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Switching characteristics of MTJ comprising CoFeSiB layers

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CoFeSiB 자유층 MTJ 의 스위칭 특성

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1. Introduction

Magnetic tunnel junctions (MTJs) have a large potential for use in high areal density read head and magnetic random access memory (MRAM) applications because they exhibit large tunneling magnetoresistance (TMR) ratios [1, 2]. Attaining a low switching field (H_{sw}) is one of the important factors in MRAM for writing capability.

In this paper, so we used the anisotropy of the material itself to get low H_{sw}. This is because, if the materials anisotropy constant (K_u) is high, we can get lower aspect ratio without struggle. From this point of view, we introduced amorphous ferromagnet (FM) CoFeSiB to the free layer in the MTJs. Amorphous FM materials have a low M_s, low coercivity (H_c), and almost zero magnetostriction. The main purpose of this study is to investigate the switching characteristics of new MTJ structures comprising CoFeSiB layers.

2. Experiment

MTJs consisting of $Si/SiO_2/Ta45/Ru9.5/IrMn10/CoFe7/AlO_x/CoFeSiB(t)/Ru60$ (in nm) were prepared by rf magnetron sputtering system in typical base pressure below 5×10^{-8} Torr under a magnetic field of 100 Oe. Tunnel barriers were formed by oxidizing 1.0 nm thick Al layers under rf plasma in a load lock chamber. We varied the junction size from 10 to 100 ㎛ with fixed aspect ratio to 1 by a photolithographic patterning procedure and ion beam etching. Annealing was done *in situ* at 200 °C in 5×10^{-4} Torr under applied field of 300 Oe for 2 h. The magnetic property and crystalline texture of the film were characterized by vibrating sample magnetometer (VSM) and x-ray diffraction (XRD), respectively. The magnetic and electric properties of MTJs were measured by a 2-point probe station. Micromagnetic Modeling based on the Landau-Lisfschitz-Gilbert (LLG) equation were carried out to investigate the effect of size variation and material properties on their magnetization transfer behaviors.

3. Results and discussion

CoFeSiB exhibits low M_s (560 emu/cc) and high K_u (2800 erg/cm^2) than CoFe (M_s: 1400 emu/cc) and NiFe (K_u: 1000 erg/cm^2), respectively. In addition, the H_c of CoFeSiB, NiFe and CoFe is 1, 2, and 140 Oe, respectively. Then, we thought that CoFeSiB is one of the candidate materials in the MTJs to the free layer.

We investigated the switching characteristics of 10×10 ㎛^{2} MTJs with different free layer materials using the TMR curves, as shown in Fig. 1. The most interesting features observed with the CoFeSiB MTJ is that, even though CoFeSiB MTJ showed relatively low TMR ratio, it displayed low H_c and high sensitivity to the external magnetic

field.

To confirm switching characteristics in real MRAM technology, we have used the micromagnetic modeling based on the LLG equation. Using this simulation tool, we could analogize the whole out of a part for inclinations of switching characteristics in sub-micron sized elements. By using the CoFeSiB free layer, the H_c is dramatically decreased compare to the CoFe free layer MTJ. Especially, high bit density MRAM array range such as 0.08~0.1 ㎛ cell size, the CoFeSiB has one-third of the CoFe MTJs in H_c (shown in Fig. 2). To get low H_{sw}, the low M_s and high K_u are indispensable and it confirmed through our experiment and simulation results.

A free layer thickness effect in comparison with the pinned layer $M_s \times t$ (M_s multiplied by thickness) was investigated. By increasing of a free layer thickness the TMR ratio decreased and H_c increased. It is thought that the demagnetization field became strong, because it is roughly proportional to the FM thickness, thus the switching characteristic became worse.

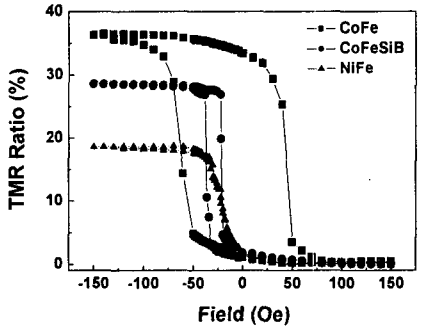

Fig. 1. TMR curves for 10×10 ㎛^{2} MTJs with CoFe, CoFeSiB, or NiFe 7 nm free layer.

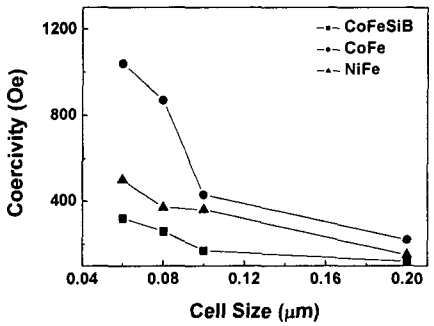

Fig. 2. Size dependence of the H_c with respect to the free layer using LLG simulation method. The measured structure free layer only (CoFeSiB, CoFe, or NiFe 7 nm).

4. Conclusion

Magnetization switching and magnetoresistance effect were investigated by using of an amorphous CoFeSiB free layers in MTJs. CoFeSiB has low M_s than CoFe and high K_u than NiFe. These properties were proven beneficial for the switching characteristics such as reducing the H_c and increasing the sensitivity by experimental results in micron-size and simulation results in sub-micron size element. By increasing CoFeSiB free layer thickness, the switching characteristics became worse because of the demagnetization field arising from the edge pole.

5. References

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