

Micromagnetic analysis of transition noise for high-density perpendicular recording

Z.J. Liu^a, H.H. Long^{a,b,*}, W.C. Ye^a, X.X. Zou^a, Z.L. Qin^a, E.P. Li^c, J.S. Chen^a

^aData Storage Institute, DSI Building, 5 Engineering Drive 1, Singapore 117608, Singapore

^bDepartment of Electrical and Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore 117576, Singapore

^cInstitute of High Performance Computing, Science Park II, Singapore 117528, Singapore

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Abstract

In this paper, specific issues related to high-density perpendicular magnetic recording processes, such as transition noise properties and cross-track correlation lengths, were investigated with the help of micromagnetic analysis. The effects of media parameters were taken into consideration, including intergranular exchange coupling, and exchange distribution, irregular grain shapes, magnetization saturation distribution, and anisotropy distribution. The micromagnetic simulation results showed that the effect of anisotropy distribution on transition noise is more significant than magnetization saturation distribution, and it is crucial to reduce this effect to achieve a high signal-to-noise ratio. Additionally, a new method to further estimate the partial erasure threshold was proposed to approximate the partial erasure effects, and the relation between the microtrack jitter and total track jitter was investigated.

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1. Introduction

In recent years, the perpendicular recording technology has attracted intensive attention due to their potential to offer higher areal-density beyond the limit of longitudinal recording technology [1]. To achieve ultra-high density recording, it is essential to reduce the medium noise. Over a past few years, a great deal of discussions concentrated on the effects of intergranular exchange coupling on the performance of recording system [2–4]. However, for high-density magnetic recording head–media combinations, the relation between medium characteristics and recording performance is not sufficiently clear due to lack of systematic study of the transition noise and their interdependence against the media parameters, such as magnetization saturation and anisotropy distribution. Based on micromagnetic analysis, transition noise property related to high-density perpendicular magnetic recording processes were investigated in this paper.

2. Micromagnetic simulation model

A three-dimensional micromagnetic model solving the LLG equation [4], is used to study the cross-track correlations length and other transition noise parameters for 400 Gbit/in² perpendicular recording system. The medium anisotropy axis direction is assumed perpendicular to the media plane with 3° deviation and anisotropy constant $K_u = 7.4 \times 10^6$ erg/cm³. The saturation magnetization is about $M_s = 750$ emu/cm³. The intergranular exchange parameter H_e ($H_e = A_{ex}/K_u D^2$) is varied from 0 to 0.1 and also has a random distribution in the media due to microstructure and irregular shapes of grains. In the simulation, the thickness of media layer and SUL are 12 and 200 nm, respectively. A 128×256 hexagonal lattice is used for modeling the recording media. One hundred independent transitions were obtained. Each transition was written on a media plane with randomly distributed irregular grain plane, which is generated using ‘pseudo Voronoi algorithm’ [5]. To produce media grain plane from such algorithm, grain seeds are scattered in accordance with log-normal distribution whilst keeping an average grain size of 5.5 nm with variation of about 30%. Fig. 1

*Corresponding author. Data Storage Institute, DSI Building, 5 Engineering Drive 1, Singapore 117608, Singapore

E-mail address: g0202811@nus.edu.sg (H.H. Long).

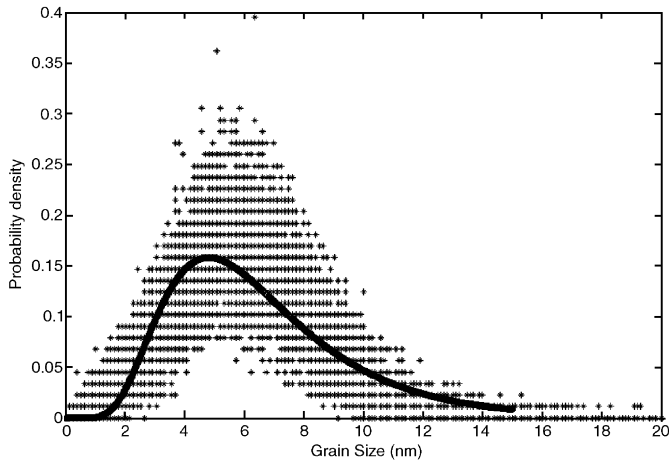


Fig. 1. Media average grain size distribution from 100 media grain plane.

plots the records of the grain size distribution recorded for the aforementioned media plane distributions.

A modified 3D head solution [6] is used to drive the recording process in simulation. The write width is 50 nm and the fly height is 6.5 nm. The return yolk width is 250 nm and the space between write pole and return yolk is 300 nm. For the recording simulations, the head field in the gap region at the air-bearing surface is set to be 29 KOe.

