested. Head A was utilized in Fig. 1. MWW of head A increased monotonically with increase of write current. On the other hands, MWW of head B saturated at write current 40 mA. It means that write current of head B above 40 mA could not modulate TPI. Fig. 3 shows a 2-D ADC map of head B. While ADC highly depended on laser current, ADC modulation by write current was relatively small. It means that head B could not reduce laser current to keep high ADC. Fig. 4 shows write current dependence of T_w calculated from THMap [6]. T_w of head A decreased with increased write current. In contrast, head B showed saturation of T_w decrease around write current 40 mA. Since media temperature is maximized under near field transducer (NFT) and decreases toward cross track direction, decrease of T_w expands write width with fixed laser current. T_w decrease by write current increase in Fig. 4 represented MWW modulation by write current well.

IV. Summary

Laser current and write current sensitivities of noise power in THMap, and of ADC were discussed. To maximize ADC, noise saturation in THMap is required, however it is not sufficient condition, especially for laser current selection. More importantly, increasing write current can reduce T_w, and widen MWW, and consequently similar ADC can be achieved in lower laser current, which must gain reliability. The amount of such an effect depended on head design.

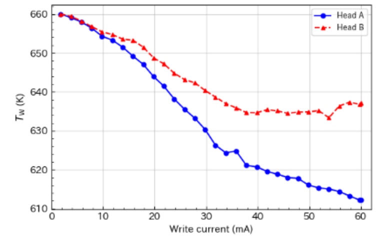

Fig. 4. Write current dependences of T_w calculated from THMap for two head designs. In T_w calculation, we assumed that T_c is 660 K.

References

[1] C. Rea, *et al*., “HAMR performance and integration challenges,” *IEEE Trans. Magn*., vol. 50, no. 3, pp. 62-66, Mar. 2014.

[2] N. A. Natekar, E. Roddick and R. M. Brockie, "Interplay of the Thermal and Magnetic Fields in HAMR," *IEEE Trans. Magn*., vol. 58, no. 4, pp. 1-8, April 2022, Art no. 3101208.

[3] S. Grans, C. Rea, G. Ju, P. Czoschke, and S. Hernandez, “Heat Assisted Magnetic Recording Areal Density Dependence on Writer Current for Conventional and Shingled Magnetic Recording,” *The 34th Magnetic Recording Conference (TMRC). IEEE*, 2023.

[4] A. Sakoguchi, J. Zhang, N. Ito and J. Lee, "Use of THMap for write performance characterization in HAMR," *IEEE Trans. Magn*., to be published.

[5] T. D. Trinh, S. Rajauria, R. Smith, E. Schreck, Q. Dai and F. E. Talke, "Temperature-Induced Near-Field Transducer Failure in Heat-Assisted Magnetic Recording," *IEEE Trans. Magn.,* vol. 56, no. 6, pp. 1-4, June 2020, Art no. 3300304.

[6] P. -O. Jubert, *et al*., “Spin-stand measurements to extract the switching distributions of heat-assisted magnetic-recording media,” *IEEE Trans. Magn*., vol. 59, no. 3, pp.1-5, Mar. 2023.

[7] S. D. Granz, *et al*., "Definition of an Areal Density Metric for Magnetic Recording Systems," *IEEE Trans. Magn*., vol. 53, no. 2, pp. 1-4, Feb. 2017, Art no. 3100104.

[8] Y. Qin and J. -G. Zhu, "Impact of Magnetic Medium Grain Height in Heat-Assisted Magnetic Recording," *IEEE Magn. Lett.*, vol. 10, pp. 1-5, 2019, Art no. 6502305.