Temperature and Electromagnetic Field Distributions of Heat-Assisted Magnetic Recording for Bit-Patterned Media at Areal Density beyond 6 Tb/in^2

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***Abstract*— Superparamagnetic effect and magnetic transition noise are the extremely challenge for magnetic recording technology. Heat-assisted magnetic recording and bit-patterned media (BPM) can solve those problems. This paper presents the temperature and electromagnetic field distributions for bit-patterned media at areal density of 6.54 to 17.92 Tb/in^2 by the finite integral technique method. We have found that the BPM can keep temperature in bit better than granular media. The temperature ratio of neighbor bits to heating bit of BPM at areal density of 6.54-7.69 Tb/in^2 is lower than 70% and increases with increasing areal density. In addition, the electric field is toward the bit and the magnetic field circulates around the heating bit.**

***Index Terms*—electromagnetic fields, nanopatterning, heat-assisted magnetic recording.**

I. INTRODUCTION

Magnetic recording is one of data storage technology with low cost per data capacity [1]. The advantages of the magnetic recording are widespread applied in many applications, one is hard disk drives. Mainstream of increasing areal density is to overcome the superparamagnetic effect at around 1 Tb/in^2 [2] by increasing the thermal stability, $K_u V/k_B T$, where K_u is magnetocrystalline anisotropy, V is grain volume, k_B is Boltzmann's constant and T is absolute temperature. With increasing areal density beyond 1 Tb/in^2, grain size must be smaller. Therefore, thermal stability can be increased by using high K_u materials as magnetic recording media. However, high K_u materials are too difficult to magnetize by conventional writing head [3]. To solve this problem, heat-assisted magnetic recording (HAMR) technique was proposed [4] because coercive field of magnetic materials can be reduced by heat, based on Brillouin function [5].

Magnetic transition is also one of ultra-high density magnetic recording problem. Conventional recording media is granular type media which each adjacent grain is close to the others. Therefore, magnetostatic field from the bits affects to the others called transition noise [6]. To eliminate this noise, bit-patterned media (BPM) [7] which each bit is isolated is proposed.

The light from laser – one of electromagnetic fields is used to heat the magnetic media in HAMR. Therefore, temperature and electromagnetic field distributions are the significant characteristics on HAMR in BPM technology at areal density beyond 6 Tb/in^2 that is investigated in this paper.

II. SIMULATION AND MODELING

Since the laser is used as heating source in HAMR. The light wave propagation from laser is based on Maxwell's equations. The changing of magnetic flux causes to induce voltage in the structure explained by Faraday's law [8]. Consequently, the current flows in the structure according to Ohm's law and generates heat described by Joule heating equation. Finally, temperature distribution in magnetic media is obtained by heat transfer equation.

Temperature and electromagnetic field distributions were simulated by finite integral technique (FIT) [9] software which is Computer Simulation Technology (CST). The 700 nm-wavelength light was used as heating source in this work. The $L1_0$-FePt - high K_u material and small grain size [10] is one of candidate magnetic material used to overcome the superparamagnetic effect. The nanopatterning dots of $L1_0$-FePt in FePt(10nm)/MgO(5nm)/FeCoNi(200nm) multilayer structure with surface area of 250×250 nm^2 is used as simulation model shown in Fig. 1. The surface area and spacing of the isolated FePt nano-dot are 5×5 nm^2 and 1-5 nm, respectively. The areal density can achieve from 6.54 Tb/in^2 at 5 nm spacing and 17.92 Tb/in^2 at 1 nm spacing. The electrical and thermal parameters for each material are shown in Table 1 [11]. Background temperature is set as 293 K and heating temperature from laser source is set as 650 K with heating time of 0.1 ns. Heating source spot is defined as a dot by discrete port at the center of magnetic layer. Boundary condition is defined as open add space.

III. RESULTS AND DISCUSSION

Figure 2 shows the electric and magnetic fields of laser in BPM at areal density of 6.54 Tb/in^2. The maximum intensity of electric and magnetic fields is at the center of heating bit and decreases along the distance from the heating bit. The direction of electric field is toward the heating bit and the direction of magnetic field circulates around the heating bit.

Figure 3 shows temperature distribution of BPM at areal density of 6.54 and 17.92 Tb/in^2. We found that the highest temperature area (in red) of BPM at areal density of 6.54 Tb/in^2 is only 5×5 nm^2 that means it is high temperature only the heating bit. On the other hand, the first neighbor bits of heating bit in BPM at areal density of 17.92 Tb/in^2 are also high temperature (in red). It indicates that the temperature of heating bit has more effect on neighbor bits with increasing areal density.

