HAMR Absorbing Carbonaceous Smear Combustion Kinetics in Different Oxygen Environment

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Heat-assisted Magnetic Recording (HAMR) technology enables areal density scaling to meet growing storage needs. In HAMR recording, a nanometer sized spot on the media surface is heated beyond the Curie temperature (~450˚C) of the FePt layer to facilitate writing. Such high temperature causes media surface materials to accumulate on heads, leading to the formation of smear that impacts the reliability and performance of HAMR near-field transducer (NFT). In this study, kinetics of the carbonaceous absorbing smear combustion is studied as a function of oxygen concentration of the environmental gas inside the enclosed chamber. Our experimental results suggest that higher oxygen leads to a faster combustion of the absorbing smear at the interface, and can help improve NFT reliability.

***Index Terms*—Heat-assisted magnetic recording, Smear, Absorbing, Kinetics, Gas composition.**

I. Introduction

SMEAR is a key challenge to commercialize heat-assisted magnetic recording (HAMR) technology. In heat-assisted magnetic recording, a near-field transducer (NFT) on the air bearing surface of the slider is used to convert optical power from a laser diode to heat a nanometer spot on the HAMR media above the Curie temperature to facilitate writing. The local nanoscale heating spot leads to carbon overcoat and lubricant desorption and degradation that transfer to the head surface [1,2,3]. Smear in the vicinity of the near-field transducer consists of various materials with different optical and thermal properties, causing recording performance fluctuation such as track width and signal to noise ratio (SNR) variation [1,2,3,5,6]. More importantly, head smear with high extinction coefficient k that absorbs light leads to smear self-heating, thereby increasing the NFT temperature. Elevated temperature leads to NFT degradation. It is hypothesized that in N_2 condition, carbonaceous smear would accumulate on NFT area, causing self-heating, while in the presence of oxygen, such smear will be oxidized, and NFT temperature decreases as a result. In this study, kinetics of the absorbing carbonaceous smear combustion is studied as a function of oxygen concentration and humidity of the environmental gas inside the enclosed chamber.

II. EXPERIMENTAL SETUP

Experiment is conducted using a Guzik spinstand enclosed inside an environmental chamber as shown in the Figure 1. Oxygen concentration can be controlled by tuning flow rates of the dry air and dry nitrogen gas inlet valves. Humidity inside the chamber is controlled using a bubbler with deionized water. Environmental chamber pressure is kept at the atmospheric pressure (1atm) and temperature is maintained at 25˚C. Temperature, relative humidity, and oxygen concentration inside the chamber are measured using sensors located near the head-media interface.

To monitor local NFT temperature changes, an embedded sensor is fabricated near the NFT, named NFT temperature sensor (NTS) [7]. A constant direct current of 2mA from a spinstand controller is applied to the sensor, and the voltage signal across the NTS sensor is measured using an oscilloscope. NTS sensor signal results from combined effect of laser power that couples to the NFT (or laser-induced NTS), and the corresponding local temperature increase due to smear. While laser-induced NTS stays constant at a fixed laser power, NFT temperature rise is a strong function of the smear extinction coefficient k at the head-media interface is shown in Figure 2.

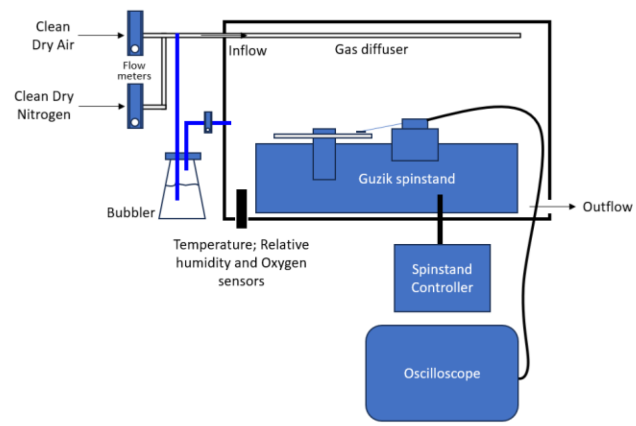

Figure 1: *Schematic of a Guzik spinstand enclosed inside an environmental chamber*

At the beginning of the experiment, the chamber was purged with dry air (20% O_2 + 80%N_2) gas. HAMR head was loaded to the MD location of the HAMR media. The head was kept flying at approximately 10nm spacing on the media surface. Laser current was optimized to target 50nm Magnetic Write Width (MWW) on the HAMR media as shown in literature [4]. After laser optimization, NTS signal was measured for 5 seconds as a baseline during HAMR writing using the optimized laser current. Then clean dry air gas was stopped, clean dry nitrogen gas was purged to the chamber until reaching <1%O_2 level inside the chamber. Following nitrogen purging, NTS signal was measured for 20 seconds continuously with the same laser current mentioned above. After continuous writing in dry nitrogen environment, both flow meters to oxygen and nitrogen are opened to reach a designated percentage of oxygen inside the chamber, ranging from 1% to 20% O_2. NTS signal was measured for another 60 seconds. Raw NTS signals were recorded and analyzed to investigate the effects of oxygen concentration on the changes of the NTS signals.