3. Transition noise properties and analysis

3.1. Transition noise parameters

The probability density function of transitions can be obtained from the micromagnetic analysis. In addition, the transition parameter a , cross-track correlation length, s , and transition noise parameter [2] under different intergranular exchange couplings can also be produced, as shown in Fig. 2 when the value of anisotropy distribution = 3%. It can be found that the cross-track correlation length is increased with increasing exchange coupling, which indicates a large media cluster is formed. For a weak intergranular exchange coupling, the transition noise parameter decreases linearly. With continuously increasing exchange coupling, the transition noise parameter changes slightly. The simulation results also show that the effect of exchange coupling on the cross-track correlation length is more pronounced than that on the transition parameter.

Fig. 3 gives the exchange dependency of the transition parameter and transition noise parameter with different anisotropy distribution. Simulations show that the transition noise parameter is increased with increasing anisotropy distribution indicating that reducing the medium anisotropy distribution can improve the performance of recording systems.

We also investigated the effect of the saturation magnetization distribution on the transition noise. As

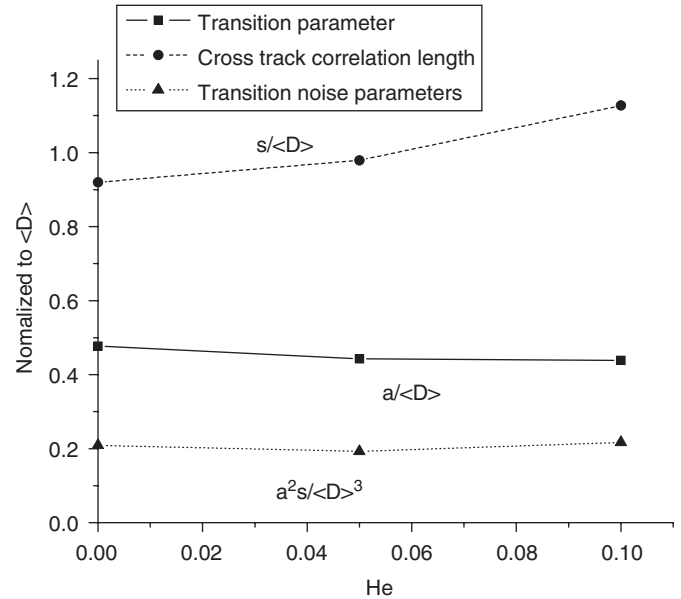


Fig. 2. Exchange coupling dependency of transition parameters, cross-track correlation length and transition noise parameters.

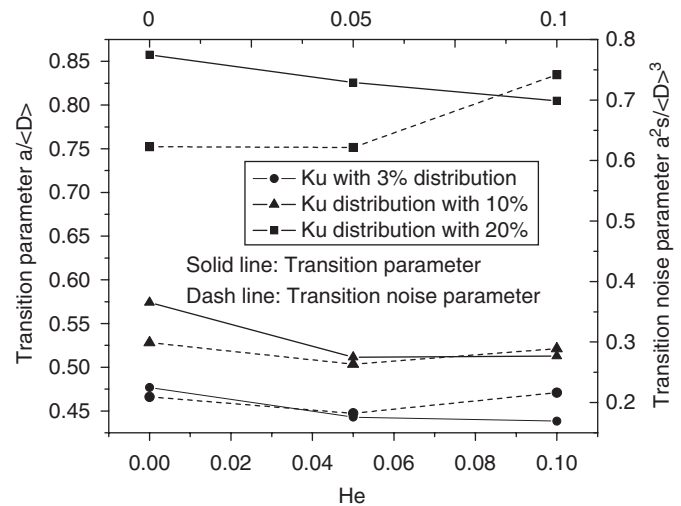


Fig. 3. Dependence of transition parameter and transition noise parameter on exchange with anisotropy distributions of 3%, 10% and 20% case.

shown in Fig. 4, it can be seen that the effect of magnetization saturation distribution is not comparable to that of the anisotropy distribution. For decoupling case, the transition parameter and transition noise parameter increase with increasing deviation of the saturation magnetization distribution. With continuously increasing the exchange coupling, the effect of saturation magnetization distribution becomes insignificant. The above micromagnetic analysis with effect of anisotropy and saturation magnetization taken into consideration indicates that a weak coupling is needed to achieve high SNR. The simulation also shows that the effect of anisotropy distribution is more pronounced and a low anisotropy

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