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

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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 ~ 40 × 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 $\mu_0H_{ac} > 0.1$ T from FGL with a frequency f over 20 GHz at small critical bias current density $J_C < 1.0 \times 10^8$ A/cm^2 [2]. Solid understanding of the underlying mechanism of the large angle(φ) out-of-plane precession (OPP) is equally essential. Recently, we demonstrated a mag-flip STO using highly spin polarized Heusler alloy $Co_2FeGa_{0.5}Ge_{0.5}$ (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 ~50% compared to that using a FePt/Fe_2Co SIL. In the present study, to generate a stable OPP mode as well as to achieve a high $\mu_0H_{ac} \propto \mu_0M_s l \times sin\varphi$ (l is the thickness of FGL), we employed Fe_2Co with μ_0M_s ~ 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 ~ 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 ~ 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 μ_0H_{ext} applied perpendicular to film plane, i.e., $\theta_H = 0$ 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 θ_H of μ_0H_{ext} from the film normal. Figures 1(c) and (e) show the ΔR- μ_0H_{ext} curves with μ_0H_{ext} applied at a slight tilting θ_H~ 4 to 5° for D~ 42 nm and 29 nm, respectively. Large ΔR rise at high μ_0H_{ext} is comparable to that at μ_0H_{ext} ~ 0, which corresponds to large angle oscillations that appears at I_{dc} = –6 mA ($|J|$ ~ 4.3 × 10^8 A/cm^2) and – 3.5 mA ($|J|$ ~ 5.3 × 10^8 A/cm^2) for D ~ 42 nm and 29 nm, respectively. Corresponding power spectra with maximum f ~ 21 and 25.5 GHz around μ_0H_{ext} ~ 1.1 T for D ~ 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 μ_0H_{ac} ~ 0.2 T can be generated (not shown) from the STOs with a pillar size of D ~ 30 to 40 nm using Fe_2Co (7 nm) FGL with high μ_0M_s ~ 2.3 T.

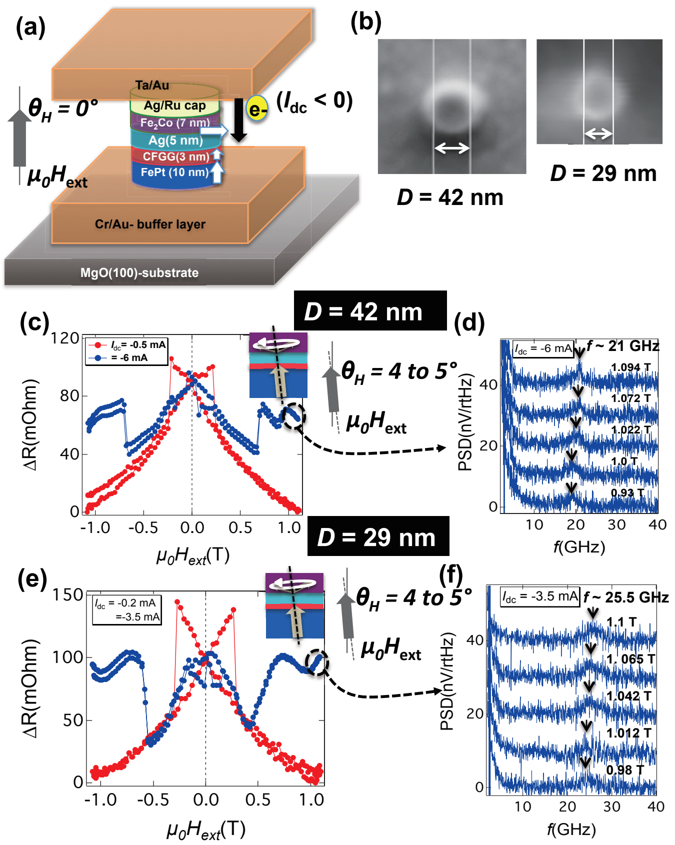

Figure 1: Schematic diagram of the STO device structure (a), SEM images of reference devices with D ~ 42 and 29 nm (b). ΔR-μ_0H_{ext} curves with μ_0H_{ext} applied at tilting angle, θ_H ~ 4-5° from film normal for (c) D ~ 42 nm and (e) D ~ 29 nm STO devices. Inset cartoons represent oscillation states of FGL. rf power spectrum (d) for D = 42 nm at I_{dc} = -6mA, and (f) for D = 29 nm at I_{dc} = -3.5 mA. f ~ 21 GHz and f ~ 25.5 GHz has been observed for D = 42 nm and D = 29 nm, respectively at μ_0H_{ext} ~ 1.1 T.

References: [1] Zhu J. *et al.,* IEEE Trans. Magn. 44, 125 (2008), [2] Takeo A. *et al.*, Intermag Conference 2014 (AD-02), [3] Bosu S. *et al.,* Appl. Phys. Lett. **108**,072403 (2016)