Thermal Relaxation in Perpendicular Double-Layered Media

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***Abstract*— Output decay by thermal relaxation in perpendicular double-layered media is studied by numerical calculation and experiments. In addition some influences due to a single pole head are pointed out. We suggest that if these influences could be avoided, thermal relaxation in perpendicular magnetic recording would be much smaller than reported so far. High recording density and low noise is possible with relatively small particles, even at large film thickness in perpendicular magnetic recording.**

***Index terms*— Thermal relaxation, output decay, single-pole head, perpendicular magnetic recording.**

I. Introduction

Thermal relaxation is becoming significant because a small bit size and a thin film are necessary for achieving high recording density and signal-to-noise ratio in longitudinal recording [1],[2]. Perpendicular magnetic recording is thought to be suitable for ultrahigh-density magnetic recording due to its low demagnetization character [3], however, this has not been sufficiently studied. In this paper, the relaxation dependence on recording density is investigated by experiments, and is compared with other results that have been reported [4],[5]. A single-pole writing head and a MR flying head were used for the experiments.

II. Simulation

A two dimensional FEM(finite element method) simulation [6] associated with a curling switching model was modified and used by introducing an exponential time decay. The grains of the media were assumed to be cylindrical with heights equal to the media thickness (here 50nm). The exchange coupling between the particles was approximated by the mean-field method [7]. The coefficient of the mean-field was determined to be 0.14 by fitting the slope of a measured M-H loop. The saturation magnetization M_s, anisotropy field H_k and coercivity H_c were 430 emu / cm^3, 4360 Oe and 1100 Oe, respectively, the same as the medium parameters in the experiments. The parameters for the simulation were the grain diameter, the average particle volume and the standard deviation of volume. These will be denoted as D, V and σ, respectively hereafter. First of all, the recording process was simulated at one density under a no-relaxation condition. Next, the demagnetization field, calculated according to the original magnetization, was subtracted from the coercivity to determine the reverse field of the grain. Here K_u (anisotropy constant) was calculated from the coercivity H_c, which is equal to the grain switching field, instead of from the anisotropy field H_k in the S-W model. Thus, the time constant τ was determined as $10^{-9}\times(K_u \cdot V / kT)$, where k is the Boltzmann constant, and T is the absolute temperature. Following a time step Δt, the magnetization was calculated by a self-consistent calculation according to the time decay defined as $M(t_n) = M(t_{n-1})\times \exp(-(-t_{n-1}+\Delta t) / \tau)$. The head output was obtained by reciprocity.

Fig. 1 shows the time decay at various recording densities and volume distributions. For a small σ / V (=0.1), there was almost no output reduction at both high and low recording density. The severe output reduction at large σ / V confirms that the relaxation of grains whose volumes are smaller than the average dominates the time decay. Meanwhile, the simulation indicates that the relaxation becomes less at high recording density than low density. This confirmed the low demagnetization characteristic at high recording density for perpendicular magnetic recording [8].

III. Experiments and results

A. Recording Density Dependence

The track width and the main pole thickness of the single-pole writing head used in the experiment were 50 μm and 300nm, respectively. The flying height of the MR head was 50nm. The medium whose specification is mentioned

Manuscript received October 17,1997
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This research was partly supported by Association of Super-Advanced Electronics Technologies, Storage Research Consortium, and Japanese Government under Grant-in-Aid for Scientific Research.

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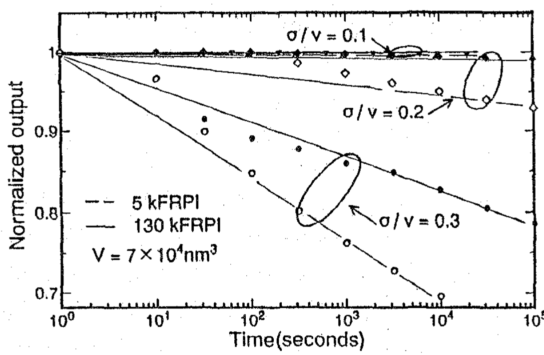

Fig. 1 Time decay at various recording densities and volume deviations.

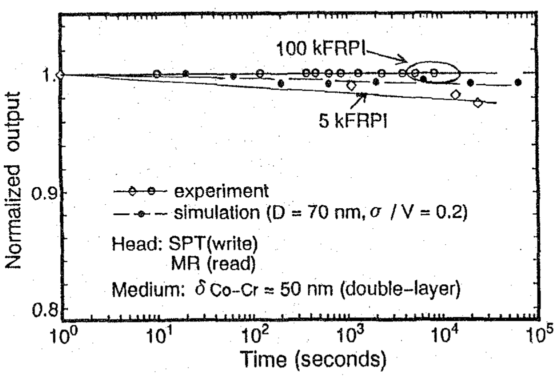

Fig. 2 Dependence of time decay upon recording density.

