NOISE SOURCES AND MECHANISMS IN HEAT-ASSISTED MAGNETIC RECORDING

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I. INTRODUCTION

As Heat-Assisted Magnetic Recording (HAMR) approaches commercialization, there are outstanding challenges that need to be addressed for a reliable and robust non-volatile storage device. One such challenge is noise sources due to the HAMR write process. We address this through dynamic micro-magnetic simulations of the HAMR write process. Every grain is assumed to obey the stochastic dynamics of the ensemble average of classical magnetic spins of Ref. [1]. Magneto-crystalline anisotropy temperature dependence from renormalization theory, $Hk(T) = Hk(0)\ (1\text{-}T/Tc)^{\beta}$, was assumed in order to close the implementation. Ab-initio [2] and recent experimental study [3] suggests $\beta = 0.36$ for $L1_0$ FePt. We note in [1] the stochastic LLB equation is similar to [4] except here stochastic effects along the ensemble average magnetization direction are allowed. Finally, [1] deterministic LLB equation is identical to [5] up to model dependent constants.

Noise sources during HAMR write process can be categorized by their physical origin: stochastic magnetization dynamics, optical/thermal variations and material distributions. We address each in turn in the following sections.

II. STOCHASTIC MAGNETIZATION DYNAMICS

Stochastic or "thermal" effects arise due to the finite temperature and size of the magnetic grains. Using a realistic thermal profile and a uniform write field Fig. 1 shows the mean and standard deviation of perpendicular magnetization of the same media sample for 640 low frequency write simulations. The only difference between the simulations is the realization of the stochastic effects. Both field magnitude and direction influence this noise source. Temporal history of write field and temperature of a grain also influences the dynamics.

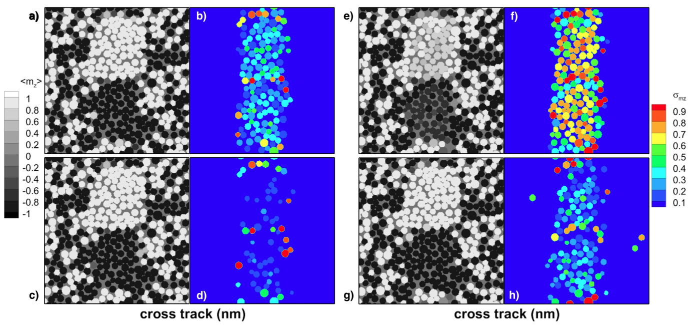

Figure 1 Media sample, 640 writes with a uniform field. a,c) are average perpendicular magnetization, b,d) are standard deviation of perpendicular magnetization, a,b) for 7kOe normal field, c,d) 10kOe normal field e-h) are the same as a-d) except field is 65^0 from normal.

III. OPTICAL AND THERMAL

During HAMR writing, optical power is deposited into the recording medium. Optical coupling variations can arise due to distributions in grain geometry and optical response. Similarly, geometry, material and thermal property distributions can result in a variation of recording grain temperature. A 'lumped element' thermal model was constructed to allow for such variations. Fig.2 shows an instantaneous temperature profile without (a) and with (b) thermal property distributions. These distributions give rise to noise in the recording metrics; e.g. transition jitter which is shown in (c) for the same media ensemble, but for various peak absorption values and thermal property variations. This thermal model can also estimate the noise source induced by power fluctuations arriving at the recording medium.

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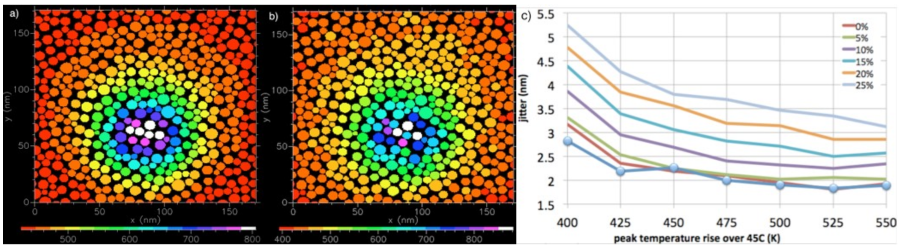

Figure 2: Instantaneous temperature (K) of grains from lumped element thermal model. a) has no distribution in absorption or thermal properties while b) has a 20% variation in thermal properties. c) resulting jitter as a function of peak temperature for multiple variations in thermal properties; blue circles is standard thermal model

IV. MEDIA DISTRIBUTIONS

Granular magnetic grains and their distributions (grain volume and pitch, saturation magnetization, Hk-both orientation and magnitude, etc.) are noise sources in both conventional and heat-assisted magnetic recording. The Curie temperature distribution, mainly due to grain volume and crystalline ordering distributions, can adversely affect recording metrics. Fig. 3 shows simulated easy axis hysteresis loops [6] of two realized recording layers differing in Hk distributions. A data track followed by two neighboring tracks were simulated for these media types for various track pitch and three constant laser powers.

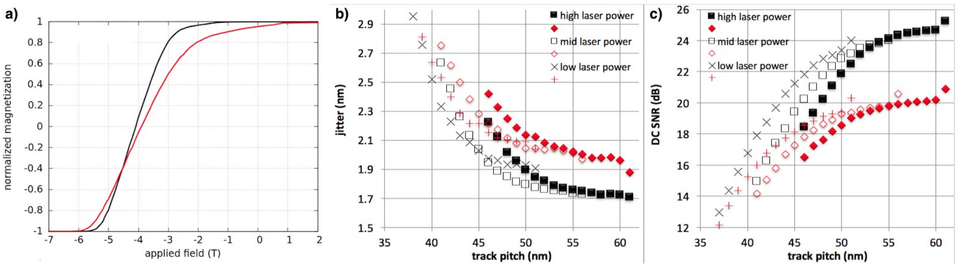

Figure 3: Two media types (red and black) are similar except for Hk distribution; a) simulated half hysteresis loop at 40 Oe/s at 300K, b) transition jitter and c) DC SNR as a function of track pitch for the two media types and three different laser powers based on 640 ensemble members. The last point in each series (largest track pitch) is for an isolated track.

V. CONCLUSION

Simulations of the HAMR write process have given insights into the sources and contributions of noise typically seen in experimental investigations. Noise arising from stochastic effects can be mitigated by controlling the write field and cooling rate. Optical/thermal distributions give rise to a variation of peak temperature and therefore different write locations degrading recording metrics. Material media distributions also give rise to noise sources, requiring identification of process conditions which control these distributions, particularly as grain size is reduced. Finally, the geometry of the magnetic patterns (e.g. BAR), including any possible curvature, affect the relative weights of these noise sources at the recording system level.

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