Micromagnetic Model Simulation of Spin-Torque Oscillator and Write Head for Microwave-Assisted Magnetic Recording – Spin Injection Layer with In-Plane Anisotropy –

Yasushi KANAI and Ryo ITAGAKI
Department of Information and Electronics Engineering
Niigata Institute of Technology
Kashiwazaki, Japan
kanai@iee.niit.ac.jp, r_itagaki@cc.niit.ac.jp

Simon GREAVES and Hiroaki MURAOKA
Research Institute of Electrical Communication (RIEC)
Tohoku University
Sendai, Japan
{simon, muraoka}@riec.tohoku.ac.jp

***Abstract*—Micromagnetic simulations were carried out to obtain stable oscillation of a spin transfer torque oscillator (STO) inserted into the gap between the main pole and trailing shield of a write head. We assumed a spin injection layer with in-plane anisotropy. Results show that reducing the magnetostatic interaction between the write head and the STO is the key to obtaining stable STO oscillation.**

Keywords*—*micromagnetic simulations, microwave-assisted magnetic recording, spin-torque oscillator, write head.

I. INTRODUCTION

Microwave-assisted magnetic recording (MAMR) [1] is one candidate for next-generation perpendicular magnetic recording [2]. Stable oscillation is one of the most important factors for spin-torque oscillators (STO) used in a MAMR system. We performed micromagnetic simulations and found that the oscillation states of the isolated (without write head), and integrated (with write head), STO models were different, i.e., stable STO oscillations were hard to obtain primarily due to the magnetostatic interactions between the STO and write head [3].

In this paper, we investigate STOs utilizing a spin injection layer (SIL) with in-plane anisotropy [4]. We also introduce a STO tilted with respect to the medium plane, along with a tilted main pole – trailing shield gap (tilted STO) to reduce the magnetostatic interactions between the STO and write head. Results show that the SIL with in-plane anisotropy worked well when the STO was isolated. Whilst the integrated STO only worked when the tilted STO was used.

II. CALCULATION MODEL

A micromagnetic model analysis was carried out considering a STO utilizing transmission spin torque. We used the commercial micromagnetic software (Fujitsu, EXAMAG v.2.1, http://www.fujitsu.com/global/about/resources/news/press-releases/2015/0324-01.html).

In Fig. 1, the isolated STO, without write head, used for the calculations is shown. A double-layered STO was used, with a non-magnetic interlayer (IL) placed between the field generation layer (FGL) and SIL. Table I lists the main parameters of the FGL and SIL that were used unless stated otherwise in Sections III and IV. We modelled both soft and hard, in-plane magnetic SILs. A uniform external field and uniform injected current were assumed along the z-axis over the STO volume. The STO was divided into cubes with 2.5 nm sides. Note that we modeled an STO with 20 nm × 20 nm area as it rotated stably with low injected current density, *J*, and low external field.

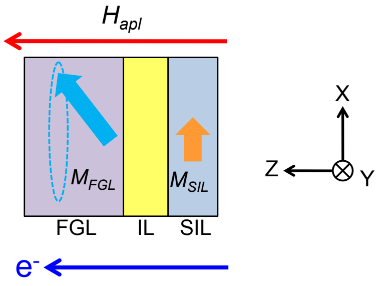


Fig. 1. STO model used for the calculations. Double-layered STO with transmission spin torque utilized.

TABLE I. MAIN PARAMETERS OF FGL AND SIL USED IN THE CALCULATIONS

	FGL	SIL
$4\pi M_s$	20 kG	6 kG
H_k (*) in-plane	31.4 Oe	31.4 Oe, 20 kOe
α	0.02	0.02
Exchange, *A*	2.5×10^{-6} erg/cm	0.75×10^{-6} erg/cm
Thickness	10 nm	2 nm
P_o = 0.5, Width × height = 20 nm × 20 nm, Inter layer = 2 nm		

* H_k: anisotropy field

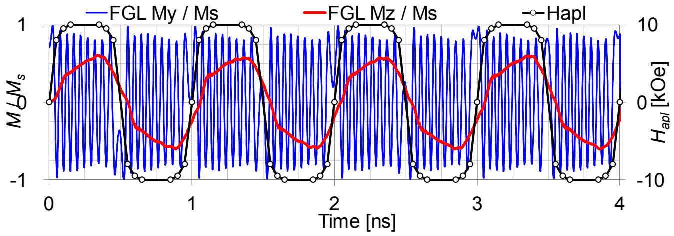
The authors acknowledge the financial support from JSPS Kaken-hi (16K06321) and Advance Storage Research Consortium (ASRC); software support from JSOL, Japan.

Submitted On: September 13, 2018
Accepted On: January 1, 2019

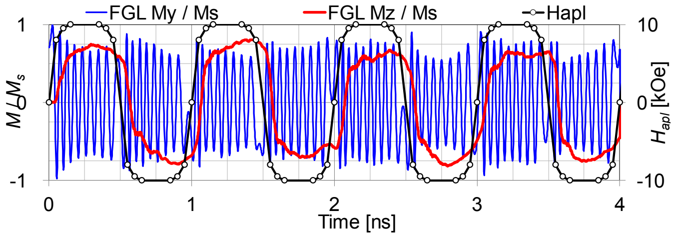
1054-4887 © ACES

III. RESULTS – ISOLATED STO –

In Fig. 2, FGL rotations under a 1 GHz, external field are shown for soft and hard SILs, where the horizontal axis is the time. The results are shown from t = 0, initial state. The left vertical axis shows M/M_s for the in-plane (M_y) and perpendicular-to-the-plane (M_z) components of the FGL magnetization averaged over the FGL volume, i.e., the FGL magnetization rotated perfectly in the x-y plane when M_y/M_s = 1. As can be seen, the FGL rotated well for both soft (H_k = 31.4 Oe) and hard (H_k = 20 kOe) SIL materials with in-plane anisotropy, which was quite different from STOs utilizing SILs with perpendicular anisotropy [3].

