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High Power Spin Torque Oscillation in a Co_2(Fe,Mn)Si Layer

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[Introduction] One of intriguing devices using the magnetization precession induced by spin torque is a spin torque oscillator (STO), which is a prospective nanometer-scaled radio frequency (rf) oscillator for the on-chip communication. However, STOs have several crucial issues need to be solved for the practical use: the enhancement of output rf power (P_{out}), the improvement of the quality in oscillation, and the increase in the frequency tunability by electric current and/or magnetic field. Although magnetic tunnel junction (MTJ)-based STOs may solve the first issue since P_{out} is roughly proportional to the square of the magnetoresistance (MR) ratio, its wide oscillation linewidth is not acceptable from the practical points of view. On the other hand, a current-perpendicular-to-plane (CPP)-giant magnetoresistance (GMR) device generally shows narrow oscillation linewidth. Thus, if the MR effect can be enhanced even for a CPP-GMR device, it could be a candidate as a high performance STO beyond MTJ-based ones. We previously demonstrated the high P_{out} in a CPP-GMR device with a full-Heusler Co_2MnSi (CMS) | Ag | CMS structure showing the large MR ratio of 36% [1,2]. The maximum P_{out} = 1.1 nW for the CMS layer was much larger than those obtained in CPP-GMR-based STOs with conventional FM layers. However, P_{out} was still lower than those in MTJ-based STOs. In this study, we show high P_{out} for a STO consisting of a $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS) / Ag / CFMS giant magnetoresistance (GMR) stack owing to its large CPP-GMR effect [3].

[Experimental procedure] Thin films were prepared on an MgO (100) single crystal substrate employing an ultrahigh vacuum magnetron sputtering system. The stacked structure is MgO subs. | Cr (20) | Ag (40) | CFMS (20) | Ag (5) | CFMS (3) | Ag (2) | Au (5) (in nanometer). Through the use of a conventional microfabrication technique, the thin film was patterned into a CPP-GMR pillar with a rectangular shape (100 nm × 170 nm). The rf voltage emitted from the CPP-GMR device was amplified by a preamplifer and was fed into a spectrum analyzer.

[Results and discussion] Clear spin torque oscillation was observed when the magnetic field was applied perpendicular to the plane of device. After the onset of oscillation, P_{out} gradually increased with the applied electric current, and the maximum P_{out} was obtained to be 23.7 nW. At the same time, the oscillation linewidth showed the minimum value of 10 MHz, leading to the excellent frequency purity (Q = 1124). We also performed micromagnetic simulation for the present CPP-GMR device, giving us the insight of magnetization dynamics induced in the CFMS free layer.

[1] R. Okura *et al.*, *Appl. Phys. Lett.* **99**, 052510 (2011). [2] T. Seki *et al.*, *J. Appl. Phys.* **113**, 033907 (2013). [3] Y. Sakuraba *et al.*, *Appl. Phys. Lett.* **101**, 252408 (2012).