Thermal Footprint Measurements for Heat Assisted Magnetic Recording

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A method for characterizing the thermal footprints generated by a heat-assisted magnetic recording head (HAMR) onto an HAMR medium is presented. It uses a static tester and has the advantage over traditional recording techniques of measuring an undistorted two-dimensional image of the temperature profile, highlighting the lower temperature background created in the medium. Two-dimensional temperature profiles obtained from different near-field transducer (NFT) designs are presented that compare very well to expectations from optical/thermal modeling.

***Index Terms*— Heat-assisted magnetic recording (HAMR), static tester, near-field-transducer designs, temperature profiles.**

I. Introduction

HEAT ASSISTED MAGNETIC RECORDING (HAMR) is being introduced in hard disk drives to enable areal densities beyond that of enhanced perpendicular magnetic recording (e-PMR) technology [1]. HAMR recording relies on locally heating the recording layer FePt magnetic grains to temperatures just above their Curie temperature (~660K), enabling data writing into the high anisotropy medium with conventional writer fields while the grains cool. The heat spot defines the writing location and is achieved by the absorption of light confined into the medium via a near field transducer (NFT) excited by a laser and positioned at the air bearing surface of the HAMR head [2-4]. The thermal profile results from both the optical characteristics of the coupled NFT-media system and the thermal transport properties of the media. The characteristics of the thermal hot spot in the recording layer play a large role in determining the areal density capability of the media: high areal densities require high thermal gradients and narrow thermal write widths to enable good on track performance and high track density.

Partial temperature profile information is accessible from down-track and cross-track gradient measurements in hard disk drives or spin-stand testers [5]. But due to the high disk velocity (~20m/sec), direct measurement of the full two-dimensional thermal profiles is practically not accessible in these recording systems.

In this work, we present a new method that allows measuring the two-dimensional temperature map generated by an NFT into the recording layer by using pulse recording with a static tester.

II. Experimental Measurement of Thermal Footprints

The thermal footprint measurements are performed using a piezo scanning write/read tester [6-8]. This setup allows for a very accurate positioning of an HDD head over a recording medium. The head slider is in contact with the disk at an optimized tilt angle and dragged over the medium at 100 μm/s. A conventional HAMR medium that is initially thermally erased is used for the measurements.

At controlled intervals, the laser diode embedded in the HAMR head is excited with 50 nanosecond pulses. Before each laser pulse, the writer coils are energized at a set amplitude and polarity. The magnetization orientation changes in the direction of the applied field only in areas where the temperature exceeds the media writing threshold. This results in the writing of isolated head footprints into the HAMR medium. A two-dimensional readback image of the media allows to measure the extent of the write footprint.

Write footprints of alternating writer polarity are written on the medium at regular interval, typically of more than 1 μm apart. The amplitude of the laser pulse is varied sequentially from a reference value, LP_{ref}, and a second value, LP. At LP_{ref}, small footprints are formed that serve as alignment marks to average hundreds of footprints generated at the laser power LP. From each average write footprint, the footprint contour is defined as the location where the readback signal amplitude is 50% of the maximum readback signal, which corresponds to a temperature isotherm in the recording layer. At the applied field used in this experiment, T_w is 625K [9].

Thermal footprints are measured and averaged for varying laser power LP, allowing to extract the footprints boundaries or T_w isotherms for each laser power (Fig. 1). Increasing the input laser power results in progressively larger magnetic footprints. These set of T_w isotherms are tomographic projections of the temperature profile generated by the NFT in the HAMR medium. The head/medium optical/thermal system is linear, such that the change in medium temperature is directly proportional to the laser power change. The T_w isotherms at different laser power LP can be converted into a temperature contour map at a fixed laser power LP_0:

$$T\left(x_{T_w}, y_{T_w}\right)_{@LP_0} = T_{amb} + \frac{LP_0}{LP}\left(T_w\left(x_{T_w}, y_{T_w}\right)_{@LP} - T_{amb}\right)$$

Typically, we chose LP_0 corresponding to a 50 nm written track width or equivalently such that the T_w contours extend up to +/- 25 nm in the cross-track direction. The contour line measured at $2\text{x}LP_0$ is the location where the temperature is $(T_w - T_{amb})/2$ or 460 K at LP_0.

