KMS-2-X14

Switching field and tunneling magnetoresistance of NiFeSiB synthetic antiferromagnet free layered magnetic tunnel junctions

(NiFeSiB 합성형 반강자성 자유층을 갖는 자기터널접합의 스위칭자기장과 터널링자기저항)

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Ⅰ. Introduction

Since an enormous interest in magnetic tunnel junctions (MTJs) for high density magnetic random access memory (MRAM) [1], the control and minimizing cell switching field (H_{sw}) to get writing margin is requested. A smaller cell, however, requires a larger H_{sw} because a large demagnetizing field arises from the poles of the submicrometer-sized cell edge, leading to large write currents. This study is intended to develop a new material with synthetic antiferromagnet (SAF) free layer structure possessing low saturation magnetization (M_s) but modest anisotropy, to obtain low H_{sw} while maintaining tunneling magnetoresistance (TMR) ratio. A lower aspect ratio can be obtained without difficulty if the material anisotropy constant (K_u) is high enough. A synthetic antiferromagnet (SAF) structure comprising of NiFeSiB layers has been devised and employed as a free layer of MTJs to enhance cell switching performance.

Ⅱ. Experimental Procedure

Magnetic tunnel junctions consisting of Si/SiO_2/Ta 45/Ru 9.5/IrMn 10/CoFe 7/AlO_x 1.5/NiFeSiB t/Ru 0.5/NiFeSiB (7- t)/Ru 60 (in nm) were prepared using *dc* magnetron sputtering system under the typical base pressure of less than 5×10^{-8} Torr. A photolithographic patterning procedure including ion beam etching was used to fabricate the junctions. The sample size was varied from 10×10 μm^2 to 100×100 μm^2 with a fixed aspect ratio of 1. A series of static calculation model based on Landau–Lifschitz–Gilbert (LLG) equation was used in this study [2].

Ⅲ. Results and Discussion

NiFeSiB film exhibited M_s of 800 emu/cm^3 and K_u of 2,700 erg/cm^3. This M_s value is as compatible as that of $Ni_{80}Fe_{20}$ but substantially lower compared to that of $Co_{90}Fe_{10}$ (1,400 emu/cm^3). Meanwhile the K_u value lies in between that of NiFe (1,000 erg/cm^3) and CoFe (30,000 erg/cm^3).

Ta 5/NiFeSiB (t_1= 1.0, 1.5, 2.0, 2.5, 3.0)/Ru (t_2= 0.3, 0.5, 0.8, 1.0, 1.2)/NiFeSiB (7-t_1)/Ta 5 (in nm) SAF structures were fabricated. A well-defined anisotropy and antiparallel alignment during the magnetization reversal occurred when t_1= 2.0 and t_2= 0.5 (not shown here) and the calculated exchange coupling energy (J_{ex}) was -0.03 erg/cm^2.

As shown in Fig. 1, NiFeSiB SAF free layered MTJs showed both reduced TMR ratio and coercivity (H_c) than those of the single free layered MTJ for the whole range of the sample size measured. We think that the reason of exhibiting relatively lower TMR ratio and H_c were due to a lower magnetostatic energy in the free layer separated by a nonmagnetic Ru space layer.

To confirm our speculation, we have employed a micromagnetic model based on the LLG equation. As shown in Fig. 2, by using the NiFeSiB 2/Ru 0.5/NiFeSiB 5 SAF structure, H_c was much decreased compared to the single free layer and other SAF structure. We found size dependence of the switching field originating from low J_{ex} both experimentally and by simulation. Interestingly, despite the undesired size dependence of the switching field, the NiFeSiB SAF free layered MTJs exhibited lower H_c values compared to CoFe or CoFeB.

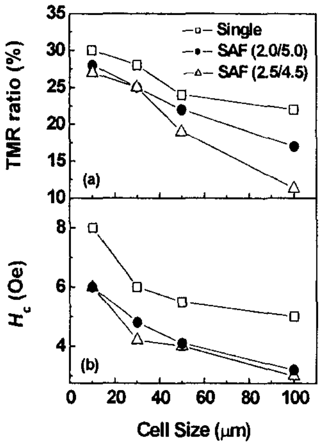

Fig. 1. Size dependence of (a) TMR ratio and (b) H_c for NiFeSiB single and SAF free layered MTJs measured at RT.

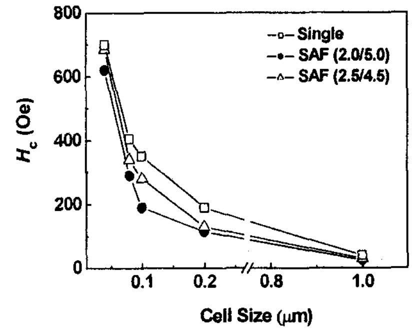

Fig. 2. Size dependence of H_c for a single and SAF free layers by the LLG simulation.

Ⅳ. Conclusions

The NiFeSiB film showed a lower M_s and a higher K_u, where these properties were found to be beneficial for the switching characteristics such as reducing H_c and increasing the sensitivity in micrometer-sized elements. This behavior was also confirmed for submicrometer-sized elements by simulation. By using NiFeSiB SAF free layer structure, the H_c could be further reduced because it has low magnetostatic energy in the free layer and low J_{ex}.

Acknowledgment

This work was supported by the Korea Ministry of Science and Technology under contract National Research Laboratory Program and the Korea Research Foundation Grant (No. KRF-2005-015-C00157) funded by the Korean Government (MOEHRD).

References

[1] T. Kim, Y. K. Kim and W. Park, J. Magn. Magn. Mater. **282**, 232 (2004).

[2] The LLG Micromagnetics Simulator™.