17p-C15-12

Bias field angle dependence of the oscillation behavior of spin-torque oscillators having a perpendicularly magnetized free layer

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Spin-torque oscillators (STOs) having a perpendicularly magnetized free layer (referred to as PMF-STO in the following) are one of the promising candidates as a nano-scale microwave oscillator because they have a single domain structure and nearly uniform internal field distribution, which should lead to a cleaner and more stable oscillation than conventional STOs having a tangentially magnetized free layer. We have fabricated PMF-STOs by sandwiching the FeB free layer with MgO layers that induce interfacial perpendicular magnetic anisotropy[1,2]. Characterization of these PMF-STOs showed significantly improved oscillation performance, such as higher quality factors, compared with conventional STOs.

However, the oscillation mechanism of the PMF-STO has not been fully clarified yet. If the spin transfer torque (STT) is symmetric with respect to the directional cosine between the free and reference layer magnetizations, the PMF-STO cannot oscillate because the magnetic configuration becomes parallel during one half and antiparallel during the other half of one rotation cycle, resulting in no net energy gain over one full rotation. In order for the PMF-STO to oscillate, the STT must have some kind of angular asymmetry. Such an angular dependence has been proposed by Slonczewski's theoretical model[3].

In this work, we measured the PMF-STO oscillation while changing both the polar angle θ and azimuth angle φ of the bias field H_B to see if the Slonczewski's theory is indeed the underlying physical mechanism of the PMF-STO oscillation. Fig. 1 shows the total power of the PMF-STO oscillation under different field directions. The result shows that the power rapidly drops as the field is tilted from the normal to the film direction (θ = 0 deg) toward the antiparallel magnetic configuration (along φ = 90 deg), and the oscillation almost stops at $\theta \sim 6$ deg. On the other hand, the power slightly increases if the field is tilted toward the parallel magnetic configuration (along φ = 270 deg). This clearly demonstrates the consistency of the PMF-STO oscillation behavior with the Slonczewski's theory.

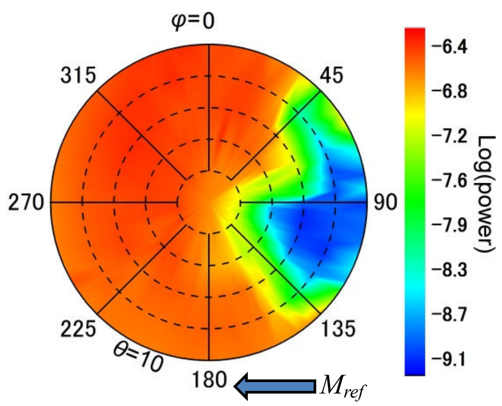

Fig. 1, total power of the PMF-STO oscillation as a function of φ and θ under fixed H_B at 300 mT and V_B at 250 mV, respectively. The circular grid lines are drawn at every 2 degrees step.

References

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