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Characterization of media cross-track thermal profile in heat-assisted magnetic recording

Baoxi Xu*, Hongxing Yuan, Jun Zhang, Rong Ji, Qide Zhang, Xiangshui Miao, Tow Chong Chong

Data Storage Institute, 5 Engineering Drive 1, Singapore 117608, Singapore

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Abstract

In the heat-assisted magnetic recording, the thermal profile of the media affects the recording performance seriously. Unfortunately, there is no direct method to measure it dynamically. In this paper, an indirect method is proposed to characterize the cross-track thermal profile with the spin-stand. The experimental results indicate that the local temperature increase has nonlinear relationship with the laser power. As the laser power increases, the thermal profile width increases. The media has a higher temperature increase and a bigger thermal profile at a slower rotation speed. The reasons for these phenomena are explained as well.

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Keywords: Heat-assisted magnetic recording; Hybrid recording; Magnetic recording media; Thermal effect

1. Introduction

As a promising approach to overcome the superparamagnetic effect and push the magnetic recording density to beyond 1 Tb/in.^{2}, the heat-assisted magnetic recording (HAMR) has attracted more efforts. In this approach, the laser is used to heat the magnetic media to reduce its coercivity so that the magnetic field of the available magnetic head is strong enough to switch the magnetic domain. During the recording process, the media's thermal profile caused by laser heating may seriously affect the recording performance. Theoretical analysis with thermal Williams–Comstock model showed that the existence of the thermal gradient caused the transition location changes along track direction and cross-track direction with assuming the thermal profiles as Gaussian shapes [1,2]. The broader track widths were caused with higher central temperature and with broader temperature distribution [2,3]. The track width broadening with laser power increase was observed in experiment [4]. Thermal erasure on the neighboring tracks is another serious problem in HAMR. It was shown that the erasure was primarily determined by the temperature profile on the media after shining of the laser beam. The sharper the thermal profile is, the more the recording performance improvement can be achieved.

All of above researches show that the thermal profile caused by laser beam affects the recording performance seriously. However, there is no research dwelling on the inherent thing, i.e., the real thermal distributions of the rotating media and its regularity. In this paper, the media's cross-track thermal distribution is investigated by using HAMR spin-stand.

2. Experiment

Up to now, there is no direct method to measure the thermal profile of the rotating disk caused by laser radiation because of the small thermal profile and the high speed rotation of the media. In this investigation, an indirect method is proposed to study it with the HAMR

*Corresponding author. Tel.: +65 68748512; fax: +65 67778517.
E-mail address: xu_baoxi@dsi.a-star.edu.sg (B. Xu).

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spin-stand. The spin-stand is a far field HAMR spin-stand [5]. The laser with wavelength of 405 nm is focused on magnetic recording layer through the glass substrate by an objective lens with numerical aperture (NA) of 0.6 and around 550 nm of laser spot size (full-width half-maximum, FWHM) is measured. The giant magnetoresistive (GMR) magnetic head with write head width of 200 nm is used, and the alignment between magnetic write head and laser beam spot can be finely adjusted. The adopted media is longitudinal magnetic recording media with structure of Glass/CrMo/CoCr/CoCrPtB/C, which is similar to the media in Ref. [6]. The temperature dependence of the coercivity (Hc) from 300 to 480 K is measured with vibrating sample magnetometer (VSM) and a linear relationship with formula:

$$\mathrm{Hc}(T) = -12.381T + 6401.6 \tag{1}$$

is obtained, where T is absolute temperature. The localized temperature is evaluated by the overall consideration of the media's coercivity dependence on temperature and the write current saturation curve net shifts [6]. The write current saturation curves of the media at different laser powers are measured and the remanent coercive current (the current corresponding to the half-value of the saturated track average amplitude (TAA)) changes are derived [7]. Based on the temperature dependence of the coercivity, the local temperature change of the media can be evaluated.

