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Improvement of Switching Disturbance in Spin-Transfer Torque MRAM

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1. Introduction

The development of magnetic random access memory (MRAM) has been accelerated since spin-transfer torque (STT) phenomenon was predicted by Slonczewski and Berger in 1996 [1, 2]. STT-MRAM, current induced magnetization switching as a novel concept scheme, provides scalability below 100 nm. Improvement of switching probability is a key factor for the realization of high density STT-MRAM. Switching disturbance due to interlayer coupling between magnetic layers, and telegraph noise is critical in the characteristics of fail bits. Interlayer coupling depends on roughness and magnetic properties (Ms, composition, anisotropy constant etc.) of MTJ film. Telegraph noise is the consequence of random jump between anti-parallel (AP) and parallel (P) magnetic configurations. The energy barrier for a transition from AP to P state is much higher than that for the reverse when a magnetic field preferring P state is applied without current.

In the current study, we discuss switching disturbance from an interlayer coupling between a free layer and a pinned layer. Switching fails due to telegraph noise will be also addressed.

2. Experimental and Results

The MTJ stacking structure was PtMn/CoFe/Ru/CoFeB/MgO/CoFeB/Ta. PtMn and CoFe/Ru/CoFeB layers were deposited as a pinning and a pinned layer, respectively. CoFeB on MgO was served as a free layer. The sputtered MTJ film was annealed in a vacuum for 2hr at 360℃ under the magnetic field of 1 Tesla. The MTJ cell width of 60nm was fabricated using photolithography and plasma etching. In Fig. 1, R-V curves (1) show switching fails in the negative voltage region, whereas R-V curves (2) display stable switching behaviors [3]. Switching fails in R-V curves (1) are caused by large Hshift in comparison with Hc. The shift results from Neel coupling due to an interlayer roughness and a stray field from pinned layer. Switching fails in R-V curves (1) is attributed to Neel coupling.

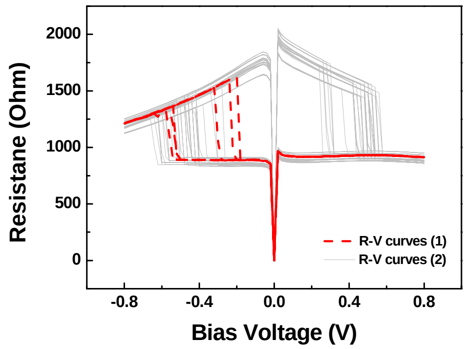

Fig. 1 R-V curves measured at dc voltage sweep mode.

Fig. 2 shows the behavior of Hshift by interlayer coupling as a function of MgO thickness. The MTJ cell width of 1um and aspect ratio of 30 were used to estimate genuine Neel coupling by interface roughness. Hshift in MgO-film thickness over 5.8Å was constant to be around -14Oe. As MgO thickness decreased below 5.8Å, Hshift was abruptly increased by the direct magnetic coupling due to pinholes. STT switching was stable at Hshift less than -14Oe. From the fitting of Fig. 2, the amplitude of 1Å and the wavelength of 19Å seem to be necessary for stable switching [4]. In order to minimize the magnetostatic interaction between a free and a pinned layer, etching process stopped just above the MgO tunneling barrier.

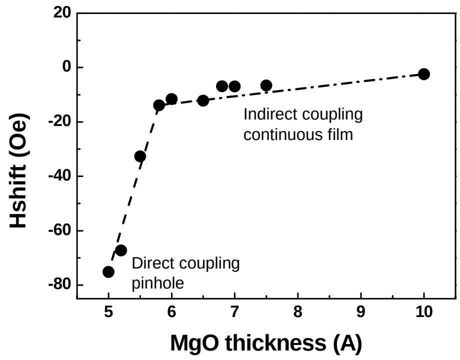

Fig. 2 Hshift as a function of MgO thickness.

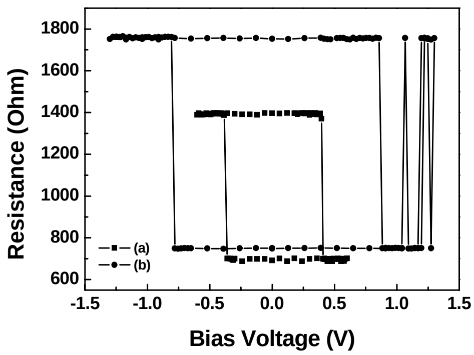

Fig. 3 (a) R-V curves without telegraph noise (b) R-V curves with telegraph noise at the pulse width of 50 ns.

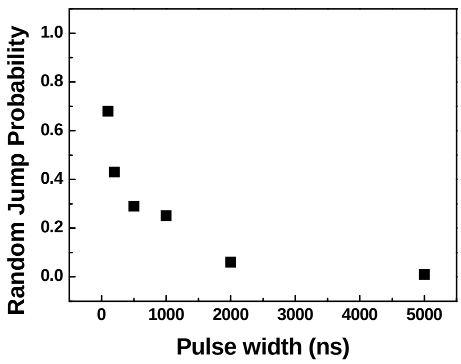

Fig. 4 Random jump probability as an increasing pulse width at R-V curve with telegraph noise.

In addition to an interlayer coupling and a stray field, telegraph noise at AP to P switching could produce fail bits. Fig. 3 shows two different types of R-V curves at the pulse width of 50 ns. While STT switching is stable at the pulse width of 50 ns as shown in Fig. 3-(a), Fig. 3-(b) shows switching oscillations in the positive voltage region. The energy barrier from AP to P transition is much higher than that from P to AP when magnetic field preferring the P state is applied without current [5]. In this case, two energy minima result from the competition between in-plane spin-torque term (aj) and out-of-plane spin-torque term (bj) at the region of the large positive bias voltage [6]. Fig. 4 shows random jump probability with increasing pulse width. Telegraph noise almost disappeared at the pulse width of 5 um. It vanished also in the low switching voltage of 0.38V, corresponding to 2MA/cm2 of Jc, as shown in Fig. 3-(a).

3. Conclusions

In this work, failing bit issue in STT-MRAM which could be caused by an interlayer coupling, and telegraph noise is figured out. An interlayer coupling, which is Neel coupling and a stray field, is improved by controlling MgO roughness and etching process. Also, telegraph noise has been eliminated by acquiring the critical current density (Jc) of 2MA/cm2.

References

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