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Switching Characteristics of Magnetic Tunnel Junctions Comprising Amorphous NiFeSiB Free Layer

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1. Introduction

Magnetic tunnel junctions (MTJs) offer promise in high density read head and nonvolatile magnetic random access memory (MRAM) applications, because they exhibit large tunneling magnetoresistance (TMR) ratios [1,2]. The switching characteristics of the high density MRAM with submicrometer-sized MTJ cells is particularly important. Therefore, in this study, we attempted to develop a new material with a low saturation magnetization (M_s) value, but modest anisotropy constant (K_u) in order to obtain a low switching field (H_{sw}) value while maintaining the TMR ratio. Among the various candidates, amorphous ferromagnetic $Ni_{16}Fe_{62}Si_8B_{14}$ attracted our attention.

2. Experimental Procedure

Magnetic tunnel junctions consisting of Ta 45/Ru 9.5/IrMn 10/CoFe 7/AlO_x 1.5/free layer *t*/Ru 60 (in nm) structures were prepared using a six-target dc magnetron sputtering system under a typical base pressure of < 5 × 10^{-8} Torr and annealing was carried out *in situ* at 200 ℃ for 2 h. Tunnel barriers were formed by oxidizing 1.0 nm thick Al layers under an rf plasma environment in a load-locked chamber. A photolithographic patterning procedure and ion beam etching was used to fabricate the junctions with a size of 10 × 10 μm^2. The magnetic and magneto-transport properties were measured by a vibrating sample magnetometer (VSM) and a 2-point probe station, respectively.

3. Results and Discussion

The crystal structures of NiFeSiB were measured using an in-plane TEM and a selected area diffraction pattern, and found to be amorphous at both as-deposition and annealed states. NiFeSiB exhibited M_s value of 800 emu/cm^3 and a K_u value of 2700 erg/cm^3.

The tunnel junctions consisted of Si/SiO_2/Ta 45/Ru 9.5/IrMn 10/CoFe 7/AlO_x/NiFeSiB 8.2, 12.3, 16.3/Ru 60 (in nm). As shown in Fig. 1, by increasing the thickness of the free layer, the TMR ratio of up to 41% was achieved. By increasing the free layer thickness, the demagnetization field became strong and the switching characteristics became worse, because the switching characteristics are roughly proportional to the ferromagnetic thickness.

To improve the TMR ratio and switching characteristics, we inserted a very thin CoFe layer (1 nm) at the tunnel barrier/NiFeSiB interface. As shown in Fig. 2, the TMR ratio and switching characteristics were improved as the NiFeSiB layer thickness was increased up to 11 nm because CoFe has higher spin polarization and K_u than NiFeSiB. But no additional improvement was observed when the thickness of NiFeSiB was further increased up to 15.2 nm. It is thought that the TMR ratio and H_{sw} characteristics were dominated by the thickness of NiFeSiB layer with inserting the CoFe relatively very thinner than NiFeSiB layer.

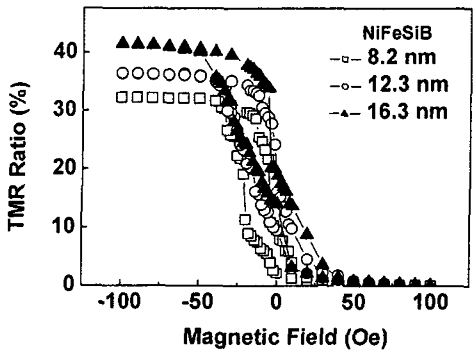

Fig. 1. TMR curves for 8.2, 12.3, and 16.3 nm NiFeSiB-based MTJs with a size of 10 × 10 μm^2.

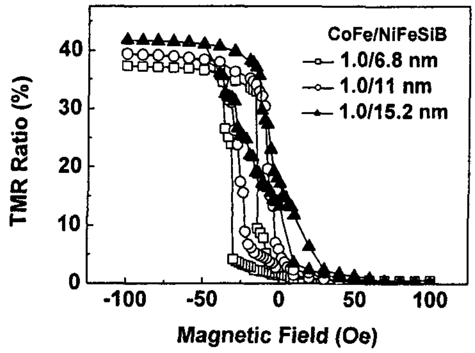

Fig. 2. TMR curves for 6.8, 11, and 15.2 nm NiFeSiB-based MTJs with a 1 nm CoFe layer.

4. Conclusions

The magnetization switching and TMR effects in the MTJs were examined using amorphous NiFeSiB free layers. NiFeSiB showed a lower M_s than CoFe, while having a higher K_u than NiFe. These properties were found to be beneficial for the switching characteristics of the MTJs, leading to a reduction in H_{sw} and an increase in the sensitivity. By inserting a thin CoFe layer at the tunnel barrier/NiFeSiB interface, the TMR ratio and switching characteristics were improved more with the increase of NiFeSiB layer thickness up to 11 nm.

5. References

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