Comparison of Ta, Pt and Ti Capping Layer on Perpendicular Magnetic Anisotropy in CoFeB-MgO-CoFeB Magnetic-tunnel-junction

Seung-Eun Lee[1], Du-Yeong Lee[1], Min-Su Jeon[2], Yasutaka Takemura[1,3], Kyo-suk Chae[1,4], Tae-Hun Shim[1] and Jea-Gun Park[1]*

Advanced Semiconductor Material and Device Development Center, [1]Department of Electronics and Computer Engineering, [2]Division of Nanoscale Semiconductor Engineering, Hanyang University, Seoul 133-791, Republic of Korea
[3]SUMCO Corporation, 1007-62 Izumisawa, Chitose-shi, Hokkaido 066-0051, Japan
[4]Samsung Electronics Co., Ltd., San #16 Banwol-dong, Hwasung-City, Gyeonggi-Do 445-701, Republic of Korea

Recently, research activities on magnetic tunnel junctions (MTJs) using crystalline MgO barrier layer have been performed for realizing to spin transfer torque magnetic random access memory (STT-MRAM). To obtain perpendicular anisotropy for STT-MRAM, various materials and structure systems have been studied. One of structures is Ta/CoFeB/MgO/CoFeB which attracted attention because of high tunnel magneto-resistance ratio (TMR), over 120 % [1]. However, the perpendicular magnetic anisotropy (PMA) of the CoFeB layer can be obtained within a very small thickness range of 1.0 nm. In addition, the physical origin of PMA in MgO/CoFeB/Ta structure is not quite clear [2]. In our paper, we investigated the effect of capping layer materials on magnetic properties in CoFeB/MgO/CoFeB magnetic tunnel junctions.

In our experiment, MTJ structures were sputtered on thermally oxidized Si substrates (001) with 12-inch-size by DC/RF magnetron sputter. The stack structure consist of, from the substrate side, Ta(5)/$Co_{20}Fe_{60}B_{20}$(1.05)/MgO (1)/$Co_{20}Fe_{60}B_{20}$(t_{CoFeB}: 0.9-1.2)/Ta or Pt or Ti(5) were fabricated, where all numbers are in the unit of nanometers. The base pressure of the sputtering chamber was less than 1×10^{-8} torr prior to deposition. Samples were then annealed 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 hours. The magnetic properties were measured at room temperature using a vibrating sample magnetometer (VSM) system. The sample size for all studies is 1×1 cm^2 from the central part of 12 inch wafer. Figure 1 shows film-level $K_u\times t$ values for different types of MTJs using the relation $K_u = K_{eff} + 2\pi Ms^2$ [3]. For the Ta case (see Fig. 1(a)), the $K_u\times t$ value was varied by annealing temperature. For the Pt case (see Fig. 1(b)), there was higher than Ta. However, It was confirmed that the variation of $K_u\times t$ value depends on both CoFeB thickness and annealing temperature. For the Ti case (see Fig. 1(c)), It was confirmed that there was no variation with both CoFeB thickness and annealing temperature. In particular, the $K_u\times t$ value was smaller than Ta and Pt. Figure 2 exhibits the magnetization versus external magnetic field (M-H) curves. For the Ta case (see Fig. 2(a)), it shows large variations of H_C, M_S and squareness by varying CoFeB thickness and annealing temperature. For the Pt case (see Fig. 2(b)), although the property of PMA was degraded from annealed at 325°C, there was no variation of H_C, M_S and squareness by varying CoFeB thickness and annealing temperature. For the Ti case (see Fig. 2(c)), there was less variations of H_C, M_S and squareness than Ta case.

In our presentation, we report the effect of capping layer on CoFeB-MgO-CoFeB magnetic tunnel junction as a function of annealing temperature by using VSM, transmission electron microscopy (TEM) and secondary ion mass spectroscopy (SIMS). In addition, we review the mechanism why the magnetic properties of MTJs are varied by capping layer materials.

* This work was financially supported by the IT R&D program of MKE/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, 721-724 (2010)
[2] C. Cheng *et al.*, J. Appl. Phys., 110, 033916 (2011)
[3] L. Zhu *et al.*, Adv. Mater., 24, 4547 (2012)

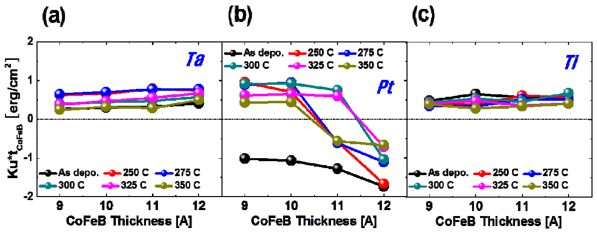

Fig. 1. The plot of $K_u\times t_{CoFeB}$ vs. CoFeB thickness: (a) Ta, (b) Pt, (c) Ti

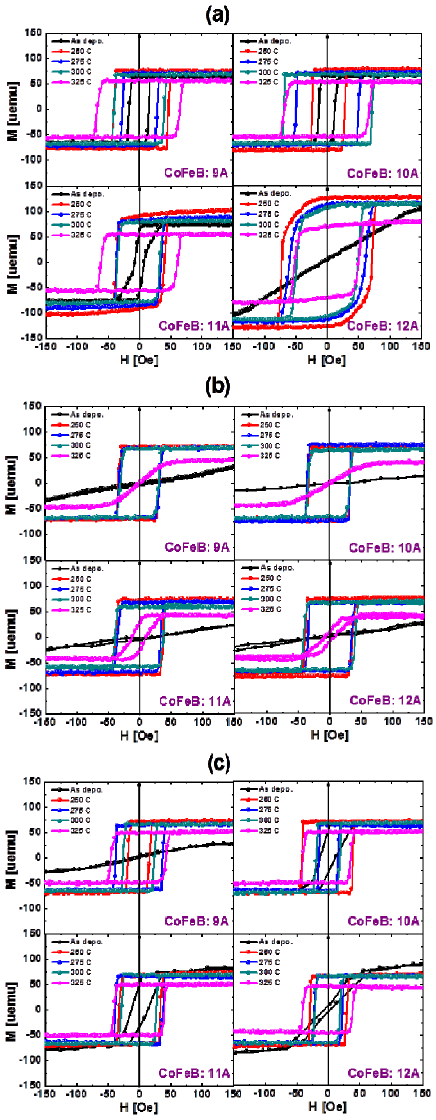

Fig. 2. M-H curves in out-of-plane direction for Ta(5) /CoFeB(1.05)/MgO(1)/CoFeB(t)/Capping layer(5) as a function of annealing temperature: (a) Ta, (b) Pt, (c) Ti