Radio-frequency signal amplification by spin torque driven ferromagnetic resonance in magnetic tunnel junctions

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Radio-frequency (rf) devices using magnetic tunnel junctions (MTJs) have attracted attention in spintronics, such as spin-torque diode effect, spin-torque oscillator, and rf amplifier. The rf amplification have been proposed theoretically by ferromagnetic resonance (FMR) in MTJ system with direct current application [1]. Currently, the rf amplification has been studied experimentally by applying rf magnetic field, however, the observed rf gain g does not exceed unity; g = 0.07 [2]. To increase rf gain, efficient technique is necessary for FMR excitation, such as rf spin-torque. In this research, we investigated rf amplification by spin-torque driven FMR in MTJs.

Figure 1 shows the film stack of MTJs and the measurement circuit. The MTJ film stack, bottom layer | CoFeB(2.0) | MgO barrier(1) | FeB(1.7) | MgO cap(1) | top layer, was deposited on Si | SiO_2 substrate by magnetron sputtering method (nm in thickness). The film was fabricated with the junction size of 80 nm in diameter. The rf current was injected to the MTJ through the bias-tee, then, the reflected signal S_{11} from the MTJ was measured by network analyzer. The direct current (dc) of 0.58 mA was applied to the MTJ by dc voltage source. Figure 2 shows absolute values of S_{11} spectra under various magnetic field inclined at 8° to the out-of-plane. The S_{11} peaks due to the spin-torque driven FMR were observed. In particular, the S_{11} peak intensity exceeds unity in the magnetic field range from 40 mT to 60 mT. This result is the first experiment that the gain of amplification exceeds unity in the MTJ-systems.

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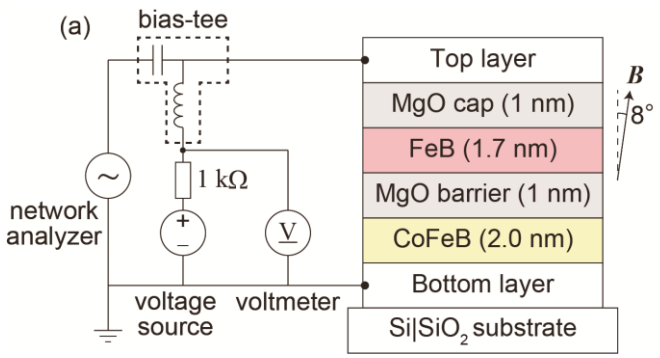

Fig. 1 Measurement circuit and MTJ film stack

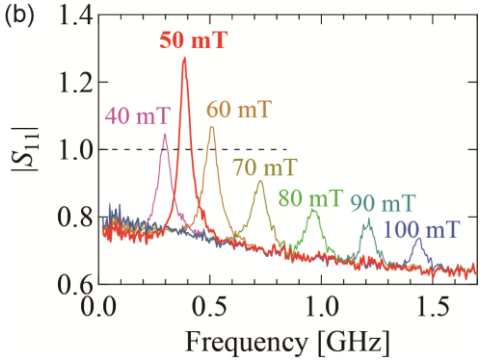

Fig. 2 Magnetic field dependence of $|S_{11}|$ spectra

[1] L. Xue, *et al.*, Appl. Phys. Lett, **99**, 022505 (2011), [2] K. Konishi, *et al.*, Appl. Phys. Lett, **102**, 162409 (2013)