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Micromagnetic Simulation of Critical Fields of Rectangular and Elliptical Cells for Toggle-Mode Magnetic Random Access Memory

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Conventional magnetic random access memory (MRAM)based on asteroid-type switching usually suffers from a narrow write margin. This problem can be greatly relieved with the use of the toggle-mode write scheme, the main ingredients of which involve the spin-flop switching and the use of a trilayer synthetic antiferromagnet (SyAF) as the free layer structure [1]. However, the toggle-mode MRAM has the issue of high switching field [2]. *In this work, we investigated the effect of the shape of the magnetic* cell on the switching behaviour in the toggle-mode MRAM by micromagnetic simulation. The trilayer SyAF cells had two different shapes, rectangle and ellipse. The total thickness was fixed at 5 nm, however the thickness of each magnetic layer was changed. The material parameters used were; a saturation magnetization (Ms) of 1500 emu/cc and an exchange stiffness constant (A) of 1.0 x 10-6 erg/cm. An interlayer exchange coupling (Jex) and an induced anisotropy field (Hu) were varied. For the rectangular cells, the switching process was greatly affected by the aspect ratio, the thickness asymmetry, and Jex. In the case of the elliptical cells, the spin-flop switching was greatly affected only by the aspect ratio and Jex. The critical fields, the spin-flop switching field (Hsf) and the saturation field (Hsat) are also dependent on the shape of the magnetic cell. Figures 1(a) and (b) show Hsf and Hsat as a function of the aspect ratio, receptively, for both rectangular and elliptical cells. Two magnetic layers have the same thickness of 2.5 nm, and Hu = 15 Oe, Jex = -0.15 erg/cm2. The values of Hsf and Hsat of the elliptical cellsare smaller than those of the rectangular cells. In both cases, Hsf increases as the aspect ratio increases. The opposite tendency is seen for Hsat. Figure 1(c) shows the window margin (WM), which is defined by Hsat/Hsf, as a function of the aspect ratio. In the small aspect ratiorange, WM of the rectangular cells is wider than that of the elliptical ones, however the difference decreases with increasing aspect ratio.

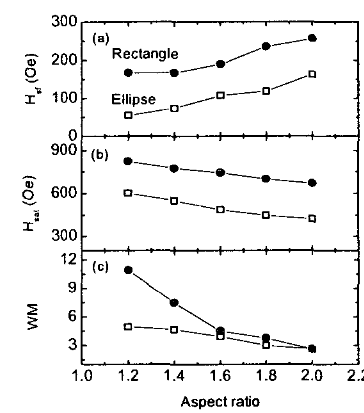

Fig 1. The critical fields of Hsf, Hsat and the writing margin (WM) as a function of the aspect ratio at two different shapes of magnetic cells, rectangle and ellipse.

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RB19

Suppression of Magnetization Ringing in Pac-Man Shaped $Ni_{80}Fe_{20}$ Elements

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Magnetic random access memory (MRAM) is a viable alternative to semiconductor memories. In the design of the MRAM device, magnetic pulse amplitute and duration to switch a magnetic element need to be optimized. We studied the effects of the magnetic pulse parameters, i.e., amplitude and duration, on the switching behavior in elongated Pac-man (EPM-I 180: 1.4 times elongated, 180° slot angle) shaped $Ni_{80}Fe_{20}$ elements using numerical micromagnetic simulations. The EPM-I geometry is defined in our previous report [1]. The 2 nm thick EPM-I element has the lateral dimension of 70 nm × 200 nm with a unit cell volume of 222 nm^3, which is smaller than the 5 nm exchange length of $Ni_{80}Fe_{20}$. An in-plane switching magnetic field pulse of 390 Oe is applied at 45° relative to the long axis of the element. Pulse duration of the applied switching field was varied from 40 to 500 picoseconds assuming zero picoseconds for the rise and fall times of the applied pulse. In all cases we studied, a magnetic field was found to be retained for at least 80 ps to complete a reversal process. *Fig. 1 shows the temporal* evolution of the average values of the normalized magnetization components (M_x/M_s, M_y/M_s and M_z/M_s), the demagnetization energy E_d, the exchange energy E_{ex}, respectively. The magnetization configurations are also shown at selected time points. As shown in Fig. 1(a), both high demagnetization energy (E_d) and shapeanisotropy cause an overshoot in magnetization after the field is removed. The overshot can be seen at the point 4, consequently the magnetization ringing is observed. The pulse duration was optimized to suppress the magnetization ringing, as demonstrated in Fig.1(b) by applying a pulse with the duration of 150 p. *In summary, it is found that the pulse width has a key role in controlling the magnetization ringing.*

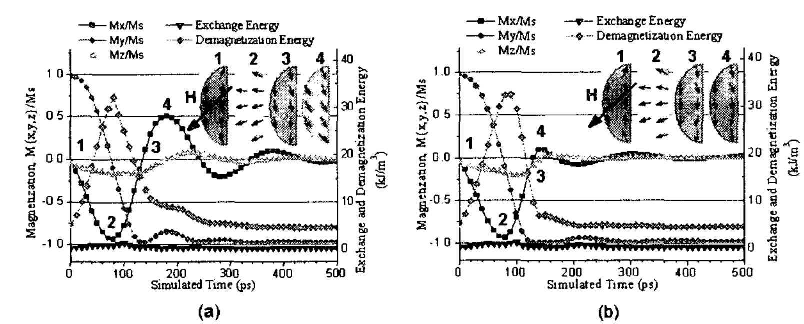

Fig. 1. Temporal evolution of the M_x/M_s, M_y/M_s, M_z/M_s, E_{ex}, E_d, and magnetization configurations from (a) 80 ps and (b) 150 ps magnetic field pulse. The pulse begins at 0 ps.

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