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2-D FEM ANALYSIS OF LONGITUDINAL MAGNETIC RECORDING MEDIA TAKING ACCOUNT OF HYSTERESIS MODEL

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Abstract - Longitudinal magnetic recording process of thin film media was simulated by the 2-D finite element method (FEM). To describe precisely the hysteresis behavior of thin film media, scalar Preisach model was used. In this paper, we discussed the formation of bit patterns and importance of modeling of minor loops in high density recording. The effects of the media coercivity and film thickness on the remanent magnetization and transition shape were investigated.

I. INTRODUCTION

In magnetic recording process, the difficulties of modeling are due to complex geometry in head-media interface and head itself, and hysteresis characteristics of recording media. Finite element method (FEM) is very useful in computing magnetic field of the system with complex geometry. For the simulation of the practical magnetic systems with hysteresis phenomena, numerical field analysis by FEM should be incorporated with hysteresis modeling.

Longitudinal magnetic recording process by FEM analysis including hysteresis modeling was interpreted by Ossart et al. in 1991 [1]. They adopted the polynomial method as a hysteresis model. This method is easy to understand and implement. But it is not always accurate and, especially, has deficiencies in description of minor loop behavior. The hysteresis behavior of magnetic materials, however, can be explained by Preisach model [2, 3]. In this work, Preisach model was introduced to describe the hysteresis behavior on the longitudinal magnetic recording process precisely.

In this simulation, only the longitudinal component of magnetization was calculated in order to simplify the computation, and this simulation is enough to analyze quantitatively the influence of the recording parameter on the recording characteristics.

II. ANALYSIS METHOD

Recording process was simulated by FEM analysis incorporated with Preisach model. Fig. 1 represents the geometry and mesh used in numerical analysis. Owing to the difference in the dimension between head and media, only the part of the head near the head gap and media was included in calculation domain and thus, the recording field was generated by the difference in magnetic vector potential, A, between upper ($A=A_u$) and lower ($A=0$) boundaries instead of head coil (Fig. 1).

Relative displacement of media to head was replaced by step-by-step movement of the media with respect to the head and dynamic situation by a succession of magnetostatic state. At each step, vector potential **A** is obtained by solving magnetostatic equation :

$$-(\nabla \cdot \nu\nabla)\boldsymbol{A}=\boldsymbol{J}+\nu_r\nabla\times\boldsymbol{M} \qquad (1)$$

where ν_r is relative reluctivity, **A** magnetic vector potential, **J** current density, and **M** magnetization. Since **M** is a function of the potential **A** in equation (1), this equation is non-linear and therefore, magnetization **M** has to be solved by the iterative method, as displayed in Fig. 2.

For implementation of Preisach model, Everett function was used, which can be obtained from the measured hysteresis loop. Hysteresis loops of two media with different coercivities were used. Their magnetic properties are shown in Table 1. To improve the convergence and efficiency in computations, M-B variables were used as implementation variables instead of M-H variables. In the simulation, only longitudinal component of magnetization was calculated as a function of longitudinal field. Detailed hysteresis modeling was described in literature [4].

CoCrTa thin film media were used as

recording media and a single crystal double metal-in-gap (MIG) head was used. Permeability of the head was fixed to 2000, gap size 3000 Å, deep gap field 11000 Oe, and head-to-media spacing 1100 Å.

Table 1. Magnetic properties of thin film media

specimen	Hc (Oe)	S	S^*	Mr (emu/cc)	thickness(Å)
I	1200	0.89	0.82	590	700
II	1700	0.88	0.91	520	600

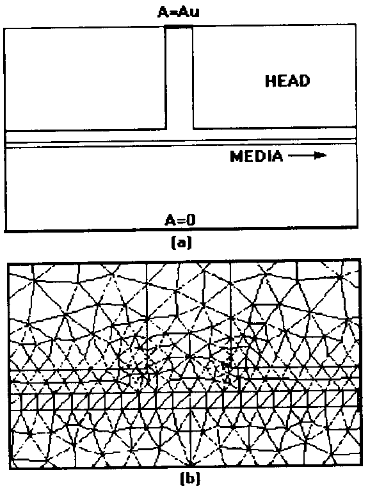

Fig. 1 Geometry and mesh used in FEM analysis
(a) head and media geometry (b) magnified mesh near gap

