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Characteristics of magnetic tunnel junctions using amorphous CoSiB free layer

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1. Introduction

Recently it has been proposed to use of amorphous magnetic materials for the free (sense) layer in magnetic tunnel junctions (MTJs) [1] because amorphous materials exhibit excellent soft magnetic properties. By varying its compositions, amorphous alloys especially exhibit a low saturation magnetization (M_s), which induced a low H_{sw} according to the Stoner-Wohlfarth's single domain model [2], and it is desirable for MTJs to increase tunneling magnetoresistance (TMR) ratio because of high spin polarization. In this study, we introduce the use of amorphous $Co_{75}Si_{15}B_{10}$, compared to both amorphous $Co_{70.5}Fe_{4.5}Si_{15}B_{10}$ and crystalline $Co_{75}Fe_{25}$ and $Ni_{80}Fe_{20}$, for the free layer in MTJs to enhance TMR ratio and the switching characteristics.

2. Experiment

Tunnel junctions consisting of Si/SiO_2/Ta45/Ru9.5/IrMn10/CoFe7/AlO_x/CoFe7, NiFe7, CoSiB7 or CoFeSiB7/Ru60 for single structure and Si/SiO_2/Ta45/Ru9.5/IrMn10/CoFe7/AlO_x/CoSiB7/AlO_x/CoFe7/IrMn10/Ru60 (in nm) for double barrier structure were prepared using a six-target dc magnetron sputtering system under typical base pressure below 2×10^{-8} Torr. Tunnel barriers were formed by oxidizing 1.2 nm thick Al layers under rf plasma environment in a load lock chamber. A photolithographic patterning procedure and ion beam etching were used to fabricate the junctions with a size of 10×10 μm^2. Annealing was carried out in situ at 200 ℃ in 5×10^{-7} Torr vacuum under a magnetic field of 2 kOe for 1 h. The magnetic properties and crystalline structure were characterized using a vibrating sample magnetometer (VSM) and X-ray diffraction (XRD), respectively. The magneto-transport properties were measured by a 2-point probe station.

3. Results and discussion

A saturation magnetization (M_s) and anisotropy constant (K_u) of CoSiB were taken to be 470 emu/cm^3 and 1500 erg/cm^3, respectively, by using VSM. Here the M_s is lower than that of CoFe (1400 emu/cm^3), NiFe (800 emu/cm^3) and CoFeSiB (560 emu/cm^3). The K_u value is higher than that of NiFe (1000 erg/cm^3) and lower than that of CoFe (30000 erg/cm^3) and CoFeSiB (2800 erg/cm^3). The crystal structure of the 100 nm thick CoSiB film was

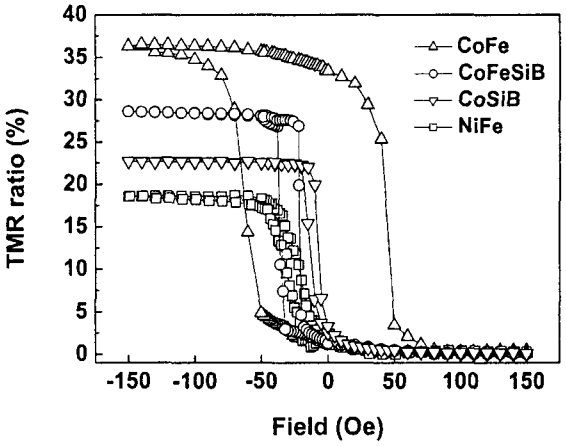

Fig. 1. TMR curves for MTJs with different free layers.

measured using XRD and found to be amorphous at both as-deposited and annealed states, as shown in the inset.

Figure 1 shows TMR curves for MTJs with different free layers. Although the TMR ratio of MTJ with CoSiB was relatively low value (23%) due to reduction of the spin polarization by the composition of magnetic transition metals, it showed better H_{sw} and sensitivity than MTJs with CoFeSiB, CoFe and NiFe free layers because CoSiB had a lower M_s and a modest K_u than CoFeSiB, conventional CoFe and NiFe. Especially, the MTJ with CoSiB free layer showed a smaller H_{sw} than that of the MTJ with CoFeSiB free layer, having good sensitivity. And, in this case, the interlayer coupling field (H_{int}) between the free layer and the pinned layer, leading an offset field for the switching of the free layer, was decreased considerably.

The voltage $V_{1/2}$, where the TMR ratio decreases to half of its zero bias value, was over 900 mV (extrapolated value) for the CoSiB-based double MTJ, while it was about 500 mV (extrapolated value) for the CoSiB-based single MTJ. Such high value of $V_{1/2}$ is desirable for high performance MRAM.

4. Summary

We have investigated the switching properties for MTJs with CoSiB free layer. MTJ with amorphous CoSiB showed lower H_{sw} with improving sensitivity compared to MTJs with CoFeSiB, CoFe and NiFe free layers because CoSiB had a low M_s and modest K_u. H_{int} for the CoSiB-based MTJ was further decreased without degrading the sensitivity. It also showed that the $V_{1/2}$ of CoSiB-based double MTJ was high enough for high density MRAM.

5. References

[1] D. Wang, C. Nordman, J. Daughton, Z. Qian and J. Fink, IEEE Trans. Magn. 40 (2004), p. 2269.

[2] E. C. Stoner and E. P. Wohlfarth, Philos. Trans. Roy. Soc. A240 (1948), p. 559.