Write error rate of voltage-driven dynamic magnetization switching

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Voltage-control of magnetic anisotropy [1,2] is a promising technique for ultimate spintronic devices with ultra-low power consumption. To apply the voltage-induced magnetic anisotropy change to the writing process, the dynamic magnetization switching triggered by the sub-ns pulse voltage has been demonstrated. [3,4] One of the important issues for the practical application is the evaluation and improvement of the write error rate (WER). However precise control of the magnetization dynamics is not easy because the proper pulse duration is about 1ns or shorter. In this study, we investigated the WER of voltage-induced dynamic magnetization switching in perpendicularly magnetized magnetic tunnel junctions (p-MTJs). [5]

A film for p-MTJ, consisting of buffer layer / [Co (0.24 nm)/Pt (0.16 nm)]^7 / Co (0.24 nm) / Ru (0.46 nm) / [Co (0.24 nm)/Pt (0.16 nm)]^5 / CoB (0.4 nm) / W (0.15 nm) / $Co_{12}Fe_{68}B_{20}$ (1.0 nm) / MgO barrier / FeB (1.8 nm) / W (2.0 nm) / cap layer, was prepared by using ultra-high vacuum sputtering machine (Canon-Anelva C-7100). The film was annealed at 350°C for 1 hour and micro-fabricated into a 120-nm-diameter p-MTJ. The magnetoresistance ratio and resistance-area product are 101% and 370 Ω·μm^2, respectively. We investigated the WER from the 10^5 repeated events at various conditions of pulse duration and pulse amplitude and external magnetic field.

First, we observed the bidirectional switching and oscillatory behavior of switching probability. These results clearly indicate that the observed switching originates from the voltage-induced magnetic anisotropy change. Figures 1 (a) – (c) show the WER as a function of pulse duration under different conditions of the in-plane magnetic field strength. The minimum of WER, $(WER)_{min}$, was obtained at the half period of the magnetization precession, which becomes shorter as increasing the in-plane magnetic field. Increase of switching time results in low $(WER)_{min}$ because the effect of thermal agitation becomes negligible. However further increase of an in-plane magnetic field increases the $(WER)_{min}$ due to the reduction of thermal stability factor. Under the optimized condition, the lowest $(WER)_{min}$ of 4×10^{-3} was obtained as shown in Fig. 1 (b). The comparison between the results of the experiment and simulation based on a macro-spin model shows a possibility of ultralow WER (< 10^{-15}).

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Reference

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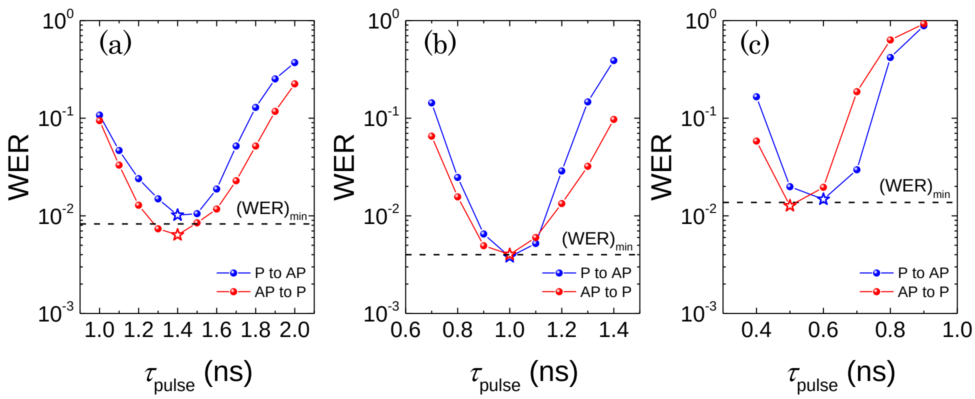

Figure 1 Write error rate (WER) as a function of pulse duration under in-plane magnetic fields of (a) 14 mT, (b) 20 mT, and (c) 38 mT. Blue and red curves represent the WER from P to AP state and AP to P state, respectively.