Spacing Control in Heat Assisted Magnetic Recording

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I. Introduction

Heat assisted magnetic recording (HAMR) is one of the promising technologies for delivering higher areal density than traditional perpendicular magnetic recording (PMR). HAMR uses thermal energy to assist magnetic switching in the media during the writing process. A few optical components are introduced into HAMR to deliver the thermal energy to the media, including a laser diode to provide energy and a near field transducer (NFT) which confines the light to a tiny spot on the media. Integrating those components into HAMR is a significant challenge, which requires extended understanding of near filed optics as well as nanoscale thermal, mechanical and magnetic behavior and multi-physics coupling. Over the last decade, the industry has made significant progress in HAMR integration, such as novel and reliable NFT devices, more robust head disk interface (HDI) materials, and thermal management of the HAMR head and media. In this report, we will focus on the successful mechanical integration of HAMR HDI: spacing control.

Spacing control in HAMR includes two major efforts: protrusion or spacing measurement, and compensation of the transient and steady state protrusions. As with the PMR head, a HAMR head will have a writer protrusion which is induced by the writer coil power, and a single thermal fly height control (TFC) or dual TFC protrusion which is a key actuator to adjust the spacing. The measurement and compensation of the writer protrusion and the TFC protrusion is the same for both traditional PMR and HAMR. However, one key difference between HAMR and PMR spacing control is the laser induced protrusions (LIP) [1-3]. A large portion of the light energy is dissipated as heat in the laser diode, NFT and other components in the HAMR head. The temperature of the head rises and thermal deformations occur whenever the laser emits light. The LIP makes the spacing control in HAMR more complicated than PMR in two ways: measurement of the LIP magnitude and compensation of the fast transient process.

II. Protrusion measurement

Several studies have provided insightful understanding of the LIP in the past few years [1-4]. The studies show that the LIP can be separated into two parts, based on their transient characteristics and physical locations, as shown in Figure 1. One part of the LIP is the NFT protrusion, which a protrusion located around the NFT, magnetic writer and reader. The laser energy is absorbed around the NFT, resulting in locally higher temperature in that region. The NFT and its surrounding structures deform and protrude towards the media. This NFT protrusion develops as fast as a few microseconds and reaches steady state in a time scale of 100 µs. The remaining part of the LIP is a much broader deformation due to the heat diffusion throughout the entire slider body. This part of the protrusion is called fly-height change (FHC). The FHC occurs over a time scale of 1 ms.

Figure 1 Laser induced protrusion in HAMR (a) localized NFT protrusion (b) fly height change due to slider crown and camber change.

The FHC can be measured from the readback signal by use of the Wallace Spacing Loss law. Strictly speaking, this measurement only provides the spacing change at the reader location. However, the reader, writer and NFT move in conjunction with the slider body during the FHC, so the reader spacing change can be treated as the FHC.

The NFT protrusion is more localized than the FHC. The NFT spacing is not equivalent to the spacing measured at the reader location. The NFT protrusion has a sharper curvature compared with the FHC, and it also indicates that traditional touchdown techniques may not be sufficient to define the contact plane between the NFT protrusion and the media. Furthermore, the TFC backoff setting becomes more complicated since the NFT protrusion affects the TFC actuation efficiency. Instead, a magnetic recording based method: burst writing scheme (BWS) has been proposed recently to overcome these difficulties [4]. This BWS constructs a calibration curve between the HAMR writing quality and the NFT spacing for a given head disk combination. This relationship can then be used to set the write spacing and measure the writer and NFT protrusion. The BWS has been successfully implemented in both spinstands and HAMR drives.

III. Transient compensation

The NFT protrusion develops in tens of µs. An outcome of this transient is a write start transient, in which the written-in amplitude is smaller at the beginning of the data writing [2, 5], as shown in Figure 2a. This transient needs to be compensated in order to achieve stable recording over all sectors. The major challenge of this transient compensation is the relatively slower response of current TFC actuator with respect to the fast NFT protrusion. Several methods have been proposed and successfully demonstrated to mitigate this write start transient [5]. By applying the appropriate profiles of the TFC power (TFC undershoot) and laser power (laser overshoot and laser prebias) to the HAMR system, the write start transient can be compensated and stable recording is achieved, as demonstrated in Figure 2b.

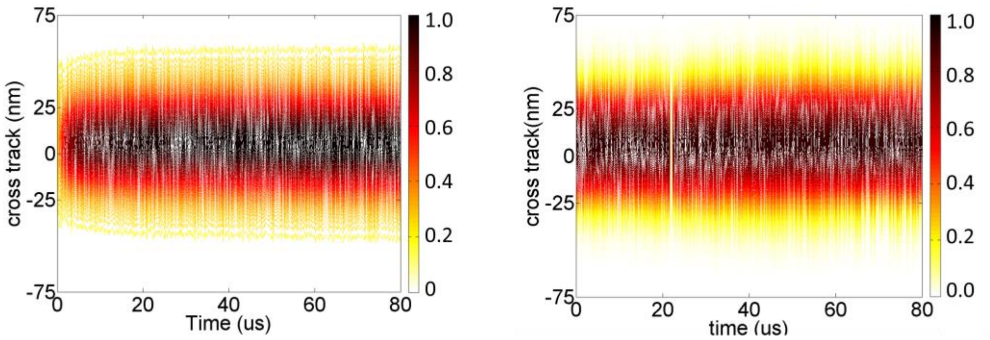

Figure 2. Two-dimensional amplitude map of a HAMR track to illustrate the write start transient and the compensation. (a) write start transient; (b) transient is compensated by TFC undershoot.

IV. Summary

In this report, we discuss the unique thermal mechanical behavior of HAMR when the laser is on: localized NFT protrusion and broad FHC. The NFT protrusion complicates the spacing control in HAMR because the magnitude is difficult to quantify and the fast transient is difficult to compensate using the TFC actuator. The BWS has been proposed and successfully implemented to measure the protrusions and assist in setting the spacing. Furthermore, this transient can be mitigated or eliminated by TFC undershoot, laser prebias and laser overshoot.

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