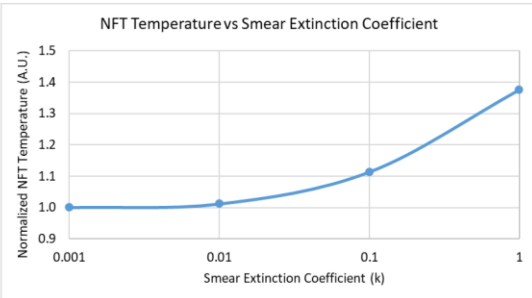

Figure 2: *NFT temperature as a function of smear extinction coefficient k*

III. EXPERIMENTAL RESULTS

After the test was completed, changes of the NTS signal (deltaNTS), was calculated by subtracting the laser-induced NTS signal, to estimate local temperature changes around the NFT caused by smear self-heating. Typical deltaNTS signals are shown in Figure 3. We observed that deltaNTS stays constant in dry air environment as shown by blue lines in Figure 3. Switching to <1%O_2 environment leads to an increase of deltaNTS signals as shown in the red lines, indicating a local temperature rise. After switching to different %O_2, the deltaNTS signals start decreasing, suggesting a decrease of the local temperature near NFT. The decrease of the deltaNTS signals is believed to be due to the removal of the absorbing smear at the head-media interface at different oxygen concentration.

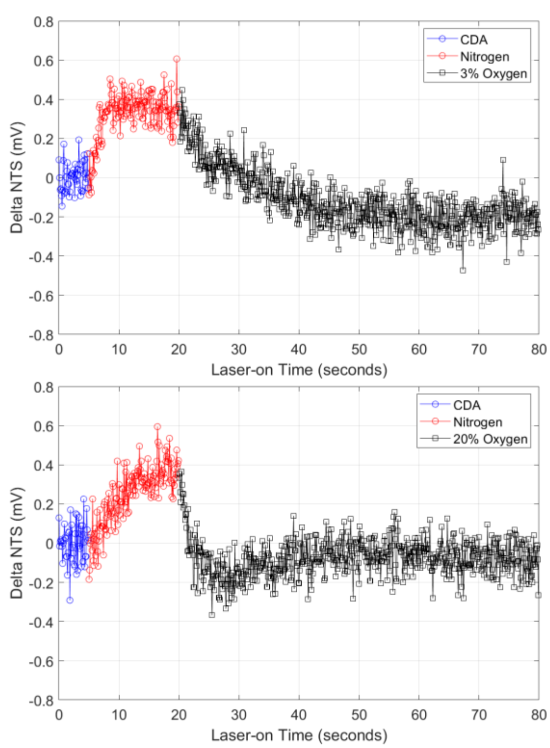

Figure 3: *DeltaNTS signals in clean dry air (CDA), nitrogen, and different oxygen concentration gas*

deltaNTS curve can be fitted using an exponential decreasing function, such as in Figure 4, to determine the time constant of the removal process of absorbing smear at the HAMR head-disk interface at different oxygen concentration, respectively. We observed that 20% oxygen leads to much faster combustion of the absorbing smear than 3% oxygen condition.

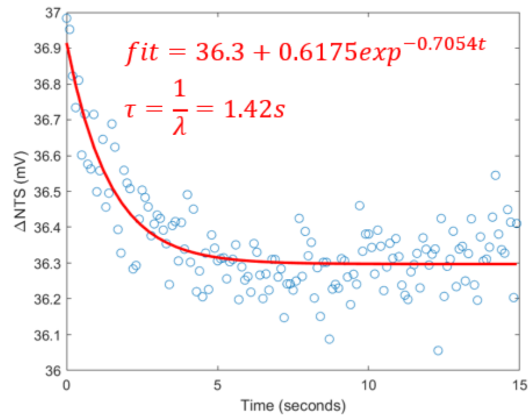

Figure 4: *Exponential decreasing function fitting for deltaNTS signal*

Our experimental results show absorbing smear combustion time constant is a strong function of oxygen percentage inside the environmental chamber in Figure 5. As oxygen percentage increases, time constant of the removal process decreases sharply, indicating a shorter duration to oxidize the absorbing smear. This finding, along with other improvements, can help with NFT lifetime improvement. Similar study was carried out on relative humidity effect which will be discussed in the full paper.

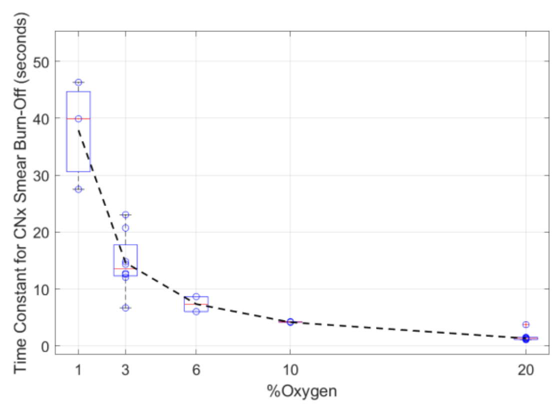

Figure 5: *Time constant to remove absorbing carbonaceous smear as a function of oxygen percentage in environmental gas composition*

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