FERROMAGNETIC RESONANCE FOR EXCHANGE-COUPLED TWO-DIMENSIONAL ASSEMBLY OF NANO-COLUMNS

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I. INTRODUCTION

The influence of intergranular exchange coupling (J_g) between columns and the magnetic anisotropy field (H_k) distribution (ΔH_k) on the ferromagnetic resonance (FMR) of the magnetic nano-column assembly is numerically investigated using the Landau–Lifshitz-Gilbert equation. The nano-column assembly is assumed to represent granular perpendicular magnetic recording (PMR) media. The FMR measurements of the PMR media with $J_g > 1$ erg/cm^2 can be used to evaluate the intrinsic values of H_k and the damping constant (α) despite the existence of ΔH_k. In case of PMR media with $J_g = 0$ erg/cm^2, the intrinsic value of α can be evaluated. However, H_k will be underestimated depending on the degree of ΔH_k.

II. RESULTS AND DISCUSSION

Fig. 1 shows the schematic diagram of the computational model for the magnetic nano-column assembly supposed for the granular PMR media. The assembly was assumed to consist of 32 × 32 columns. In addition, a single column comprised four computational units of size 8 × 8 × 4 nm. The magnetic easy axes of all units were assumed to align with the z−direction. Each unit was assumed to have an M_s of 616 emu/cm^3, γ of 1.936 × 10^7 Oe^{-1}s^{-1}, and α of 0.032 corresponding to $Co_{74}Pt_{16}Cr_{10}$–8 mol (SiO_2) [1]. H_k of each column had a Gaussian distribution with an average (H_k^{ave}) of 16.2 kOe and full width at half maximum (ΔH_k) of 0–2 kOe. The intergranular exchange coupling acting between contiguous columns (J_g) was changed from 0 to 5 erg/cm^2.

A. FMR for PMR media without intergranular exchange coupling

Fig. 2 (a) shows χ" curves for PMR media with various ΔH_k. The resonance field (H_{res}) increased from 2.6 to 2.8 kOe with increase in ΔH_k from 0.0 to 2.0 kOe. The line width as given by the full width at half maximum (ΔH_{res}) took constant value of 0.71 kOe, even with changes in ΔH_k. When M_s was increased to 1000 emu/cm^3 and H_k to 15 kOe, H_{res} showed a similar shift to the higher field side with increase in ΔH_k (details not shown in figure). For reference, values of H_{res} and ΔH_{res} were estimated from the conventional Kittel equation [2]. The estimated values of H_{res} (H_{res}^{Kittel}) and ΔH_{res} (ΔH_{res}^{Kittel}) are 2.6 kOe and 0.71 kOe, respectively. The aforementioned behavior of H_{res} cannot be explained by the Kittel mode. To discuss the aforementioned behavior of H_{res} and ΔH_{res} against an increase in ΔH_k, the χ" curve of each column is shown in Fig. 2 (b) and (c). In this figure, black lines show the χ" curve for each column and the red line shows the χ" curve for the medium. In the case of (b) $\Delta H_k = 0.0$ Oe, the χ" curves of all columns were in good agreement. This indicates that the magnetic moment of each column was resonating in the parallel arrangement. On the other hand, in the case of (c) $\Delta H_k = 2.0$ kOe, the χ" curve for each column had one large maximum at the same H_{bias} of 2.8 kOe, and had countless local maxima and minima in the range H_{bias} < 2.8 kOe. These local maxima and minima canceled between columns. As a result, clear resonances did not appear on the χ" curve of the media, and a long tail by the lower field side of the H_{res} of 2.8 kOe was observed on the χ" curve of the media. This suggests that the parallel arrangement of the magnetic moment of each column cannot be maintained at resonance (hereafter, called as the incoherent mode).

B. FMR for PMR media with intergranular exchange coupling

In figure 3 (a), χ" curves for FMR media with ΔH_k of 2.0 kOe and various J_g of 0.0, 1.0, and 5.0 erg/cm^2 are shown. In the case of $J_g > 1.0$, the χ" curves completely overlapped and H_{res} values of 0.71 kOe were in agreement with H_{res}^{Kittel}. The value of ΔH_{res} did not depend on ΔH_k. This result suggests that the resonance of the magnetic moment of each column changes from the incoherent mode to the Kittel mode with increase in J_g.

