Magnetization switching by two successive voltage pulses

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We reported magnetization ($M$) reversal in magnetic tunnel junction (MTJ) with Ta/CoFeB/MgO by the application of either electric field or current (spin transfer torque) pulse.  [1,2] Here, we demonstrate a new scheme for $M$ switching, in which the advantages of $E$-induced and STT switching are combined.

A stack structure, sapphire substrate/Ta/Ru/Ta/Co$_{20}$Fe$_{60}$B$_{20}$(0.9 nm)/MgO(1.3 nm)/Co$_{20}$Fe$_{60}$B$_{20}$(1.8 nm)/Ta/Ru, is sputtered and fabricated into a 40-nm-diameter MTJ between coplanar strip lines by electron beam lithography and Ar ion milling. Device is annealed at 300°C for 1 hour in vacuum (10^-6 Torr) under magnetic field perpendicular to the plane. All magnetic layers possess perpendicular easy axis. The product of device area and resistance is $14 \Omega \mu$m$^2$, and tunnel magnetoresistance ratio is 125%.

Magnetic easy axis of free (top) layer switches from perpendicular to in-plane during the application of voltage pulse $V_E$ with amplitude of +0.7 V and duration of $t_E$. The change of easy axis direction induces $M$ precession around in-plane component of external magnetic field. The probability of $V_E$-induced $M$ switching takes the highest value (~100%) at which $t_E$ is nearly a half of precession period (~1.25 ns in the present device). The switching probability is sensitive to $t_E$, and that over 90% is obtained only for $t_E = 1.25\pm0.15$ ns. For the same device, we induce also STT-$M$ reversal by the application of voltage pulse $V_{STT}$ with amplitude $\pm0.5$ V and duration of $t_{STT}$. The probability of $V_{STT}$-induced $M$ switching exceeds 90% when $t_{STT}$ is longer than ~10 ns.

We propose a new scheme for $M$ switching by the application of successive two voltage pulses, $V_E$ and $V_{STT}$, where we expect that $M$ precession is induced by $V_E$ and that the final $M$ direction is determined by $V_{STT}$. Figure indicates the switching probability from as functions of $t_E$ and $t_{STT}$. The result shows that one can obtain broader $t_E$ range with high switching probability than that solely by $V_E$, and shorter switching time than that solely by $V_{STT}$.

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References


Figure: Contour mapping of magnetization switching probability from parallel (P) to anti-parallel (AP) state as functions of two successive voltage pulse durations. $t_E$ is duration for the first voltage pulse (0.7 V) and $t_{STT}$ for the second pulse (0.5 V).