MICROMAGNETIC MODEL SIMULATIONS CONSIDERING WRITE HEAD, SPIN-TORQUE OSCILLATOR, AND DOUBLE-LAYERED MEDIUM ALTOGETHER

Yasushi KANAI[1], Ryo ITAGAKI[1] Simon J. GREAVES[2] and Hiroaki MURAOKA[2]

1) Niigata Institute of Technology, Kashiwazaki, Japan, kanai@iee.niit.ac.jp

2) Tohoku University, Sendai, Japan, {simon, muraoka}@riec.tohoku.ac.jp

I. INTRODUCTION

Previously we considered several spin-torque oscillator (STO) designs integrated into the write head for microwave-assisted magnetic recording (MAMR) [1], where the main pole and trailing shield (MP-TS) gap was perpendicular to the medium surface [2]. We found that STOs tilted with regard to the medium surface had more stable oscillation than STOs oriented perpendicular to the medium. Media recording simulations have shown that MAMR has advantages over conventional perpendicular magnetic recording. However, it is necessary to model the entire head, STO and recording medium together in order to determine the effect of magnetostatic interactions between the components.

In this work micromagnetic model simulations were performed to investigate STO integrated into the MP-TS gap of the write head (integrated STO). First, the oscillation states of a tilted STO were investigated in a model comprising the write head, STO and medium soft underlayer (SUL). We found that inserting the STO into a non-parallel MP-TS gap resulted in more stable oscillation compared with an STO in a MP-TS gap perpendicular to the medium surface. Second, we performed full micromagnetic simulations of the write head, STO, SUL and recording layer (RL) and the oscillation of the tilted STO was investigated. We found that the RL affected STO oscillation to some extent, however, the effect was smaller than that from the write head. We also discuss medium recording simulations carried out using the full model.

II. MODELING AND RESULTS

Fig. 1 shows the write head model used for the calculations. We assumed a tapered main pole and narrow MP-TS gap (20 nm) for high recording field and high recording field gradient. The recording field and the recording field gradient peaked at a trailing shield angle, ϕ, of 40°. To fit the STO into the MP-TS gap, it should be tilted with regard to the medium surface and head air-bearing surface (ABS). Note the taper angles of the MP and TS were different in order to reduce magnetostatic interactions between the write head and the STO. The FGL can be either on the MP- or TS- side, as shown in Fig. 2, and we treated the current density in the STO as nonuniform as the surface of the STO should be exposed to the ABS. Note L is dependent on θ in Fig. 2, e.g., L = 16.2 nm when θ = 15°, L = 11.9 nm when θ = 30°, and L = 6 nm when θ = 45°. Table I shows the major parameters of the FGL and SIL used in the calculations.

Prior to the integrated model simulations, we investigated isolated STOs with MP- and TS-side FGLs. It was found that when the FGL was on the MP-side the magnetization did not oscillate stably, presumably due to less spin torque field. Putting the FGL on the TS side resulted in stable oscillation, as shown in Fig. 3. In Fig. 4, stable FGL oscillation is shown for the integrated STO model without RL; this was possible due to the small FGL area (20 nm × L to 20 nm), although a large injected current density was necessary. It is also noted that the oscillation was poor compared with the isolated STO.

We also performed full micromagnetic simulations considering the write head, STO, SUL and RL (12 nm thick ECC granular medium) and the oscillation state of the tilted STO was investigated as shown in Fig. 5. Compared with Fig. 4, we found that the RL affected the STO oscillation to some extent, however, the effect was smaller than that from the write head. With the assistance of the microwave field, some signals were written on ECC media with hard layer H_k = 48 kOe, on which it was impossible to write without microwave assist. Details will be discussed in the full paper.

Yasushi KANAI
E-mail: kanai@iee.niit.ac.jp
tel: +81-257-22-8111
Engineering Department
Niigata Institute of Technology
Kashiwazaki 945-1195, Japan

The authors acknowledge the financial support from JSPS Kaken-hi (16K06321) and Advance Storage Research Consortium (ASRC); software support from JSOL, Japan.

REFERENCES

1) J.-G. Zhu, X. Zhu, and Y. Tang, "Microwave assisted magnetic recording," *IEEE Trans. Magn.*, 44(1), 125-131 (2008).
2) Y. Kanai, K. Yoshida, S. Greaves, and H. Muraoka, "Micromagnetic model analysis of spin-transfer torque oscillator and write heads for microwave-assisted magnetic recording," *IEEE Trans. Magn.*, 53(2), Art ID 3000211 (2017).