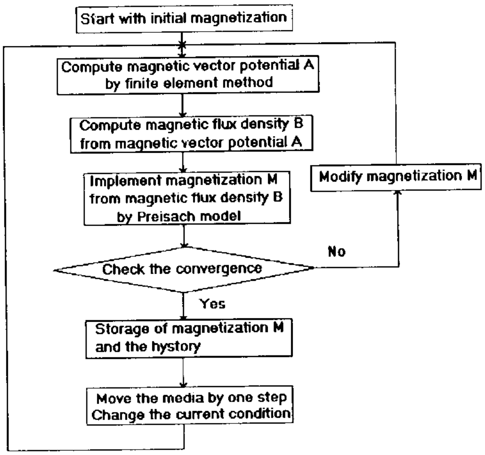

Fig. 2 Procedure of computation

III. RESULTS AND DISCUSSIONS

A. Formation of the single transition

Fig. 3 shows a procedure to form the single transition. Thin film media were assumed to be fully demagnetized at the initial state. Fig. 3(a) is a bit pattern when no displacement takes place. The curves shown in Figs. 3(b), (c), and (d) represent bit patterns when the recording field is unchanged, removed and reversed, respectively, after the media move 9 steps (5400 Å) to the right direction. In Figs. 3(a) and (b), the saturated region after 9-step moving is a little longer than that when no displacement takes place. This is because the field produced by an initially-formed positive bit is added to the applied head field and slightly stronger field is applied in the neighborhood of the initially-formed bit. When the field is removed, the magnetization in every place on the media approaches to that of its remanent state. When the field is reversed, the previously formed positive bit pattern is eroded to some extent by the reverse field, and forms the single transition. At this time, the peak value of magnetization is lower than that when the field is removed.

B. Effects of recording density on the hysteresis behavior

Resulting from the successive displacement of media and the periodic change in the polarity of head current, multi-transition can be obtained. Fig. 4 represents the traces of the field and the magnetization experienced during the movement from a point (i0) of −0.6 μm from the gap center to a point of 1.2 μm from the gap center. Three different recording densities are considered, that is, 35 kbpi (bit length, BL = 7200 Å), 50 kbpi (BL = 5400 Å), 80 kbpi (BL = 3000 Å).

If a certain point (i0) on the media moves towards the unsaturated region after passing the saturated region and at this time, field is reversed, its trace is not located on the major loop but on the minor loop (i4↔i5 in Fig. 4(c) and Fig. 5(c)). The probability that this phenomenon takes place increased with increasing recording density, irrespective of starting point. This phenomenon is well displayed in Figs. 4 and 5. For 35, 50 kbpi, the trace is not far away from the major loop, while for 80 kbpi, the trace is not on the major loop but on the minor loop.

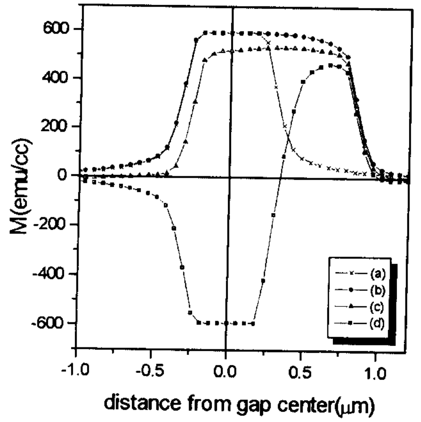

Fig. 3 Bit patterns with respect to position (Hc = 1700 Oe)
(a) bit pattern formed by a positive field, without moving the media
(b),(c), and (d): bit patterns after 9 steps (5400 A) moving, when recording field is unchanged (b), removed (c), and reversed (d)

