The Computational Analysis of HAMR Media Noise with a Multilayer Micromagnetic Media Model

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Heat-assisted magnetic recording (HAMR) media noise is a critical factor in determining HAMR recording performance. In this study, we employ an exchange-coupled multilayer media model to analyze the media noise. We present a computational investigation of THMap metrics, especially the top and bottom edges of the THMap, to extract the switching distributions. We focus on the cap magnetic properties and interlayer vertical exchange coupling to evaluate their impact on the THMap metrics. We find that introducing the domain wall ("incomplete switching") into a proper location of multilayer stack reduces the media noise. In parallel, we run recording simulations to relate THMap metrics to the recording performance. These results contribute to a better understanding of future HAMR media design.

Index Terms— **Areal Density, Heat Assisted Magnetic Recording, micromagnetic simulation**

I. Introduction

Heat-assisted magnetic recording (HAMR) is a breakthrough storage technology to increase the storage capacity in hard disk drives. It has the capability to push areal density (AD) growth beyond 5Tb/sq.in [1]. A key component of HAMR is L10-FePt medium, which consists of small grains with high magnetic anisotropy field (Hk). The medium distributions, such as the Hk and Curie temperature (Tc) distributions, are critical factors for limiting the recording performance in the writing process. Previously, several efforts have been made to mitigate the transition noise; a composite medium structure with superparamagnetic writing layer [2] and incoherently switched magnetic grains with sufficient height [3] were proposed to reduce jitter noise. Here we investigate the media noise using THmap metrics. In our exchange-coupled multilayer media model, the cap magnetic properties and interlayer vertical exchange coupling are varied to see how the media noise is affected. We present recording simulations to relate THmap metrics to recording performance.

II. HAMR Simulation Setup Description

A. Implementation & media

In this study, we introduce an exchange-coupled multilayer media with granular grains. The micromagnetic simulation method has been described previously [4]. The magnetization reversal of each sub-layer of grains is described by the stochastic Landau-Lifshitz-Bloch equation [5].

There are 6 sub-layers in our media model. The bottom 5 layers are composed of FePt ordered alloy and have the same magnetic properties. The top layer is composed of cap material. We vary cap Hk from 10 kOe to 50 kOe and interlayer exchange coupling constant from 1 erg/cm^2 to 8 erg/cm^2.

B. Thermal profiles and writer fields

In our recording simulations, we employ 2-D Gaussian thermal profiles that peak at 90% with a 10% conical background [4]. However, in THmap simulations, for simplicity, we stretch these profiles in the cross-track direction, assuming them to be uniform across the medium slab crosstrack width.

This study uses finite-element electromagnetic (FEM) simulations to calculate writer field maps. Both high (65 mA) write current and low (5 mA) write current field maps are calculated for the experimental writer design.

III. Results And discussion

A. THmap metrics

The THmap method has been developed to characterize the switching distributions at recording time scales [6]. Using DC noise simulations or measurements, a 2D map of the grains' switching probabilities are extracted as functions of both the writer fields and medium temperatures.

In this work, we focus on simulating the bottom and top edges of the map, corresponding to laser peak temperature sweeps under low and high writer currents. We calculate noise power based on the readback signal for media A and B. Their cap Tc is fixed at 1000 K, cap Hk values are 30 kOe and 10 kOe respectively, and a weak exchange coupling 2erg/cm^2 is artificially introduced between the topmost FePt layer and the other four FePt layers beneath it for medium B. As shown in Fig 1, the peak noise power of medium A (blue) at 65 mA write current is higher than at 5 mA, while for medium B (green) the peak noise power at 65 mA write current is lower than at 5 mA.

B. Noise power reduction mechanism

To understand why the two media's noise powers have different relative heights, we first vary the cap Hk and plot the noise power at 5 mA write current. Fig 2 shows that noise power decreases with the increase of cap Hk, when the laser peak temperature is at or above FePt Tc 660 K. Next, we select the media with low Hk cap (10 kOe), then vary the vertical exchange coupling strength between the topmost FePt layer and the other four FePt layers beneath it. As shown in Fig 3, near the writing temperature, noise power reduces with the decrease of interlayer vertical exchange coupling at 65 mA write current.

