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Modeling of the write and read back performances of hexagonal Ba-ferrite particulate media for high density tape recording

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ABSTRACT

In this study, the signal-to-noise ratio (SNR) performances of longitudinally, randomly, and perpendicularly oriented particles, based on hexagonal barium ferrite (h-BaFe) platelets with an average volume of 2400 nm^3 have been studied as a function of the recording head to media distance by numerical micromagnetic simulations. The distances from the write head to media and from the read head to media were varied independently. For a fixed read distance and varied writing distances, the SNR was decreasing in larger write distance. An optimum write distance of 40 and 50 nm was found for the longitudinally oriented media and the perpendicularly oriented media, respectively. The optimum write distance for longitudinally oriented media, 40 nm, resulted in the local minimum SNR for the perpendicularly oriented media. In most write distances the perpendicularly oriented media show the outstanding best performance, but near the write distance of 40 nm the longitudinally oriented media work as good as the perpendicularly oriented media. In a fixed write distance with various read distances, the SNR was almost constant in each media whereas the average signal amplitude was exponentially decayed in larger read head to media distance. The best SNR was found in the perpendicularly oriented media at write head to media distance $d_{write}=20$ nm and read head to media distance $d_{read}=40$ nm. The best SNR value is 11.9 and 24.4 dB in time domain and frequency domain, respectively.

1. Introduction

The areal recording density for magnetic tape recording based on the particulate media has been increased enormously, 42% annually in the past few years. In 2007, 6.7 Gbit/in^2 areal density was achieved [1]. One of the causes for obtaining high areal densities was the application of densely packed hexagonal barium ferrite (h-BaFe) platelets, which have many advantages over metal particles (MP): chemical stability, high coercivity, and small particle size [2–5]. The small aspect ratio of the h-BaFe particles enables themselves to be easily aligned by applying of an external field during the coating procedure on the polymer tape [6]. The 6.7 Gbit/in^2 writing and read-back processes were performed using randomly oriented h-BaFe media. However, as h-BaFe particles have been originally suggested for perpendicular media, recent results reveal a higher signal-to-noise ratio (SNR) when the media particles are aligned to a certain direction [7,8].

Basically, SNR depends on the quality of the writing and the reading process, as well as on the media quality itself. Since the tape recording media are mostly used as backup media and should be easily removed from the head block, the head to media distances are not as stationary as in the case of hard disk media. The mechanical fluctuation of the media to head distances has a possibility to affect on the read and write processes [9]. In this study we have investigated the SNR performance as a function of the write and read head to media distance, for differently oriented h-BaFe particulate media with a constant packing density of 40%.

2. Particulate media modeling

The average diameter and thickness of the hexagonal h-BaFe platelet are given as 21 and 7 nm, respectively, with volume distribution of 25% according to experimental observations [10]. The microstructural models as input for the micromagnetic simulation of the h-BaFe particulate media were prepared by an implementation of the Lubachevsky–Stillinger packing algorithm [11,12]. The packing process was started from a pre-defined aspect ratio of 3:1 (diameter to thickness), preferred orientation (mean azimuth angle $\langle\theta\rangle$ and mean polar angle $\langle\phi\rangle$) and degrees of spatial misorientations (standard deviation of the

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angles, $\Delta\theta$ and $\Delta\phi$) with Gaussian distribution (Fig. 1a). The particles started to grow from the randomly distributed seed points until the spatial packing density reaches about 40%, which reproduces the experimental results [7]. The microstructural models of the particulate media models are shown in Fig. 1b. As input parameters for the micromagnetic simulations we used a mean saturation magnetization M_S=275 emu/cm^3 and a mean uniaxial crystalline anisotropy K=1.25 × 10^6 erg/cm^3 with a standard deviation of 20% [10]. Due to the anisotropic shape of the h-BaFe particles, the linear packing densities were determined by the particle alignment as shown in Fig. 1b.

Three types of particulate media models, named as #L (longitudinally oriented), #R (randomly oriented), and #P (perpendicularly oriented) are prepared (see Table 1). The magnetic storage layer consisting of approximately 3000 h-BaFe platelet has a length of 1300 nm, a width of 200 nm, and a thickness of 100 nm. The $\Delta\theta$ and $\Delta\phi$ of #L and #P are set to 30°. The #R media was prepared as a perpendicularly oriented one with $\Delta\theta=\Delta\phi=60°$, following the experimental observations that the h-BaFe particles are self-aligned during the coating procedures. The hysteresis loops for applied homogeneous external field are shown in Fig. 1c and d. According to the hysteresis loops, the chosen $\Delta\theta$ and $\Delta\phi$ values lead to squarenesses and coercivities which are close to experimental data as shown in Table 1 [7,12,13].

