

# Time-resolved measurement of spin-transfer-torque-induced magnetization switching in CoFeB-MgO magnetic tunnel junctions with perpendicular easy axis

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It was shown that single-shot time-resolved measurements is useful to understand the magnetization switching mode induced by spin-transfer-torque (STT) in nanoscale magnetic tunnel junctions with perpendicular easy axis (p-MTJ) [1, 2]. In this study, we investigate the STT-induced magnetization switching in CoFeB-MgO based p-MTJs from the time-resolved measurements.

A stack, from substrate side, Ta(5)/Pt(5)/[Co(0.4)/Pt(0.4)]<sub>5</sub>/Co(0.4)/Ru(0.52)/[Co(0.4)/Pt(0.4)]<sub>2</sub>/Co(0.4)/Ta(0.3)/CoFeB(1)/MgO/CoFeB(1.6)/Ta(5)/Ru(5) is deposited on a sapphire substrate by dc/rf magnetron sputtering. Numbers in parentheses are nominal thickness in nm. The stack is processed into circular MTJs with a diameter  $D$  ranging from 40 to 125 nm on a coplanar waveguide. We apply pulse voltage  $V$  to the MTJ from a pulse-generator, and measure the transmitted voltage by an oscilloscope to detect magnetization dynamics during the switching. The current  $I$  flowing through the MTJ is also measured by the oscilloscope.

Figure 1 shows a typical temporal change in the transmitted voltage after the application of  $V$  ( $I = 960 \mu\text{A}$ ) for parallel (P) to antiparallel (AP) switching in a 125-nm-diameter MTJ. We evaluate two characteristic times; incubation time  $t_A$  and dynamical switching time  $t_B$  after  $t_A$  (see Fig. 1). From 1000-time events at various  $I$ , we evaluate median values,  $\tau_A$  and  $\tau_B$ , of  $t_A$  and  $t_B$ . For P-to-AP and AP-to-P switching, both  $\tau_A$  and  $\tau_B$  decrease with increase of  $I$ . The dependence of  $\tau_A$  and  $\tau_B$  on  $I$  is compared with that obtained from macrospin simulation. The simulation reproduces the overall trend in the switching behavior, however,  $\tau_B$  ( $\tau_A$ ) in P-to-AP (AP-to-P) switching shows a larger reduction with increasing  $I$  for the experiment than the simulation.

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## References

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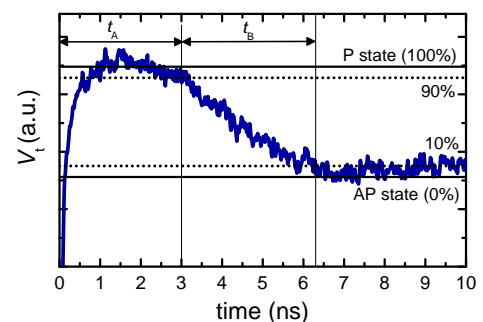


Figure 1 Transmitted voltage for parallel to anti-parallel switching in the 125-nm-diameter MTJ at applied pulse current of 960  $\mu\text{A}$ .