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Switching properties of magnetic tunnel junctions with CoFeSiB free layer

(CoFeSiB 자유층을 갖는 MTJs의 스위칭 특성)

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1. Introduction

Since the discovery of a large tunneling magnetoresistance (TMR) at room temperature, magnetic tunnel junctions (MTJs) are one of the most promising candidate for applications such as magnetic random access memory (MRAM) [1, 2]. One of the major problems with high density MRAM using submicrometer-sized MTJs is to obtain a low switching field (H_{sw}), which is important for low power consumption. By using the SAF structure, we can reduce the H_{sw} originating from the reduction of the magnetostatic energy and the magnetostatic coupling energy. In this study, H_{sw} and magnetization reversal processes in CoFeSiB single and SAF free layers were investigated by SMOKE and the Landau-Lifschitz-Gilbert (LLG) simulation, respectively.

2. Experimental Procedure

To investigate the cell switching characteristics, we designed the cell structures consisting of various free layer structure such as Si/SiO$_2$/CoFeSiB (single or SAF) 7 (in nm). Thin film deposition was carried out using a six-target *dc* magnetron sputtering system under the typical base pressure of less than 5×10^{-8} Torr. A magnetic field of 100 Oe was applied during deposition to induce uniaxial magnetic anisotropy in the ferromagnetic layers. To fabricate the 10×10 ㎛^{2} cells, a photolithographic patterning procedure including ion beam etching was used with a fixed aspect ratio of 1. Annealing was carried out *in situ* at 200 ℃ in a 5×10^{-4} Torr vacuum under an applied field of 300 Oe for 2 hr. A series of static calculation model based on the Landau-Lifschitz-Gilbert (LLG) equation and the surface magneto-optic Kerr effect (SMOKE) measurement were performed to uncover the magnetization reversal processes.

3. Results and Discussion

The SMOKE measurement results were taken to confirm the strength of the H_{sw} for both CoFeSiB single and SAF films. In CoFeSiB single free layer, magnetization reversal was completed when applied magnetic field was 26 Oe. In the SAF free layer, the magnetization reversal was completed when applied magnetic fields were 21 Oe and 22 Oe for CoFeSiB 1.5/Ru 1.0/CoFeSiB 5.5 and CoFeSiB 2.5/Ru 1.0/CoFeSiB 4.5 (in nm) SAF structures, respectively. By reduction of the magnetostatic energy in the free layer and magnetostatic coupling energy between free and pinned layer in the SAF structure, a complete magnetization reversal field is lower than that required for the single free layer.

Figure 1(a) and (b) show the magnetization profiles obtained by the LLG simulation for the single and SAF free layers, respectively. The magnetization switching process for $1\times1\ \mu m^2$ cells started from the remanent states. In case of CoFeSiB single layer, the interior of the element rotates almost uniformly at the two edge poles followed by rotation toward the reversal direction and four domain walls were formed just before the complete magnetization reversal. For the SAF (CoFeSiB 1.5/Ru 1.0/CoFeSiB 5.5) free layer structure, two domain structure was presented just before the complete magnetization reversal. Thus, a lower H_{sw} was required for this case compared to CoFeSiB single one. Although the CoFeSiB 2.5/Ru 1.0/CoFeSiB 4.5 SAF structure exhibited a similar reversal behaviour compared to the CoFeSiB 1.5/Ru 1.0/CoFeSiB 5.5 SAF structure (not shown here), it required more H_{sw} due to poorly defined SAF characteristics

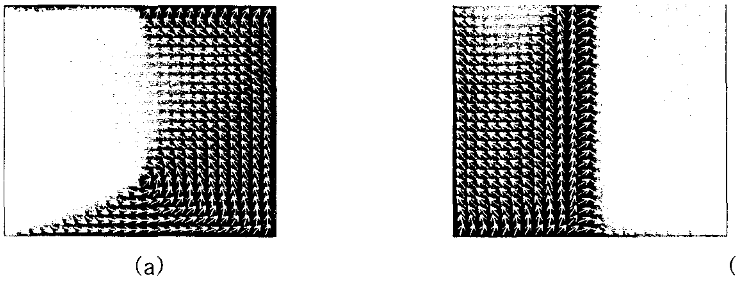
(a) (b)

Fig. 1. Magnetization reversal process of (a) CoFeSiB single and (b) SAF (CoFeSiB 1.5/Ru 1.0/CoFeSiB 5.5 (in nm)) free layers, where the applied fields were 50 and 35 Oe, respectively, computed by the LLG simulator. One spin unit cell is $20\times20\ nm^2$.

4. Conclusions

The switching behaviours were confirmed for the micrometer-sized elements experimentally using SMOKE. A micromagnetic modelling study was also carried out for the submicrometer-sized elements. By using CoFeSiB SAF free layer structure, the H_{sw} could be further reduced because it has low magnetostatic energy in the free layer and a low magnetostatic coupling energy between free and pinned layers.

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