Fig. 1(a)-(b) shows two-dimensional temperature maps measured on the same recording medium using HAMR heads with two different NFT designs. The laser power LP_0 is adjusted for each case to the same 50-nm wide written track width. The first NFT design produces low temperature background that

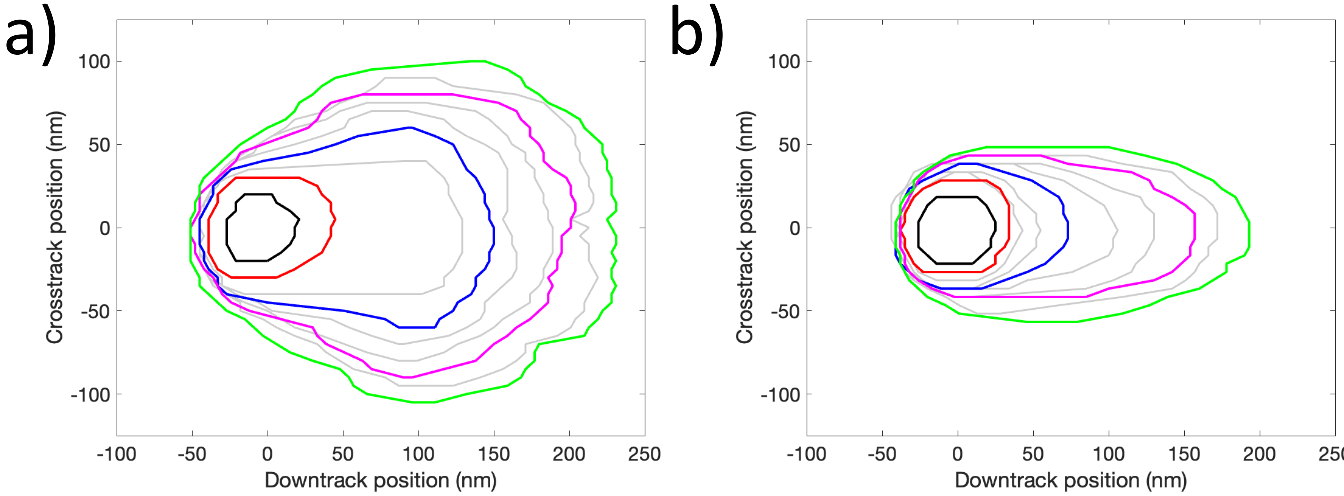

Fig. 1. Two-dimensional thermal footprints measured for HAMR heads with different NFT designs on the same HAMR medium. The temperature footprints are for a laser power that produces 50-nm wide written tracks. Color lines correspond to isotherms at (black) 625K, (red) 600K, (blue) 550K, (magenta) 500K, and (green) 475K. Grey lines are intermediate isotherms that are less than 20K apart.

extends towards the leading side of the footprint and widely cross-track. The medium is heated to 500 K at +/- 100 nm from the track center, which given typical switching temperature distributions of HAMR media [9] can lead to noticeable adjacent track erasure. The second NFT design is modified to significantly reduce the extent of the low temperatures in the cross-track direction, which lead to improved recording capability.

III. Conclusion

With the combination of slow head motion and fast laser diode pulse, the proposed method provide a means to measure an instant and non-smeared two-dimensional temperature profile that is characteristic of the NFT and medium optical and thermal designs. Thermal profiles for different combinations of NFT designs and media designs can be obtained, highlighting the low temperature background in the recording medium. These profiles can be compared to optical/thermal simulation results to validate assumptions used in the modeling, extract optical/thermal properties of the media, and more generally to reveal performance limiters in the head/medium optical and thermal designs.

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