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Effect of intergranular interactions on recording characteristics

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ABSTRACT

The dependence of intergranular exchange interaction on medium SNR was investigated by micromagnetic simulation. It was found that the medium SNR at a high recording density takes its maximum value at the point where the magnitude of the maximum intergranular exchange field is about same as that of the maximum demagnetization field.

1. Introduction

Intergranular interaction are of two types. One is magneto-static interaction (demagnetization), and the other is intergranular exchange interaction. The magnetization curve of a medium is determined by both the dispersion of magnetic constants of individual grains in the medium and by the interaction between grains. The recording characteristics of a medium also depend on both of these factors, together with the recording head-field distribution [1,2]. In order to understand the recording process, it is, therefore, necessary to establish how the magnetization process of the medium is affected by these intergranular interactions. In practice, the magnitude of magneto-static interaction does not vary widely if the materials of the recording layer are fixed, because the magneto-static field in a medium is determined by saturation magnetization. On the other hand, the magnitude of intergranular exchange interaction varies considerably according to the underlayer materials, and the conditions of their manufacture. It has also been reported that recording characteristic can be improved by introducing a moderate intergranular exchange interaction [3–6], but no clear reason was given for this.

In order to clarify the effect of intergranular interaction on recording characteristics, the magnetization and recording processes were analyzed by using a micromagnetic simulation [7].

2. Calculation parameters

Table 1 shows the parameters of the medium and recording head used for a calculation. A cell size of 10 nm is used, and the dimensions are assumed to be cubic. A medium with a thickness of 10 nm is also used. Normal distribution is assumed for the dispersion of each parameter. The magnetization curves and recording patterns are calculated by the LLG equation. The average anisotropy field strength of the medium is fixed at 15 kOe, and only the intergranular exchange stiffness and saturation magnetization are changed. The thermal fluctuation is considered as a random field [6]. The sweep time of the magnetization curve is set to 20 ns, because the recording is performed within the order of nanoseconds. The applied pulse width is 2 ns for the remanent magnetization curve.

3. Results and discussion

3.1. Influence of magneto-static interaction on the magnetization curve

Fig. 1 shows the magnetization curves with an anisotropy field dispersion σ_{Hk} of 10% for several saturation magnetizations M_s, where the intergranular exchange stiffness A_{ex} is roughly zero. The dashed line represents the magnetization curve of the medium with no intergranular interaction. The magneto-static field differs in each curve. The magnetization curve with the smallest M_s has the steepest gradient, because the demagnetization field is smallest in the medium with the smallest M_s. The gradient of the magnetization curve decreases as M_s increases, due to the increase of the demagnetization field. The magnitude of the nucleation field H_n in the medium decreases, and the magnitude of the saturation field H_s increases with higher M_s. Fig. 1(b) shows the remanent curve of a medium when M_s is 500 emu/cm^3. The dashed line represents the media with no intergranular interaction. The demagnetization field effectively expands the switching field distribution.

3.2. Influence of intergranular exchange interaction on the magnetization process

Fig. 2 shows the magnetization curve of the medium for various intergranular exchange stiffnesses when M_s is 500 emu/cm^3. The magnitude of the H_n increases and that of H_s falls as A_{ex} increases.

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Table 1
Calculation parameters

Medium parameters	
Anisotropy field	15 kOe
Anisotropy field dispersion	1% and 10%
Dispersion of easy axis direction	5°
Intergranular exchange stiffness	$0.001–1.5\times10^{-6}$ erg/cm
Saturation magnetization	300, 500, 800 emu/cm^3
Soft under layer thickness	100 nm
Saturation flux density	1 T
Permeability	250
Temperature	300 K
Write head parameters	
Saturation flux density	2 T
Permeability	500
Pole width/length	0.2/0.2 μm
Magnetic spacing	20 nm
Head to medium relative speed	15 m/s

