HP-06

Realization of ultra-wide resonance detection regime of spin-torque diode radio-frequency detector by utilizing tilted fixed-layer magnetization.

T. ZENG[1], Y. ZHOU[2], K. LIN[3], P. LAI[1], P. PONG[1]

1. Electrical and Electronic Engineering, The University of Hong Kong, Hong Kong; 2. Physics, The University of Hong Kong, Hong Kong; 3. Materials Engineering, National Chung Hsing University, Taichung, Taiwan

Among the massive studies related to spin-torque-induced magnetization dynamics, the spin-torque diode effect has intrigued intensive interests due to its potential application as a radio-frequency detector, which enables us to rectify an alternating current in nanoscale MTJ through synchronizing the current with the resonant oscillation of the TMR. Previous researches [1] mainly focused on improving the sensitivity of the spin-torque diode radio-frequency detector, while the studies aiming to broaden the resonance detection regime are still insufficient. In this work, we proposed a novel spin-torque diode radio-frequency detector structure based on titled fixed-layer MTJ. The results showed that the resonance detection regime could be significantly improved, which is largely conducive to the practical applications of spin-torque diode effect.

The system considered in this study is a three-layer MTJ sandwich structure as presented in Fig. 1(a). The lateral dimension of the NiFe thin film free layer is assumed to be an elliptical shape of 130×70 nm^2 with a thickness of 3 nm, while the thickness of the fixed layer FePt is 20 nm. The parameters [2] used in the calculation are as follows: α= 0.01, γ= 1.76×10^{11} Hz/T, M_s= 860 kA/m, H_k= 0.01 T, and H_d=1 T. The injected current density is set with 5.9×10^7 A/cm^2. The unit vectors pointing in the direction of the magnetizations of the free layer and the fixed layer are denoted as **m** = (0,1, 0) and **M** = ($\sin\theta_p\cos\phi_p$, $\sin\theta_p\sin\phi_p$, $\cos\theta_p$), where ϕ_p is set with 90° in this case. In order to sense RF signals of different frequencies, we integrate both the spin-transfer-torque (STT) effect and the alternating-voltage-controlled magnetic anisotropy (VCMA) effect into the simulation.

We perform the calculation of the spin-torque diode voltage after the injection of the RF current signals under different perpendicular applied field as shown in Fig. 1(b) and Fig. 1(c). It is observed from Fig. 1(b) that when the fixed layer magnetization is parallel to y-axis (no tilted fixed layer), the MTJ can detect RF current signals from 1.25 GHz to 1.8 GHz as the perpendicular applied field increases from 0 Oe to 1200 Oe. Meanwhile, the magnitude of the diode voltage also increases from 27.5 μV to 150 μV. Therefore, due to the VCMA effect we integrate in this study, we realize a voltage-tunable RF detector, which is similar to those observed earlier [3]. We derive a theoretical model to explain this phenomenon, which will be presented in the full paper. When the fixed-layer magnetization starts to become tilted (θ_p = 35°) as shown in Fig. 1(c), it is found that the MTJ can detect RF current signals from 1.1 GHz to 8.9 GHz as the perpendicular applied field increases from 0 Oe to 1200 Oe. However, the magnitude of the diode voltage only increases from 11 μV t0 75 μV. We depict the dependence of the resonance detection regime Δf on the titled angle θ_p of the fixed-layer magnetization in Fig. 2. The maximum detection regime Δf =7.8 GHz is obtained when θ_p is equal 35°, which is 1100% larger than the detection regime of the non-titled fixed layer. The above results clearly demonstrate that tilting the fixed-layer magnetization can drastically increase the resonance detection regime. This novel spin-torque diode radio-frequency detector by utilizing tilted fixed-layer magnetization can enable the fabrication of high performance diode detector with ultra-wide detection regime while maintaining good sensitivity.

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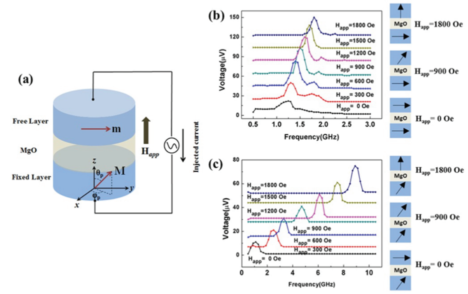

Fig. 1. (a) Schematic view of the simulated MTJ structure. M is the tilted fixed-layer magnetization. The free-layer magnetization **m** is separated from the fixed layer by a MgO layer. The external field is applied along the z-axis while the positive current is applied along z-axis. The RF detection voltage as a function of the RF input frequency under various magnetic fields applied perpendicular to the MTJ when (b) θ_p = 90° (non-tilted fixed layer) and (c) θ_p = 35° (tilted fixed layer).

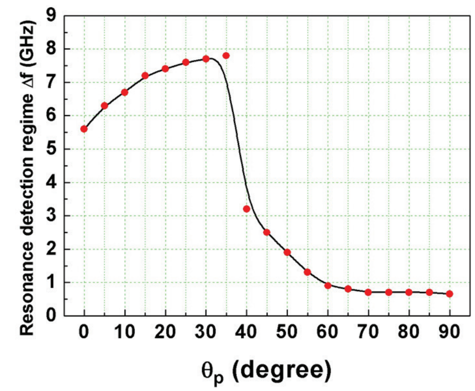

Fig. 2. Dependence of the resonance detection regime Δf on the titled angle θ_p of the fixed-layer magnetization.