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Characteristics of magnetic tunnel junctions with amorphous CoFeSiB free layer by function of the oxidation time in the tunnel barrier

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비정질 CoFeSiB 자유층을 갖는 자기터널접합의 터널장벽 산화시간에 따른 특성

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1. Introduction

Magnetic tunnel junctions (MTJs) have received great interest for their potential application in magnetic read heads and nonvolatile magnetic random access memory (MRAM) [1]. Recently, amorphous materials were introduced as a "free" and/or "pinned" ferromagnet (FM) layer in MTJs, this is because amorphous materials have a low saturation magnetization (M_s), low coercivity (H_c), and almost zero magnetostriction (λ). MTJs with amorphous materials exhibit a lower H_c, and switching field than crystalline materials. Which are all desirable for read heads, MRAM, and a variety of magnetic field sensors. In this paper, we prepared MTJs with amorphous CoFeSiB as free layer, and presented the dependence of the TMR ratio and junction resistance on oxidation time.

2. Experiment

The MTJs with the structure of substrate/Ta450/Ru95/Ir$_{22}$Mn$_{78}$100/Co$_{75}$Fe$_{25}$70/Al(12)+oxidation/CoFeSiB70/Ru 600 (in Å) were deposited by dc magnetron sputtering system in that time a magnetic field of 100 Oe was applied during deposition to induce the uniaxial magnetic anisotropy in FM layer. The base pressure of the vacuum chamber was below 2×10^{-8} Torr and the argon gas pressure was 2 mTorr. The tunnel barrier was formed by depositing a thin Al layer followed by plasma oxidation for 4 ~ 20 s in a load lock chamber. The junctions were fabricated using a photolithographic patterning procedure and ion beam etching and the junction area was $10 \times 10\ \mu\mathrm{m}^2$. Annealing was applied under a magnetic field of 300 Oe at 180 °C for 1 h. The magnetic and electric properties of MTJs were measured by a 2-point probe station.

3. Results and discussion

Figure 1 shows the typical resistance-magnetic field (*R-H*) curve for the annealed junction with 11 s oxidation time. The TMR ratio is 30%, resistance junction area product (R×A) is 330 $\mathrm{k}\Omega\,\mu\mathrm{m}^2$, H_c is 4 Oe, and interlayer coupling field (H_{int}) is 22 Oe. This lower TMR ratio but better H_c and switching characteristic than CoFe used MTJs. In addition, the barrier thickness of 14.6 Å and barrier height of 4.2 eV were obtained by fitting the *I-V* curves to the Simmons model [2, 3]. Figure 2 shows the *I-V* curves for MTJs with different oxidation time. It is clearly seen that greater the oxidation time, the resistance increases and non-linearity appears more clearly. The dependence of the TMR ratio and the resistance on oxidation time is shown in Fig. 3. For shorter oxidation time (<7s), the TMR ratio decrease sharply because the reduction of the TMR ratio for the under-oxidized junctions is attributed to the incomplete oxidation of the Al layer. As the oxidation time increased, the 12 Å-thick Al layer became progressively oxidized, and the barrier became thicker. It leads to MTJs in decreasing the TMR ratio and increasing the resistance, due to a partial oxidation of the CoFe bottom layer.

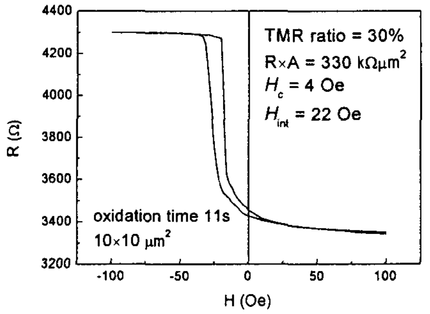

Fig. 1. Typical *R-H* curve for CoFeSiB used to free layer in the MTJ.

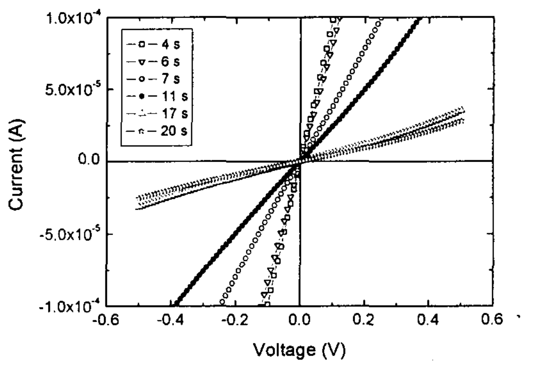

Fig. 2. The *I-V* curves for MTJs with different oxidation time.

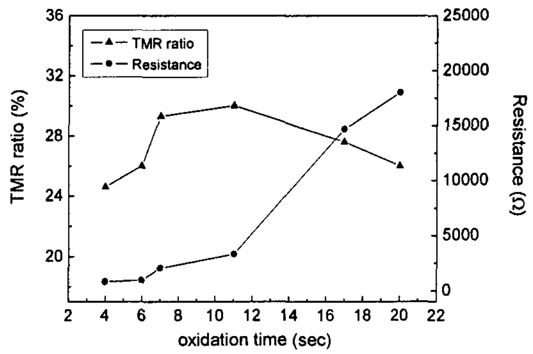

Fig. 3. The TMR ratio and the resistance as a function of the oxidation time.

4. Conclusion

We investigated the MTJs with the structure of Ta450/Ru95/IrMn100/CoFe70/Al(12)+oxidation/CoFeSiB70/Ru 600. It has better switching characteristic than conventionally used CoFe free layer MTJs. As the oxidation time increased, the TMR ratio decreased gradually and the junction resistance increased, which related with the oxidation of CoFe bottom layer. For very short time oxidation, the TMR ratio decreased sharply because of under-oxidized Al layer. The non-linearity of the *I-V* curves, the TMR ratio, and the junction resistance as a function of the oxidation time were reflected either under-oxidized Al layer or the oxidation of CoFe bottom layer.

5. References

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