Microstructure design of Spin-Torque-Oscillator for microwave assisted magnetic recording applications using micromagnetic simulation

NIMS[1], Danube University Krems, Austria[2], Technical University of Vienna, Austria[3]
○H. Sepehri-Amin[1], S. Bosue[1], Y. Sakuraba[1], T. Schrefl[2], C. Abert[3], D. Suess[3], and K.Hono[1]
E-mail: h.sepehriamin@nims.go.jp

Microwave assisted magnetic recording (MAMR) is considered as one of good candidates for next generation higher areal density magnetic recording technology. For MAMR writer, mag-flip spin-torque-oscillator (STO) consisting of out -of-plane magnetized spin injecting layer (SIL) and in-plane magnetized field generating layer (FGL) is required. Microwave frequency of above 20 GHz is required to be oscillated with a current density below 1.0×10^8 A/cm^2 [1,2]. However, this has not been realized experimentally. In this work, we employed micromagnetic simulations to study the effect of spin polarization (β) and saturation magnetization ($\mu_0 M_s$) of SIL and FGL on the oscillation behavior of a mag-flip STO device.

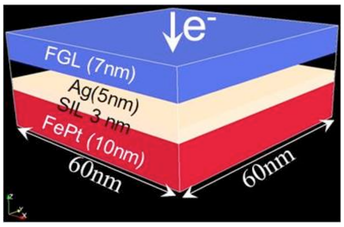

Fig.1: modelled STO device for the micromagnetic simulation.

A mag-flip STO device was modeled with a geometry of FePt (t_{FePt}=7nm), spin injecting layer (t_{SIL} = 3nm), Ag (t_{Ag} = 5nm), and a field generating layer (t_{FGL} = 7nm) as shown in Fig. 1 and tetrahedron meshes were used. Spin-torque acting owning to a spin-polarized current pumped from top to bottom of the device was calculated by solving the Landau-Lifshitz-Gilbert (LLG) equation augmented by Slonczewski spin-transfer torque term. In order to study the influence of spin polarization and magnetization of SIL on the oscillation behavior of FGL, the spin accumulation term is coupled to a local magnetization term by a torque term in the LLG equation [3].

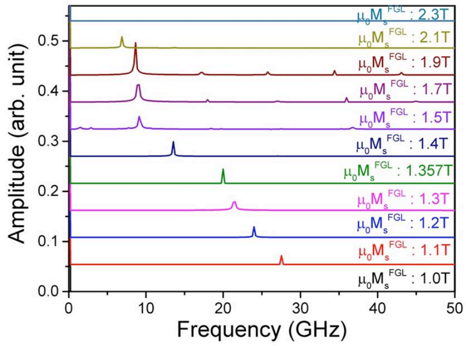

Fig.2: Frequency spectrum of STO device with different saturation magnetization ($\mu_0 M_s$) of FGL layer. Applied magnetic field was 1.0 T and applied current density is 1.2×10^8 A/cm^2.

Figure 2 shows frequency spectrum of a STO device with a cross-sectional size of 60×60 nm^2. Frequency peaks shifts to smaller values with increasing $\mu_0 M_s$ of the FGL layer, and no oscillation was found for $\mu_0 M_s$=2.3 T. In addition, multi-mode oscillation and spin waves were observed for $\mu_0 M_s$= 1.7 and 1.9 T. However, by the reduction of the size of STO device from 60×60 nm^2 to 30×30 nm^2, a uniform oscillation was observed due to the reduction of the demagnetization field. The frequency and the oscillation angle are increased with spin polarization of FGL. Micromagnetic simulations showed that the increase of $\mu_0 M_s$ of SIL can hinder magnetization switching of FGL and is beneficial to induce out-of-plane oscillation in the FGL. Figure 3 shows frequency spectrum as a function of spin polarization of SIL. This simulation was carried out by solving spin diffusion equations in parallel to LLG equation to consider the effect of spin accumulation at the interfaces. The frequency peak increases from 21 GHz to 25 GHz by increasing the spin polarization of SIL from 0.5 to 0.85, for the current density of just 1.0×10^8 A/cm^2. Higher spin polarization in SIL layer leads to a smaller threshold for the current density to oscillate the FGL layer.

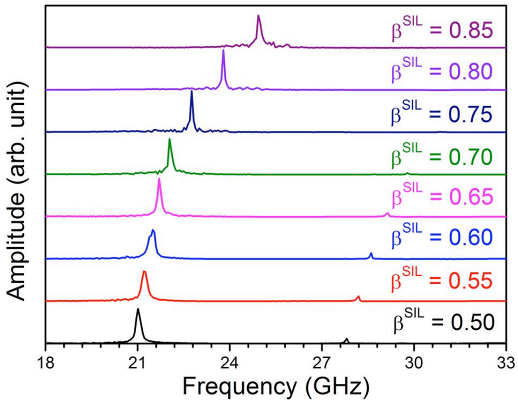

Fig.3: Influence of spin polarization of SIL on RF peak of STO device shown in Fig. 1. Applied magnetic field was 1.0 T and applied current density is 1.0×10^8 A/cm^2.

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[3] C. Abert et al. J. Magn. Magn. Mater. 345 (2013) 29.