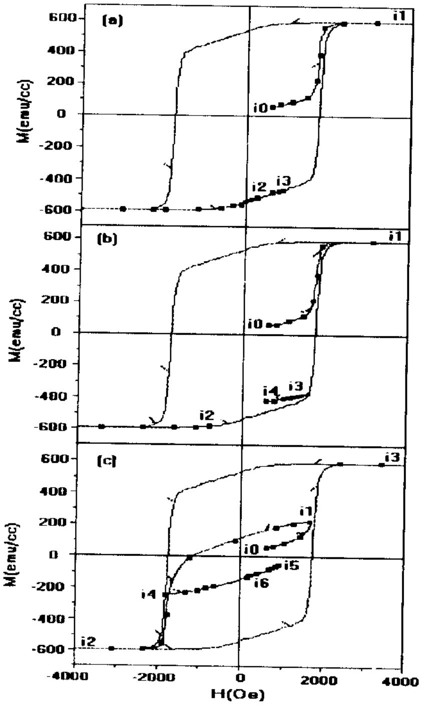

Fig. 4 Hysteresis loop of a certain point on the media at three different recording densities when it moves 1.8μm passing the head gap. Magnetization and field are subsequently changed from i0 to i1, i2, i3, and so on.
(a
) 35 kbpi (b) 50 kbpi (c) 80 kbpi

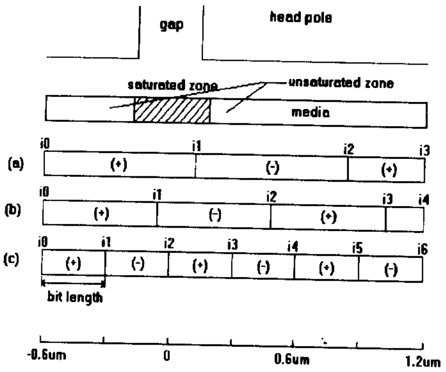

Fig. 5 Schematic drawings of bit length, head position, saturated zone, and sign of the field at each bit
(a) 35 kbpi (b) 50 kbpi (c) 80 kbpi

C. Effect of the media coercivity on the recorded bit pattern

To achieve the high density recording, the increase in coercivity of the media and the reduction of media thickness are necessary. In this paper, the effects of media coercivity and film thickness on the recording performance are analyzed quantitatively.

Fig. 6 represents bit patterns of the recording media with two different coercivities in three different recording densities. In Fig. 6, normalized Mr, which is the remanent magnetization of bit divided by remanent magnetization obtained in hysteresis curve, is used for the comparison of the recorded pattern. Fig. 7 shows the effects of recording density and media coercivity on normalized maximum (peak) Mr value. In Fig. 7, it is shown that as recording density increases, Mr (max) in the media with low coercivity (Hc = 1200 Oe) is attenuated more rapidly than Mr (max) in the media with high coercivity (Hc = 1700 Oe) and at high density recording regime, the difference of Mr (max) becomes larger. Mr (max) and transition shape are affected by the media coercivity. As the recording density increases, the broadening of the bit pattern is more severe for low coercivity media, and for media with low coercivity, and the bit pattern at very high recording density cannot be written on the media owing to the broadening of the transition region.

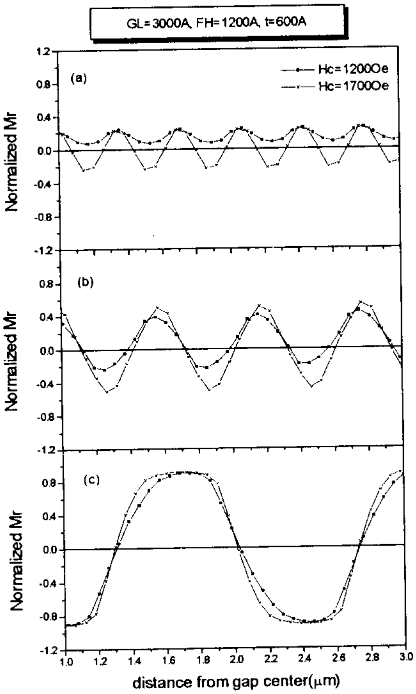

Fig. 6 Bit patterns of recording media with two different coercivities in three different recording densities: (a) 140 kbpi (b) 80 kbpi (c) 35 kbpi