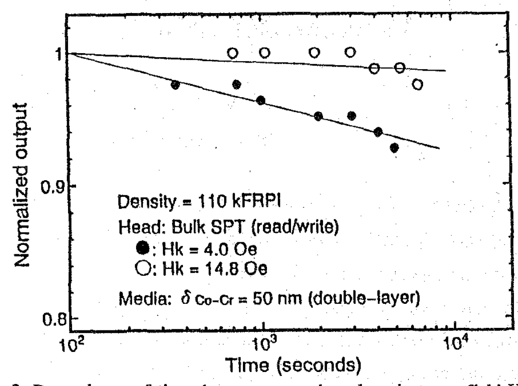

Fig. 3 Dependence of time decay upon main pole anisotropy field H_k.

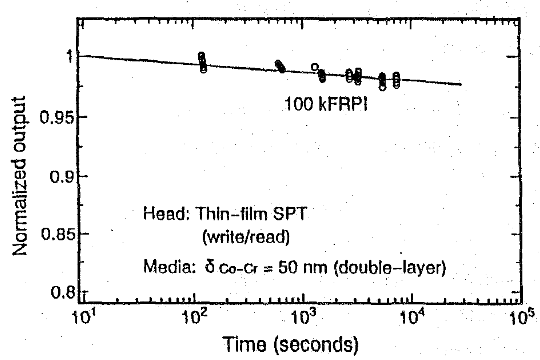

Fig. 4 Time decay of output with thin-film return path head.

above was used. To avoid any influence from the writing head during the reading process, the single-pole head was removed from the medium immediately after writing, while the MR head kept reading. Fig. 2 shows the dependence of the time decay upon the recording density. Over the measured time range, almost no output reduction of the signal of 100 kFRPI was observed, in good agreement with the simulation as shown by the filled circles in the figure. Even at a very low recording density of 5 kFRPI, where the demagnetization field is not small in perpendicular magnetic recording, the reduction in output was less than 3%. The results in the experiment also confirm the advantage of low demagnetization field at high recording density for perpendicular magnetic recording.

B. *Influence of Single-Pole Writing Head*

1) The anisotropy field effect in the head: Although the time decay in the simulation and the experiment were shown above to be not very large, this result is inconsistent with a previous experiment [4]. In order to confirm this, measurements with single-pole heads of various H_k were carried out. Fig. 3 shows the dependence of time decay upon the main pole anisotropy field (H_k). The output reduction was much larger when a low H_k head was used. In contrast, the output reduction was reduced to less than 3% after two hours by increasing H_k to 14.8 Oe. It has been suggested that the domain structure in a single pole head having a main pole with a low anisotropy field may not be stable during the reading process [9] and that this domain instability would demagnetize the medium. It is well-known that the domains are stable in high H_k pole materials.

2) The head structure: A low inductance thin-film single-pole flying head was used to measure the output reduction in the perpendicular medium [10]. The coil was designed to be near the main pole so that the recording sensitivity and overwrite characteristic are improved compared with the bulk single-pole head. Fig. 4 shows time decay using this thin-film head for writing and reading. At a recording density of 100kFRPI, about 3% output reduction was measured after 2 hours; if this logarithmic reduction is maintained, the data suggests that the output will be reduced to 95% of the original output after 10 years. The thin-film return path performs like a shield, shunting the external field

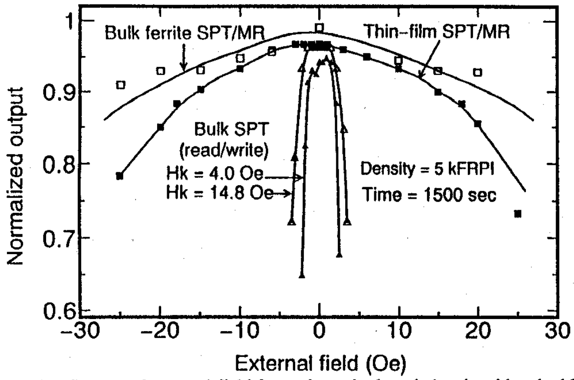

Fig. 5 Influence of external field for various single pole heads with a double-layered medium.

affecting the main pole.

3) The external field influence: Fig. 5 shows the output reduction against external field. For a regular bulk single pole head the output reduced to 60% after 1500 seconds for H_k=4.0 Oe and 80% for H_k=14.8 Oe, at an applied field of about 2 Oe. On the other hand, the output reduced to 80% at an applied field of 20 Oe for a thin-film return path single-pole head. This field is much larger than reported before [4], which means that head structure is also important for the signal erasure with a head. That is, the external magnetic flux flow passes through the return path and reduces the influence of the external field on the main pole.

IV. Conclusion

Thermal relaxation in perpendicular double-layered media was investigated by simulation and experiments. The severe reduction in output observed was accounted for by a low head anisotropy field and the effects of an external field. The head condition should be carefully examined for the measurements of the output decay in perpendicular double layer recording. Because of the small demagnetization field at high recording density in perpendicular recording, we can reduce thermal relaxation by using relatively small particles and still achieve high recording density and low noise because of the large film thickness. However, this requires a small volume and coercivity distribution and a consideration of the influence of domain instability in single-pole head and head structure.

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