Surface Roughness Effects of Pt Seed-layer under Full-Heusler Co_2FeAl/MgO-based Magnetic Tunnel Junctions on Perpendicular Magnetic Anisotropy

Kyo-Suk Chae[1,2], Du-Yeong Lee[1], Min-Su Jeon[1], Seung-Eun Lee[1], Tae-Hun Shim[1] and Jea-Gun Park[1]*

[1]Advanced Semiconductor Material and Device Development Center, Hanyang University, Seoul 133–791, Republic of Korea
[2]Samsung Electronics Co., Ltd., San #16 Banwol-dong, Hwasung-City, Gyeonggi-Do 445-701, Republic of Korea

STT-MRAM has been considered to be the promising candidate of next generation memory because it has the read and write operation of around ~10 ns and non-volatile memory characteristics without refresh operation. In order to realize the scalability of STT-MRAM under 30-nm feature size, a major challenge is to obtain the thermal stability ($K_u \times V/k_BT$), high TMR ratio and low critical current density (J_{CO}) magnetization switching of free layer [1]. Recently, Co-based full-Huesler materials have been reported that the perpendicular-magnetic tunneling junctions (p-MTJ) using Co_2FeAl(CFA) full-Huesler alloys and MgO barrier with coherent tunneling on MgO(001) substrate can obtain TMR(91%), K_u (3×10^6 erg/cm^3) and low α (0.004) [2,3].

In this study, the roughness effect of Pt seed layer was investigated in CFA/MgO/$C_2Fe_6B_2$(CFB) p-MTJ. The films of p-MTJ multi-layers were deposited on Si/SiO_2 substrates by high vacuum magnetron sputtering system with the using pressure of 1×10^{-8} torr. the stack structures, from the substrate side, MgO(2)/Pt(t_{Pt})/ CFA(0.8)/MgO (1.8)/CFB(1.4)/Ta(7) were fabricated, where Pt thickness was 1, 2, 6, 8, and 10 nm to consider the roughness effect of seed layer. The films were sputtered by DC/RF magnetron in an argon atmosphere (10 sccm). After p-MTJs fabrication, *ex-situ* annealing (T_{ex}) was performed at a temperature ranging from 250 to 350°C in a vacuum environment above 10^{-6} torr under a perpendicular magnetic field of 3 Tesla for 2 hrs.

Figure 1 shows that the hysteresis loops for p-MTJs with t_{Pt}=2 and 10 nm without and with annealing at 250 and 350°C. Surprisingly, In spite of T_{ex}=350°C, we definitely obtained the perpendicular magnetic anisotropy (PMA) characteristics using CFA material.

Figure 2 shows that the hysteresis loop of *M-H* for p-MTJ stacks with various Pt thicknesses. Especially, the steps of the separated magnetization switching of the CFA and CFB layers are clearly observed at only t_{Pt}=2 nm at T_{ex}=300°C. However, one magnetic switching was appeared at over T_{ex}=325°C because CFA material has only high thermal stability.

Figure 3 shows the surface information of Pt seed layer, the sample consist of, from the substrate side, Si/SiO_2/MgO(2) /Pt(t_{Pt})/CFA(0.8) with t_{Pt}=1, 2, 6, and 10 nm at an annealing temperature ranging from as-deposition to 350°C. As a result, thinner seed layer and higher temperature can achieve better surface morphology.

Figure 4 shows HR-TEM images, lattice fringes of Pt seed layer can be clearly observed at t_{Pt}= 2 nm, indicating the formation of well textured B2 structure resulting from a good the flatness of Pt seed layer. However, in case of t_{Pt}= 10 nm, B2 structure was partially observed because of rough interface due to thick Pt seed layer. To achieve the robust p-MTJ characteristics, the flat surface roughness of seed layer is very important.

In our presentation, we will report the roughness effect of Pt seed layer under CFA/MgO/CFB p-MTJ by using VSM, AFM and HR-TEM, etc. In addition, we will review the mechanism how the magnetic properties of various p-MTJs are influenced by surface morphology of Pt seed layer.