Figure 3 (b) and (c) shows the χ" curve of each column for these media. In the case of (c) $J_g = 5.0$ erg/cm^2, almost all of the local maxima and minima and the maximum at the 2.6 kOe as observed for

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H_{res}^{Kittel} mainly remained. This indicates that the resonance changed from the incoherent mode to a state near the Kittel mode, because of the increase in intergranular exchange coupling.

III. CONCLUSION

From the viewpoint of evaluating the intrinsic magnetic properties, the FMR measurement of PMR media with $J_g > 1$ erg/cm^2 can help in evaluating the intrinsic values of H_k and α despite the existence of ΔH_k. In the case of PMR media with $J_g = 0$ erg/cm^2, the intrinsic value of α can be evaluated. On the other hand, H_k is underestimated depending on the degree of ΔH_k, even if the H_k distribution has a large value of 2 kOe. However, the difference of the evaluated and intrinsic values of H_k is 0.2 kOe at most. In the presentation, FMR for more simple assembly is considered to understand the relationship between H_{res} and J_g.

REFERENCES

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[2] C. Kittel, *Phys. Rev.*, **73**, 155, (1948).

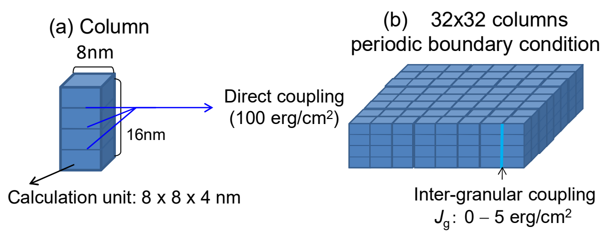

Fig. 1 Schematic views of the computational model for PMR media. (a) Each crystalline column was assumed to be composed of four computational units of 8 × 8 × 4 nm size. (b) Media was assumed to be composed of 1024 columns.

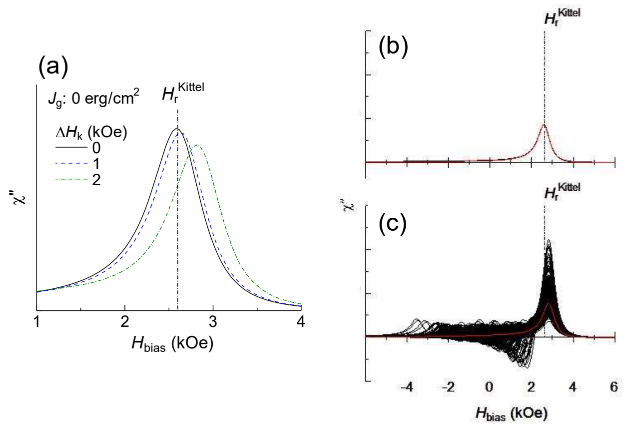

Fig. 2 (a) H_{bias} dependence of the χ" of PMR media with no intergranular exchange coupling (J_g) and various ΔH_k. Dependence of χ" on H_{bias} for each nano-column with (b) ΔH_k = 0 and (c) 2 kOe.

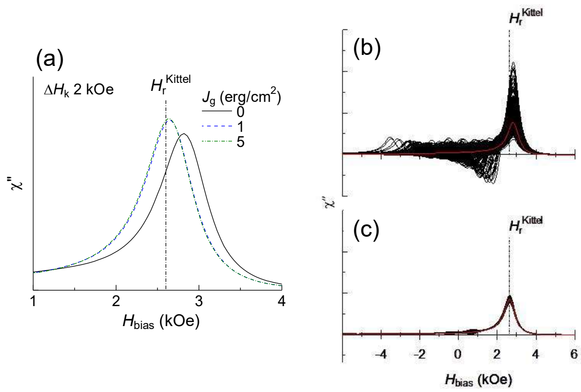

Fig. 3 (a) H_{bias} dependence of the χ" of PMR media with ΔH_k of 2.0 kOe and various J_g. Dependence of χ" on H_{bias} for each column in the PMR media with (b) J_g = 0 and (c) 5.0 erg/cm^2.