In order to obtain the cross-track thermal profile, the following method is proposed: firstly, the laser beam spot is focused on one track (called as central track) and the magnetic head is aligned on same track, the write current saturation curves are measured and then the temperature changes at this track are evaluated at different laser powers; secondly, the magnetic head is moved to adjacent tracks (first tracks) but the laser spot is still kept on central track, the write current saturation curves at this track are recorded down and the corresponding temperature changes are obtained; thirdly, the procedure in the second step is repeated for other tracks (second tracks, third tracks, fourth tracks, etc., but always keep the laser spot on central track) and their temperature changes are obtained. The thermal profiles at different laser powers and different rotation speeds can be plotted finally. In this study, the rotation speeds are 2000 and 3000 rpm, which correspond to 6.5 and 9.75 m/s linear speeds, respectively. The write speed is 5 MHz and the track pitch is 450 nm.

3. Results and discussion

The write current saturation curves of the central track and the fourth track (away from central track) at 2000 rpm are shown in Fig. 1(a and b), respectively. The decreases of the saturation current with increasing laser power indicate that the coercivity of the media has been reduced. The corresponding remanent coercive currents at these two tracks are plotted in Fig. 2(a). It illustrates clearly that as the laser power increases, the remanent coercive current reduces. The remanent coercive current of the fourth track reduces slowly and near linearly. But the remanent coercive current of central track reduces faster and nonlinearly. From these results and the temperature dependence of the coercivity, the temperature increases at both tracks with increasing laser power are obtained as shown in Fig. 2(b). The main reasons for the nonlinear temperature increase can be understood by the following explanations:

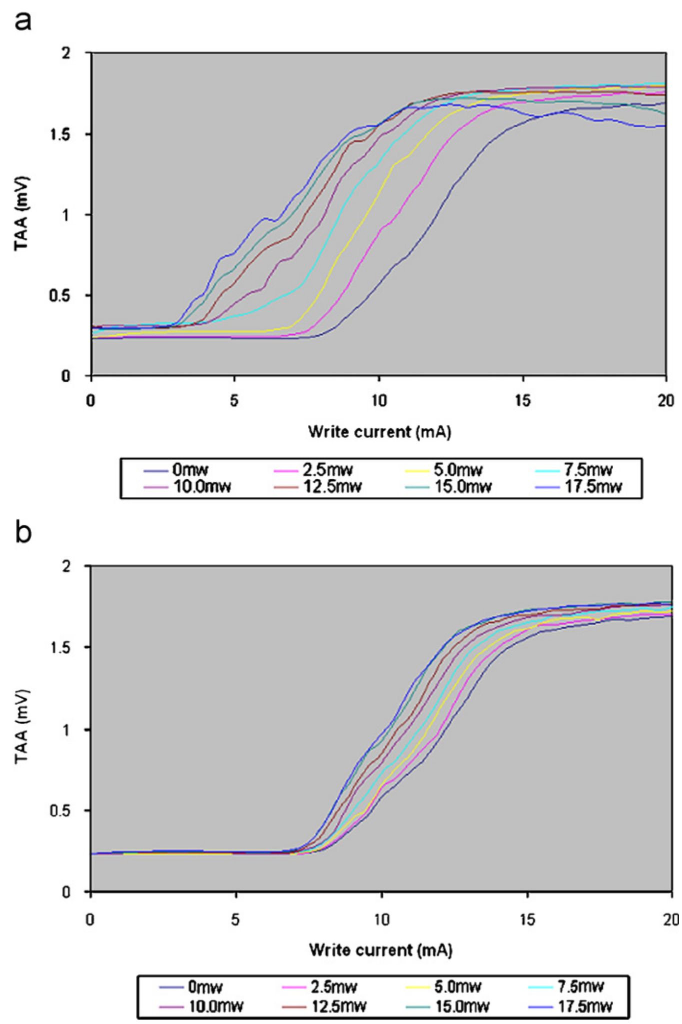

Fig. 1. Write current saturation curves of the central track (a) and the fourth track (b) at 2000 rpm.

(a) Most of the alloy have the property that their thermal conductivity increases with increasing temperature [8–10]. In this experiment, the recording material is alloy too. As the temperature increases, the material's thermal conductivity increases. This will lead to more thermal energy conducting to the ambient area and slow down the temperature increase rate.

For simplicity, one-dimensional (1D) heat diffusion equation is used in the discussion.