If the grains are fully saturated and act as macrospins, the noise power reaches maximum when 50% of the grains switch. However, if grains are partially switched or form internal domain walls within the height of a grain (also referred to in this work as "incomplete switching"), there is a significant reduction of media noise. Such domain walls could be introduced by weak vertical exchange coupling or a hard-to-switch cap layer." In Fig 4, we plot the incomplete switching fraction as a function of temperature. When both writer field and interlayer exchange coupling are weak, the thermal fluctuation field dominates for temperatures near and above FePt Tc, which increases the probability of incomplete switching in the grains. A more interesting case is medium B under strong writer field: there is about 9% incompletely switched grains, leading to lower noise power as previously shown in Fig 1. This is because below the writing temperature of FePt, the writer field is still strong enough to switch the soft cap and generate a domain wall within FePt layers.

C. Recording Simulations

In the above discussion, we calculate only the medium DC noise power in THmap. We also explore the recording transition noise. In the following isolated track simulation, the laser peak temperature is fixed at 718K. Here we compare the calculated jitter for pure FePt, medium A and medium B in Fig 5. There is almost no improvement for medium A, while there is a large jitter noise reduction for medium B, in correlation to the reduction of the high write current noise power.

IV. CONCLUSIONS

We present THmap DC noise power calculations for various media, and transition noise calculations to check the recording performance. In medium stack design with proper cap selection and interlayer vertical exchange coupling strength modulation, incompletely switched grains are generated, and thus a medium noise reduction occurs. More results for media with various cap properties and exchange couplings will be presented in a subsequent paper to substantiate this conclusion.

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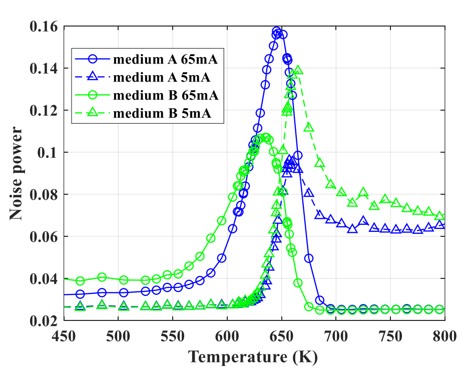

Fig. 1. Noise power as a function of laser peak temperature at the maximum write current 65 mA and at the minimum write current 5 mA.

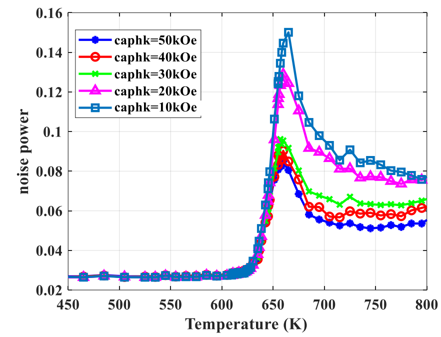

Fig. 2. Simulated noise power versus laser peak temperature at the minimum write current 5 mA. Each media has the same cap Tc 1000 K, but cap Hk varies.

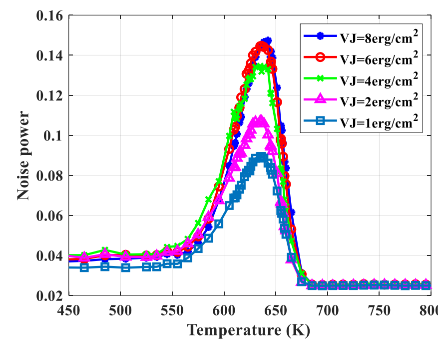

Fig. 3. Plots of noise power at maximum write current 65 mA. Interlayer vertical exchange coupling between varies.

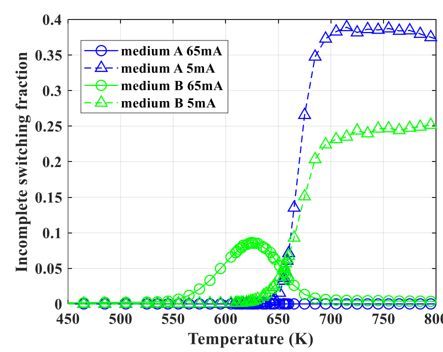

Fig. 4. Fraction of incompletely switched grains as a function of laser peak temperature for medium A and medium B.

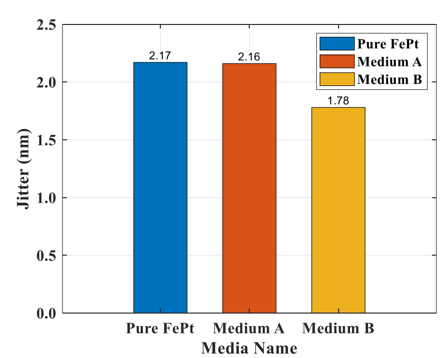

Fig. 5. Comparison of transition jitter for 3 media