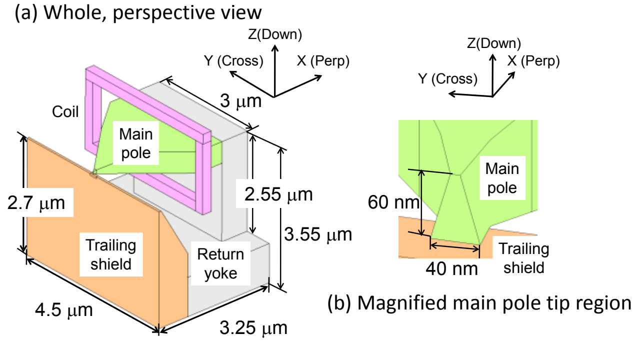


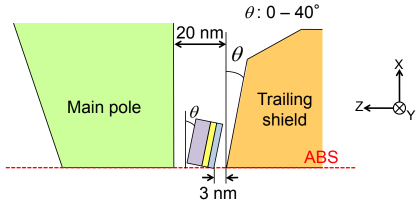
(a) SIL H_k = 31.4 Oe (in-plane)



(b) SIL H_k =20 kOe (in-plane)

Fig. 2. FGL rotations vs. time for soft and hard SILs. $J = 3.0\times10^8$ A/cm^2.





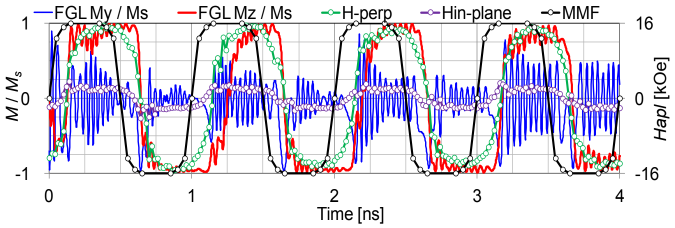
(c) Arrangement of STO and write head

Fig. 3. Schematics of write head and STO integrated into the tilted MP–TS gap used in the calculations.

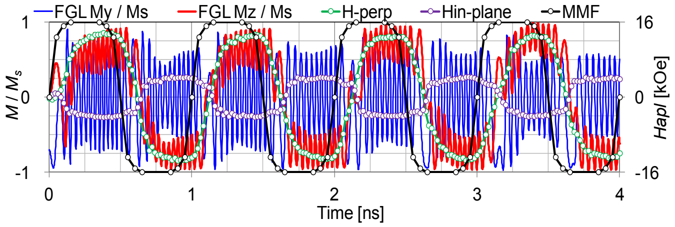
IV. RESULTS – INTEGRATED STO –

In Fig. 3, the STO was integrated into the main pole and trailing shield (MP–TS) gap of the write head. We considered both perpendicular STOs (STO perpendicular to the medium plane (parallel to ABS)), and tilted STOs (STO tilted to the medium plane). In the tilted STO, the magnetostatic interactions between the STO and the write head were smaller than the perpendicular STO. The STOs had the same parameters shown in Table I.

In Fig. 4, FGL rotations vs. time are shown for the perpendicular and tilted STOs when a 1 GHz coil current was applied. It is seen that the perpendicular STO did not rotate stably, while the tilted STO worked quite well. It is also seen that the oscillation state of the integrated STO was quite different from isolated one. This shows that an integrated STO utilizing an SIL with in-plane anisotropy works only when used in a tilted MP-TS gap.



(a) Perpendicular STO: $\theta = 0°$



(b) Tilted STO: $\theta = 40°$

Fig. 4. FGL rotations vs. time. Integrated perpendicular and tilted STO models. Applied MP-TS gap fields to FGL are also shown. $J = 3.0\times10^8$ A/cm^2, SIL H_k = 20 kOe (in-plane).

REFERENCES

[1] J.-G. Zhu, X. Zhu, and Y. Tang, "Microwave assisted magnetic recording," IEEE Trans. on Magn., vol. 44, no. 1, pp. 125-131, Jan. 2008.

[2] Energy-assisted Recording Technology, [Online.] Available: https://play.vidyard.com/JZLozr2ujb2jR964BaFNPW

[3] Y. Kanai, R. Itagaki, S. Greaves, and H. Muraoka, "Micromagnetic model analysis of various spin torque oscillators with write head for microwave-assisted magnetic recording," IEEE Trans. on Magn., vol. 53, no. 11, Nov. 2017. Art. no. 3001105.

H. Sepeheri-Amin, S. Bosu, C. Abert, Y. Sakuraba, S. Kasai, M. Hayashi, D. Suess, and K. Hono, "Design and development of spin-torque-oscillator for microwave assisted recording," The Magnetic Recording Conference, E2, Tsukuba, Japan, Aug. 2017.