Mag-flip spin torque oscillator using highly spin polarized Heusler alloy as spin injection layer for microwave assisted magnetic recording

S. Bosu, H. Sepehri-Amin, Y. Sakuraba, S. Kasai, M. Hayashi, and K. Hono
National Institute for Materials Science, 1-2-1 Sengen, Tsukuba, Japan 305-0047

A major challenge of microwave assisted magnetic recording (MAMR) is the development of a mag-flip spin torque oscillator (STO) [1] with a cross section area of \( \sim 40 \times 40 \) nm\(^2\) or less consisting of an in-plane magnetized field generating layer (FGL) and a perpendicularly magnetized spin-injection layer (SIL) that is able to generate a large ac field \( \mu_0 H_{ac} \) \( \approx 0.1 \) T from FGL with a frequency \( f \) over 20 GHz at small critical bias current density \( J_c \leq 1.0 \times 10^8 \) A/cm\(^2\) [2]. Solid understanding of the underlying mechanism of the large angle(\( \theta \)) out-of-plane precession (OPP) is equally essential. Recently, we demonstrated a mag-flip STO using highly spin polarized Heusler alloy \( \text{Co}_2\text{FeGa}_{0.5}\text{Ge}_{0.5} \) (CFGG) as a spin injection layer (SIL) [3] for the reduction of \( J_c \). We reported, the usage of FePt/CFGG SIL reduces \( J_c \) by \( \sim 50\% \) compared to that using a FePt/Fe\(_2\)Co SIL. In the present study, to generate a stable OPP mode as well as to achieve a high \( \mu_0 H_{ac} \) \( \approx \mu_0 M_s l \times \sin \theta_l \) (\( l \) is the thickness of FGL), we employed Fe\(_2\)Co with \( \mu_0 M_s \approx 2.3 \) T as FGL in combination with a highly spin polarized CFGG (\( l=3 \) nm) SIL perpendicularly magnetized with FePt (10 nm). We prepared cylindrical shape STO devices with diameter, \( D \sim 29 \) and 42 nm to investigate STO properties. Fig. 1(a) shows the schematic diagram of the experimental CPP nano-pillar STO devices. The SEM images for \( D \sim 42 \), and 29 nm STO devices are presented in Fig. 1(b). When FGL is oscillating in uniform OPP mode, rf spectrum can not be detected for external magnetic filed \( \mu_0 H_{ext} \) applied perpendicular to film plane, i.e., \( \theta_l = 0 \) since the relative angle between the FGL and SIL is constant during oscillation. Therefore, to obtain a finite \( \Delta R(t) \), i.e., to detect the \( f \) spectrum, it is necessary to tilt slightly the \( \theta_l \) of \( \mu_0 H_{ext} \) from the film normal. Figures 1(c) and (e) show the \( \Delta R- \mu_0 H_{ext} \) curves with \( \mu_0 H_{ext} \) applied at a slight tilting \( \theta_l \sim 4 \) to \( 5^\circ \) for \( D \sim 42 \) nm and 29 nm, respectively. Large \( \Delta R \) rise at high \( \mu_0 H_{ext} \) is comparable to that at \( \mu_0 H_{ext} \sim 0 \), which corresponds to large angle oscillations that appears at \( I_{dc} = -6 \) mA (\( |J_f| \sim 4.3 \times 10^3 \) A/cm\(^2\)) and \( -3.5 \) mA (\( |J_f| \sim 5.3 \times 10^3 \) A/cm\(^2\)) for \( D \sim 42 \) nm and 29 nm, respectively. Corresponding power spectra with maximum \( f \sim 21 \) and 25.5 GHz around \( \mu_0 H_{ext} \sim 1.1 \) T for \( D \sim 42 \) and 29 nm, respectively, in Figs. 1(d) and (f) are in the OPP mode. Our micromagnetic simulation results also imply that large ac magnetic field \( \mu_0 H_{ext} \sim 0.2 \) T can be generated (not shown) from the STOs with a pillar size of \( D \sim 30 \) to 40 nm using Fe\(_2\)Co (7 nm) FGL with high \( \mu_0 M_s \sim 2.3 \) T.