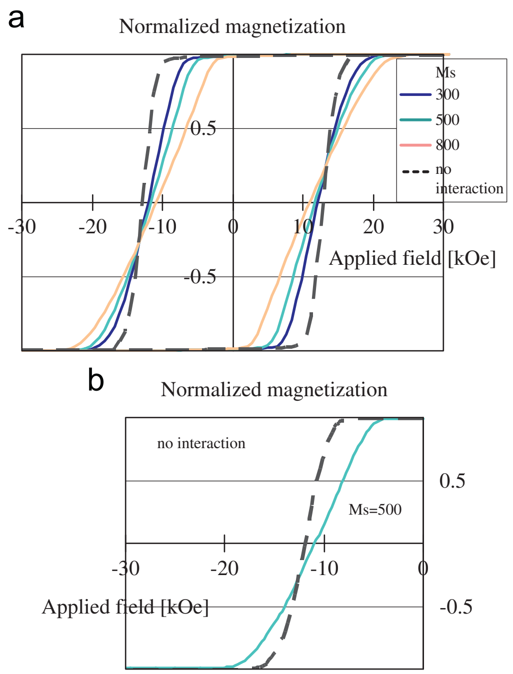

Fig. 1. Magnetization curves of perpendicular media with weak intergranular exchange interaction and anisotropic field dispersion of 10% at a temperature of 300 K. (a) Magnetization curves of media with various saturation magnetizations. (b) Remanence curves of media with and without interaction.

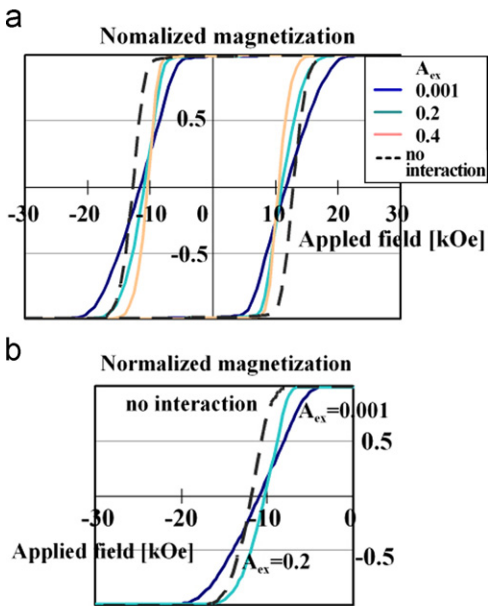

Fig. 2. Magnetization curves of perpendicular media with saturation magnetization of 500 emu/cm^3 and anisotropic field dispersion of 10% at a temperature of 300 K. (a) Magnetization curve of media with various intergranular exchange stiffnesses. (b) Remanence curve of media with and without interaction.

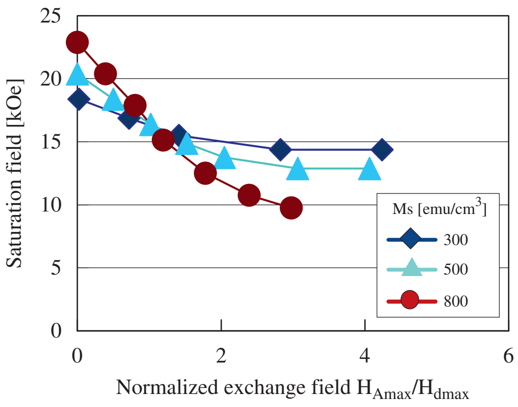

Fig. 3. Saturation field dependence on a normalized maximum exchange field for anisotropy field dispersion of 10%.

The gradient of the magnetization curve accordingly increases with A_{ex}. Fig. 2(b) shows the remanent curve. Its gradient is reduced by the effects of demagnetization. The gradient of the remanent curve does, however, approach that of the curve without interaction when A_{ex} is 0.2×10^{-6} erg/cm. It seems that the exchange field makes the effective switching field distribution narrower.

Fig. 3 shows the dependence of the saturation field on the normalized maximum exchange field H_{nex}, where the maximum exchange field is normalized to the maximum demagnetization field, $4\pi M_s$. In the case of large M_s, H_s is large for small H_{nex} but decreases rapidly as H_{nex} increases. All curves intersect around H_{nex} of 1.0, where the maximum exchange field is same as the maximum demagnetization field. The demagnetization field and the exchange field take the maximum values near the saturation field. All saturation fields of the medium with differing M_s approach the same value as that of the medium without interaction, because the exchange and demagnetization fields cancel each other out, and the medium behaves, therefore, as if there is no interaction field. However, the nucleation field does not agree with the values found for the medium without interaction. Near the nucleation field, the demagnetization field reaches maximum value, but the exchange field is very small.

3.3. Influence of magneto-static interaction on recording characteristics

Fig. 4 shows medium SNR dependence of saturation magnetization at a linear recording density of 1000 kFCI, when the intergranular exchange stiffness is very small. Medium SNR is calculated by the signal output and integration of noise in the expression

$$\mathrm{SNR}=20\log\left(p_i\Big/\sqrt{\sum_{k\neq i}p_k^2}\right)$$