Reduction of bias current density using Heusler alloy spin injection layer in mag-flip spin-torque oscillator devices for microwave-assisted magnetic recording

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The main challenges of microwave assisted magnetic recording (MAMR) for next generation high areal density magnetic recording are development of a mag-flip spin torque oscillator (STO) [1] consisting of the in-plane magnetized field generating layer (FGL) and the perpendicular magnetized spin-injection layer (SIL) that is able to generate a large H_{ac} from FGL with a frequency over 20 GHz at small bias current density $J_C < 1.0 \times 10^{12}$ A/m^2 [2]. We have investigated the oscillation behavior of a mag-flip STO device (Fig. 1(a)) with 100 nm diameter circular pillar using highly spin polarized ferromagnetic Heusler alloy, $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (CFGG), perpendicularly magnetized with FePt as SIL to reduce J_C, and also compared with a typical ferromagnetic alloy CoFe SIL. ΔR-H_{ex} curves in Fig. 1 (b) and (c) for CFGG and CoFe SILs, respectively, for various negative dc bias currents I_{dc} with H_{ex} applied perpendicular to film plane (θ ~0°) reveals higher MR values for CFGG SIL than CoFe SIL. Moreover, for CFGG SIL when $|I_{dc}| > 5.5$ mA a sudden jump to the intermediate resistance state at high H_{ex} region in the ΔR-H_{ex} curves indicates excitation of magnetization dynamics by the reflected spin current from the SIL interface. On the other hand, for CoFe SIL intermediate resistance state appears for $|I_{dc}| > 13$ mA. Such difference in MR and I_{dc} seems to be due to the higher spin polarization in CFGG than CoFe. Figures 1(d), and (e) show, ΔR-H_{ex} for $|I_{dc}| > 9$ mA, and corresponding rf signals for CFGG SIL respectively, with H_{ex} slightly tilted θ ~7° from the film normal. A maximum f ~12 GHz has been observed for H_{ex} ~ 10 kOe, which systematically decreases following Kittle's equation. Moreover, the blue shift of f with I_{dc} (not shown here) also confirms detection of oscillation perpendicular to plane for the bias current density J_C ~ 0.95 to 1.15 × 10^{12} A/m^2, which is close to the desired J_C for application.

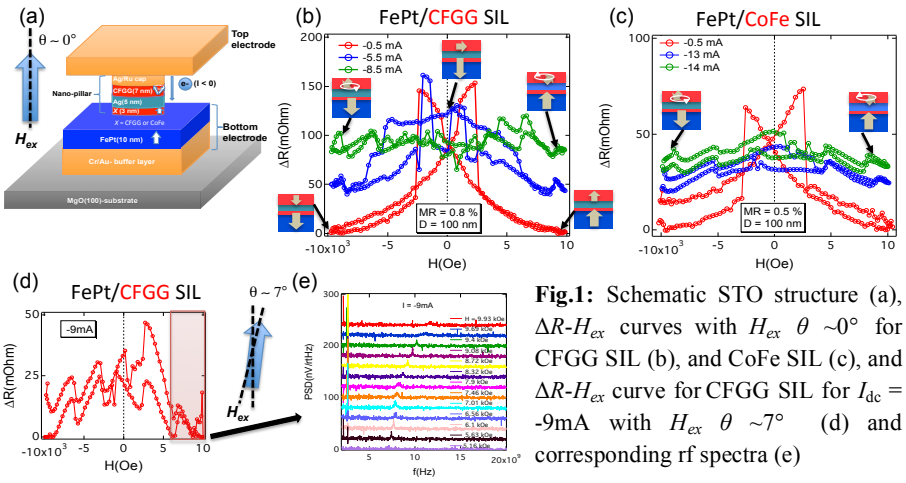

Fig.1: Schematic STO structure (a), ΔR-H_{ex} curves with H_{ex} θ ~0° for CFGG SIL (b), and CoFe SIL (c), and ΔR-H_{ex} curve for CFGG SIL for I_{dc} = -9mA with H_{ex} θ ~7° (d) and corresponding rf spectra (e)

References: [1] J. Zhu *et al.,* IEEE Trans. Magn. 44, 125 (2008), [2] A. Takeo *et al.*, Intermag Conference 2014 (AD-02)

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