Electric-field induced magnetization switching in CoFeB/MgO magnetic tunnel junction with thick MgO barrier

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Magnetization switching energy is expected to be reduced by the electric-field induced scheme, because charging/discharging energy of the capacitor is a few orders smaller than the Joule heating consumed by the conventional current-induced scheme for magnetic tunnel junctions (MTJs). So far, we used the CoFeB/MgO/CoFeB MTJ as a pseudo-capacitor [1,2], in which, even for the electric-field switching, the energy was governed by the Joule heating resulted from tunnel current. In this work, to reduce the Joule heating, we use a CoFeB/MgO with high junction resistance *R* by increasing MgO barrier thickness.

We fabricate a MTJ with a diameter of 60 nm from a stack of Ta(5)/Pt(5)/[Co(0.34)/Pt(0.4)]$_{\times 6}$/Co(0.4)/Ru(0.42)/[Co(0.34)/Pt(0.4)]$_{\times 2}$/Co(0.34)/Ta(0.3)/$Co_{20}Fe_{60}B_{20}$(1)/MgO(2.8)/$Co_{18.75}Fe_{56.25}B_{25}$(1.8)/Ta(5)/Ru(5) (numbers in parentheses are nominal thickness in nm) deposited on a sapphire substrate. The device resistance-are product *RA* is 176 kΩμm^2 at zero bias, which is several-order larger than those for the current-induced switching devices. Figure shows the product of switching probabilities ($P_{PtoAP}P_{APtoP}$) from parallel (P) to anti-parallel (AP) and from AP to P by the application of an electric-field pulse of 0.78 V/nm as a function of pulse duration t_{pulse}. The probability of almost unity is obtained at t_{pulse} ~ 1.25 ns, at which the switching energy is evaluated to be 6.3 fJ/bit. While this is one or two-order smaller switching energy than those reported so far [3], the energy is still dominated by the Joule heating. This is due to stronger bias dependence of *R* for MTJs with thicker MgO, neglected in the previous report on MTJs with high *R* [4]. In order to suppress the Joule heating, one needs search ways to reduce the bias dependence of *R* as well as the threshold electric field for the switching.

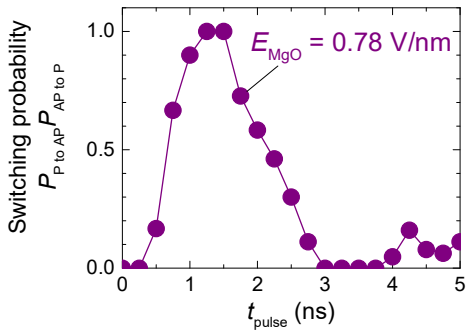

Figure: Electric-field pulse duration t_{pulse} dependence of the product of magnetization switching probabilities $P_{PtoAP}P_{APtoP}$ from P to AP and from AP to P states.

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References

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