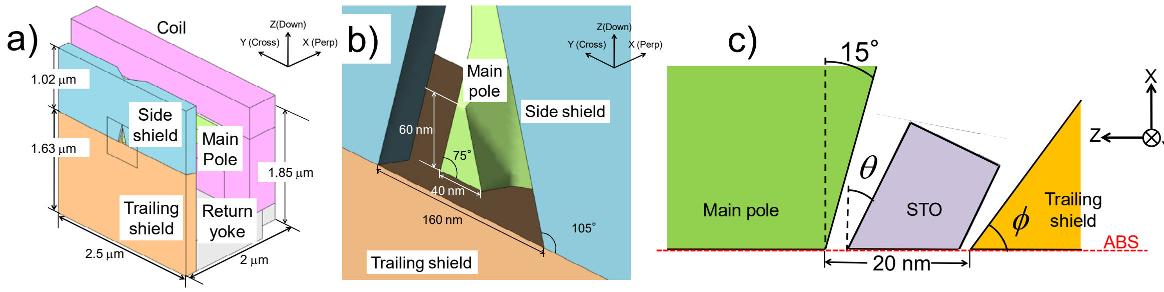

Fig. 1 Schematic structure of write head used for the calculations. a) Whole, perspective view, b) magnified main pole tip region (STO was not displayed) and c) arrangement of STO and write head.

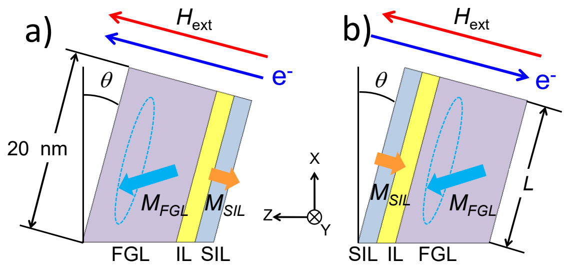

Fig. 2 Tilted STO with regard to the medium surface and ABS. a) FGL is on main pole (MP) side and b) FGL is on trailing shield (TS) side.

Table I Major parameters of FGL and spin injection layer (SIL) used in the calculations

	FGL	SIL
$4\pi M_s$	20 kG	6 kG
H_k (*)	31.4 Oe	31.4 Oe
α	0.02	0.02
Exchange, A	2.5×10^{-6} erg/cm	0.75×10^{-6} erg/cm
Thickness	10 nm	2 nm

Po = 0.5, Width = 20nm, Height = L to 20 nm, Inter layer = 2 nm.

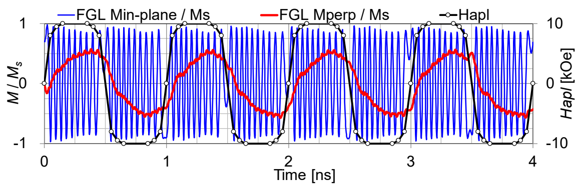

Fig. 3 FGL rotation vs time. Isolated STO. θ = 15°, FGL: TS side, H_{ext} =20 kOe$_{pp}$, J = 3.0×10^8 A/cm^2.

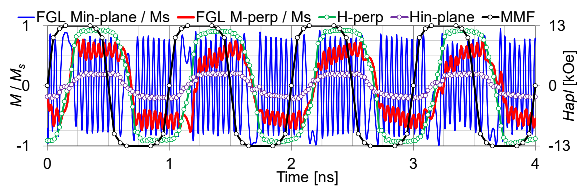

Fig. 4 FGL rotation vs. time. Integrated STO without recording layer. θ = 15°, FGL: TS side, J = 6.0×10^8 A/cm^2. Black line (MMF) shows head coil current of 0.2 AT$_{pp}$; green (H-perp): perpendicular component of head field in FGL; purple (H-in-plane): in-plane component of head field in FGL; blue (FGL M-in-plane): in-plane component of FGL magnetization; red (FGL M-perp): perpendicular component of FGL magnetization.

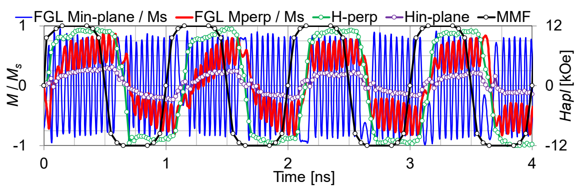

Fig. 5 FGL rotation vs. time. Integrated STO with recording layer. θ = 15°, FGL: TS side, J = 6.0×10^8 A/cm^2. Head coil current = 0.2 AT$_{pp}$.