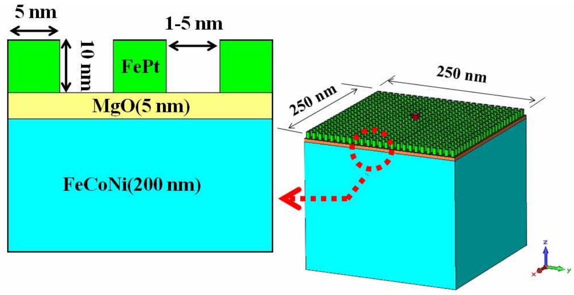

Fig. 1. $L1_0$-FePt bit-patterned media structure.

TABLE I
MATERIALS PROPERTIES AT 293 K AND 700 NM

Materials	ρ (kg/m^3)	c (kJ/(kg·K))	K (W/(m·K))	$n+ik$	σ (S/m)
FePt	8,862	0.421	99.2	2.68 +i3.58	-
FeCoNi	8,761	0.428	20.0	-	5×10^6
MgO	3,580	0.96	45.0	-	89
Air	1.205	1.005	0.0257	1	-

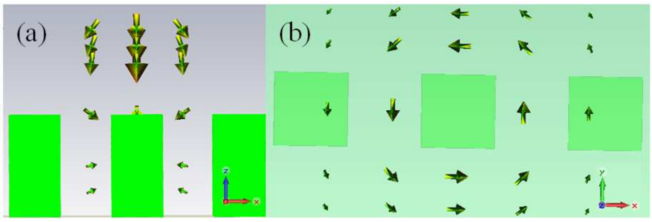

Fig. 2. The distribution of (a) electric field and (b) magnetic field at 6.54 Tb/in^2.

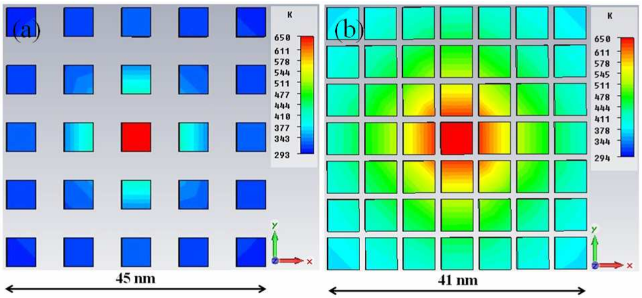

Fig. 3. Temperature distribution of BPM: (a) 6.54 Tb/in^2 with 5 nm bit size and 5 nm spacing and (b) 17.92 Tb/in^2 with 5 nm bit size and 1 nm spacing.

The temperature ratio of the neighbor bits of heating bit and the heating bit is shown in Fig. 4. The temperature of heating bit, the first neighbor bit next to heating bit and so on is indicated by T_{bit1}, T_{bit2}, and so on, respectively. We found that $T_{\text{bit2}}/T_{\text{bit1}}$ is the highest. The thermal effect of BPM at areal density of 6.54-7.69 Tb/in^2 is lower than 70% and increases with increasing areal density.

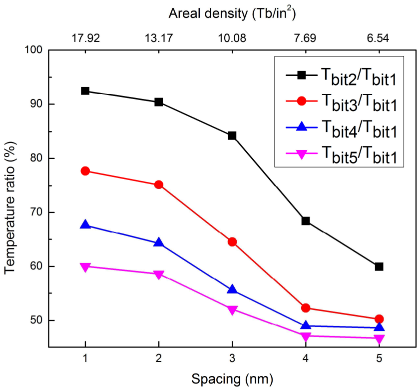

Fig. 4. Temperature ratio of BPM with areal density of 6.54-17.92 Tb/in^2.

IV. CONCLUSIONS

The temperature and electromagnetic field distributions of HAMR for BPM at areal density beyond 6 Tb/in^2 are investigated by FIT method. The BPM can keep temperature in bit better than granular media. The $T_{\text{bit2}}/T_{\text{bit1}}$ of BPM at areal density of 6.54-7.69 Tb/in^2 is lower than 70% and increases with increasing areal density. The electric field is toward the bit and the magnetic field circulates around the heating bit. These results lead to develop the future magnetic recording for ultra-high areal density.

V. ACKNOWLEDGEMENTS

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