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Enhancement of spin-torque diode sensitivity at high-frequency by utilizing dynamic coupling of free and reference layers

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Spin-torque diode (STD) is a magnetic tunnel junction (MTJ) that rectifies RF currents by synchronizing the RF currents and magnetoresistance (MR) oscillation caused by spin-transfer torque [1]. Recently, Miwa *et al*. reported the higher sensitivity of the STD than that of the Schottky diodes [2]. However, the STD sensitivity decreased with increasing the frequency [1]. For practical application such as high-speed telecommunications, it is important to develop the method to enhance the STD sensitivity at high frequency.

In this study, we proposed a method to enhance the STD sensitivity using the dynamic coupling of the free and reference layers (Fig. 1(a)). We expect the enhancement of the resistance oscillation and therefore the STD sensitivity if the dynamic coupling where the two layers oscillate in antiphase is realized. The operation frequency of the proposed STDs is determined by the condition that the eigen frequencies of the two layers become the same. The eigen frequencies can be tuned by varying the angle of in-plane applied field (ϕ_H, see Fig. 1(b)). We measured the ϕ_H dependence of the zero-biased STD voltage of an MgO-based MTJ to find ϕ_H where the coupling occurs. The MTJ was composed of [CoFe(1 nm)/Ta(0.3 nm)/CoFeB(1.5 nm)/CoFe(0.5 nm)] reference layer/MgO/CoFeB(1.5 nm) magnetic free layer with a design junction area of 100×200 nm^2-sized ellipse, and its MR ratio and resistance at the parallel state are 182% and 256 Ω. The magnitude of the applied field was 0.5 kOe. Figure 1(c) shows the eigen frequencies calculated by a macrospin model. As expected from Fig. 1(c), the observed eigen frequencies in Fig. 1(d) cross at ϕ_H ~100°, where the STD sensitivity took the highest value of 51 mV/mW (after impedance matching correction) at 6 GHz within the range 0°≤ ϕ_H ≤180°. Detailed STD spectrum and its analysis will be presented. This work was supported by JSPS KAKENHI Grant Number 25790045.

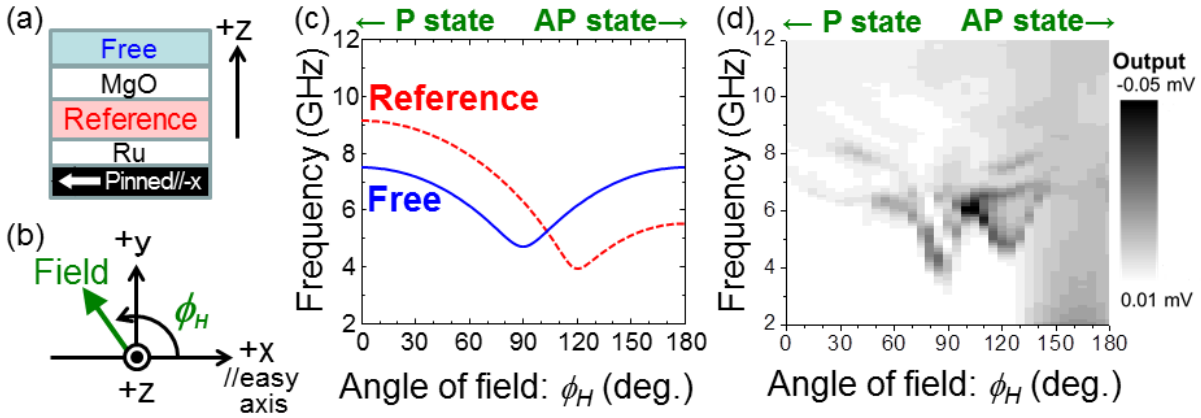

Fig. 1 (a) Structure of MgO-based magnetic tunnel junction stack. (b) Definition of angle of in-plane magnetic field (ϕ_H). (c) Macrospin calculation: ϕ_H dependence of eigen frequency of the free and reference layers. (d) ϕ_H and frequency dependence of STD output voltage. In (c) and (d), the in-plane magnetic field of 0.5 kOe was applied and P (AP) denotes parallel (antiparallel).

[1] A. A. Tulapurkar *et al*., Nature **438** (2005) 339. [2] S. Miwa *et al*., Nature Mater. **13** (2014) 50.