3. Micromagnetic simulation

Our finite element numerical micromagnetic software code enables us to solve the Landau–Lifshitz–Gilbert equation of motion for the magnetization of an entire magnetic device [14,15]. The finite element simulations are based on the hybrid boundary element method [16]. In the case of magnetic recording simulations, the input are the data of the detailed microstructure of the recording media, the geometry of the write head, the layer stack and shield geometry of the read head, the intrinsic properties and the current waveform of the write current, etc. Macroscopic properties like current waveform, read-back voltage, transition jitter are input/output of a multiscale simulation that

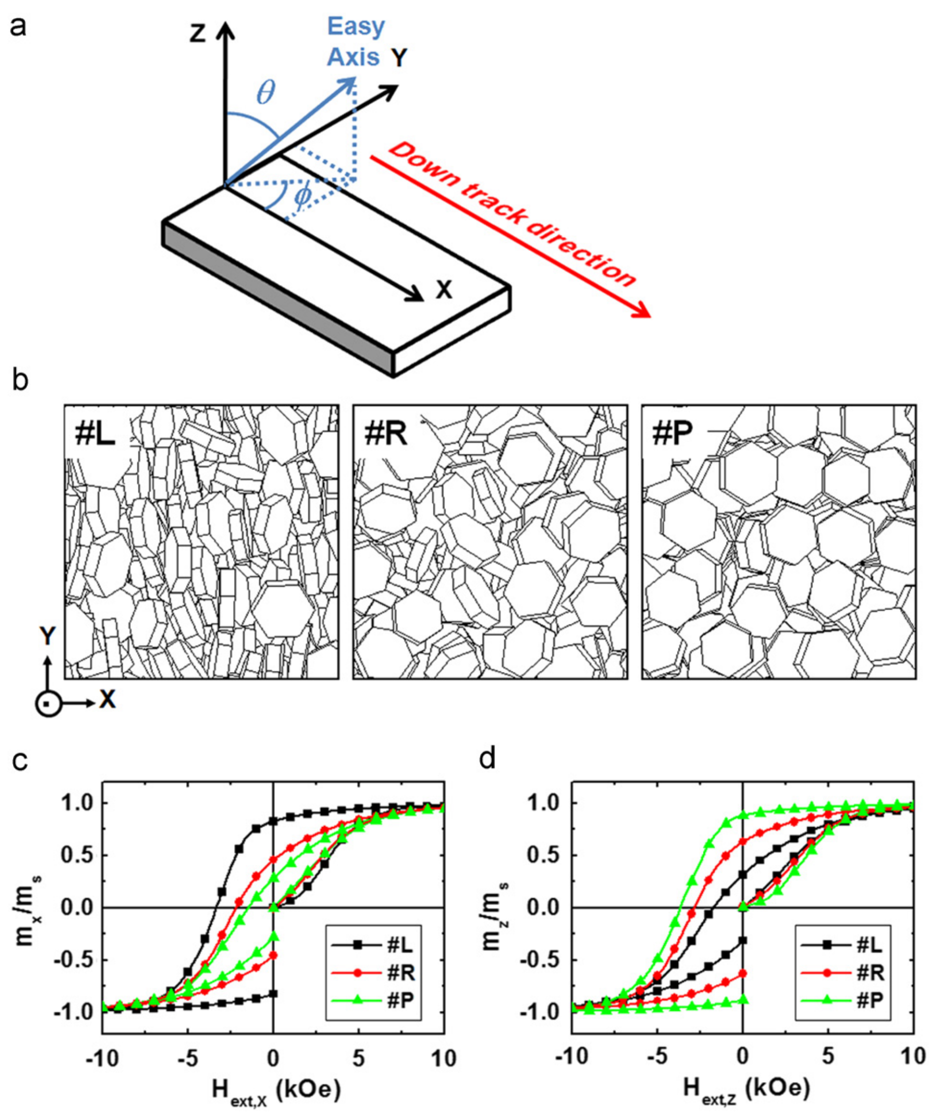

Fig. 1. (a) Coordinate system of our simulations. *x*-axis is corresponding to the down track direction of magnetic tape recording media, where *y* and *z* axes are the cross track direction and the perpendicular direction, respectively. (b) Top view 100 × 100 nm^2 sized images of the longitudinally (#L), randomly (#R), and perpendicularly (#P) oriented media. (c) Hysteresis loops of the models, under homogeneous longitudinal field. (d) Hysteresis loops of the models, under homogeneous perpendicular field.