* This work was financially supported by the IT R&D program of MOTIE/KEIT [10043398, Fundamental technology development of materials of magnet resistance change (MR ratio >120%) and tunneling barrier for advanced low power memory device].

Reference

[1] S. Ikeda *et al*., Nature materials 9 (2010) 721–724.
[2] Z.C. Wen *et al.*, Appl. Phys. Express. 5, 063003 (2012)
[3] Y. Cui *et al.*, Appl. Phys. Lett. 102, 162403 (2013)

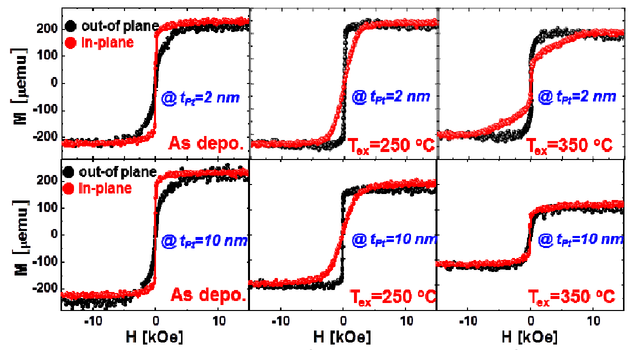

Fig. 1. *M-H* curves in out-of plane & in-plane for p-MTJs with t_{Pt}=2 and 10 nm without and with annealing at 250 and 350°C.

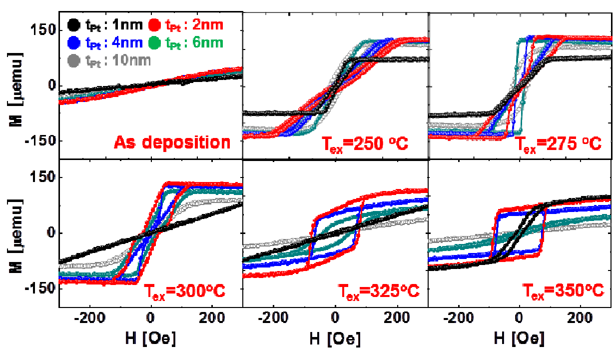

Fig. 2. *M-H* curves in out-of-plane direction for p-MTJ stacks without and with annealing at to temperature ranging from 250 to 350°C

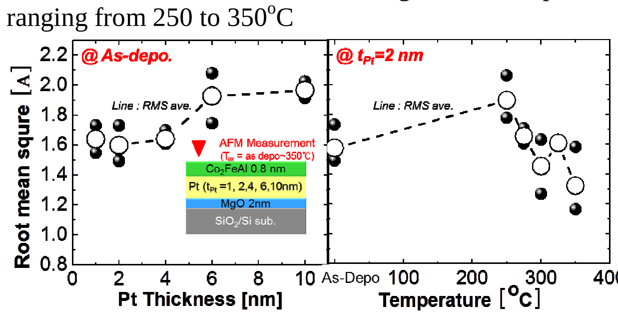

Fig. 3. Surface roughness (RMS) for p-MTJ stack with t_{Pt}=1, 2, 4, 6, and 10 nm at various annealing temperatures.

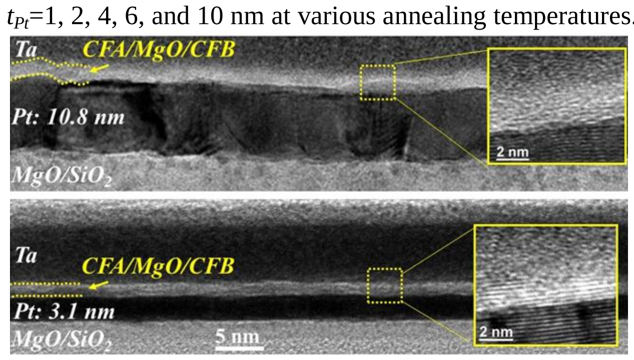

Fig. 4. Cross-sectional HR-TEM Images of p-MTJ stacks at T_{ex}=300°C.