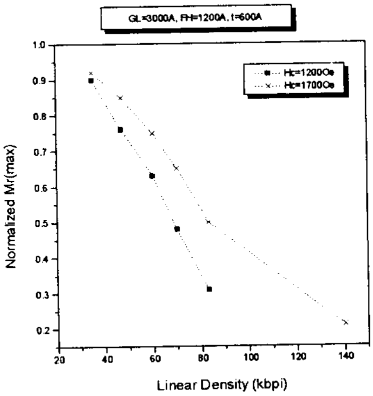

Fig. 7 Effect of media coercivity on Mr(max) in various recording densities

D. Effect of the film thickness on the recorded bit pattern

To investigate the effect of film thickness on the recorded bit pattern, writing process of the media with three different thicknesses was simulated, as shown in Figs. 8 and 9. In low recording density regime, the remanent magnetization increased with increasing film thickness. As the recording density increases, degree of decrease in the remanent magnetization was increased with increasing film thickness. Thus, for very high density recording regime, the remanent magnetization decreased with film thickness. For high recording density (140 kbpi), the slope of transition is steep and the width of transition is small in 300 Å thick media. Therefore, to achieve the high density recording, the film thickness should be small.

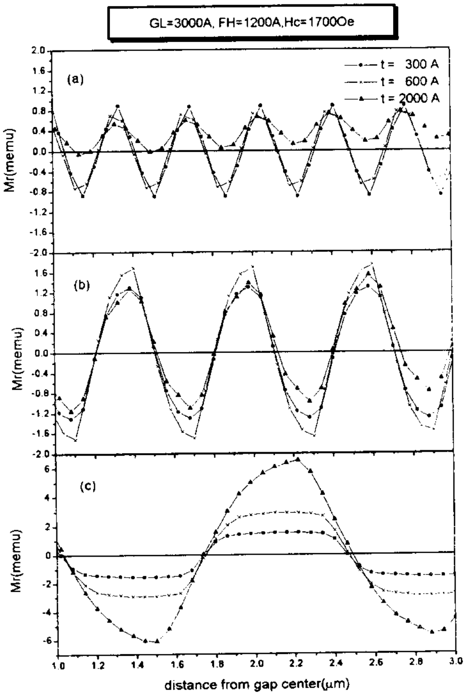

Fig. 8 Bit patterns of recording media with three different thicknesses in three different recording densities :
(a) 140 kbpi (b) 80 kbpi (c) 35 kbpi

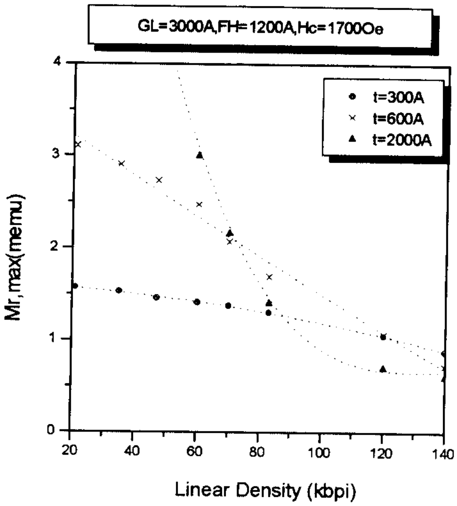

Fig. 9 Effect of media thickness on Mr (max) in various recording densities

Ⅳ. CONCLUSION

The magnetic recording process of thin film media was simulated by 2-D FEM analysis including hysteresis modeling. It was found that minor loop modeling plays an important role in high density recording, thus the model that fits precisely the experimental minor loop is needed. The Preisach modeling used in this study would be a powerful tool in the simulation of high density recording process.

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