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Effect of Pt Capping Layer on Perpendicular-Magnet Anisotropy in CoFeB-MgO-CoFeB Magnetic Tunnel Junction

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Perpendicular spin-transfer-torque magnetic random access memories (pSTT-MRAMs) have recently been considered to be promising non-volatile memories because of their high speed and low power consumption. Achieving good crystalline MgO barrier layers and thermally stable and higher magnetic resistance (MR) ratios for magnetic tunnel junctions (MTJs) are particularly key issues to be realized perpendicular magnetic anisotropy (PMA) in spin transfer torque. Utilizing interface-induced PMA (i-PMA) via a sandwiched thin CoFeB/MgO/CoFeB MTJ has been attracting attention due to its simple structure and high anisotropy constant [1,2]. We investigated the dependence of PMA on annealing temperature and upper CoFeB thickness in the Pseudo-spin valves (P-SV) of a Ta/ CoFeB/MgO/CoFeB/Pt MTJ in this study to understand how the Pt capping layer influenced the crystalline linearity of the MgO (001) barrier layer.

In our experiment, the P-SVs of MTJs were grown on thermally oxidized 12-inch Si wafers. The structure of the MTJs consisted of a Ta bottom electrode (5 nm), a lower CoFeB (1.05 nm) layer, a layer barrier MgO (1 nm), an upper CoFeB (variable t_{CoFeB}: 0.9, 1.0, 1.1, and 1.2 nm) layer, and a capping Pt (5 nm) electrode, where sputtering targets of $Co_{20}Fe_{60}B_{20}$, MgO, Pt, and Ta were used. The MTJs were fabricated with cluster direct-current and radio frequency magnetron sputtering and then annealed at an annealing temperature ranging from 250 to 350°C under a perpendicular magnetic field of 3 T for 2 hrs. The MTJs were subject to PMA measurements at room temperature using a vibrating-sampling-magnetometer (VSM). The cross-sectional crystalline linearity of MTJs was analyzed by transmission electron microscopy (TEM).

Figure 1 plots the magnetization vs. the external magnetic field (M-H) curves for the Ta (5 nm)/CoFeB (1.05 nm)/MgO (1 nm)/CoFeB (variable t_{CoFeB}: 0.9, 1.0, 1.1, and 1.2 nm)/capping Pt (5 nm) at T_a =275°C and 3 T. All as-sputtered MTJs demonstrated in-plane characteristics, as can be seen from the *M-H* curves in the insets in Fig. 1. After annealing, however, the out-of-plane characteristics deteriorated with the increasing thickness of the upper CoFeB layer [3]. Figure 2 plots the anisotropy constant multiplied by the upper CoFeB thickness ($K_u \times t$) as a function of upper CoFeB thickness and annealing temperature. The MTJs with an upper CoFeB thickness of 0.9 and 1.0 nm exhibited PMA for all annealing temperatures, otherwise, the MTJs with an upper CoFeB thickness of 1.2 nm demonstrated in-plain anisotropy regardless of annealing temperatures. Also, we observed HR-TEM images of the MTJs at T_a =275°C and the as-deposited MTJs. The annealed MTJs with an upper CoFeB layer of 1.0 nm had fully latticed fringes in the MgO barrier, as shown in Figs. 3(a) and (c). However, the MTJs with upper CoFeB layers of 1.2 nm without annealing indicated that the MgO barrier was inter-mixed with Pt, resulting in a thin non-uniform MgO barrier, as shown in Figs. 3(b) and (d).

In our presentation, we report the effect of Pt capping layer on CoFeB/MgO/CoFeB magnetic tunnel junction as a function of annealing temperature by using TEM, and Secondary Ion Mass Spectroscopy (SIMS). In addition, we review the mechanism why the magnetic properties of MTJs are varied by Pt capping layer.

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Reference

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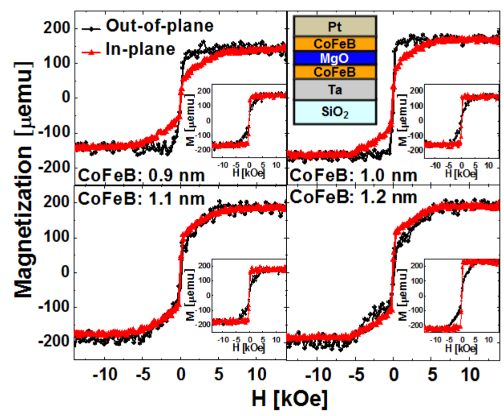

Fig. 1. Magnetization vs. external magnetic field (*M-H*) curves for MTJs as a function of upper CoFeB layer thicknesses

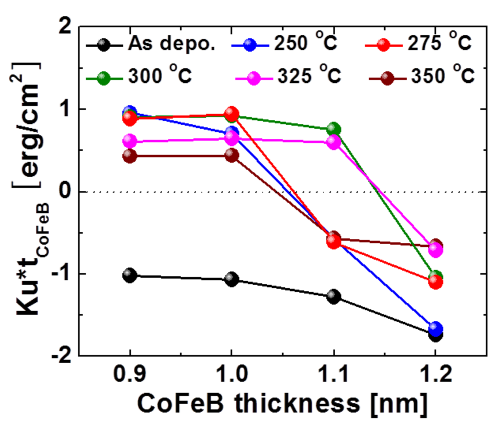

Fig. 2. Dependence of $K_u \times t$ on annealing temperature under 3 T and upper CoFeB layer thickness

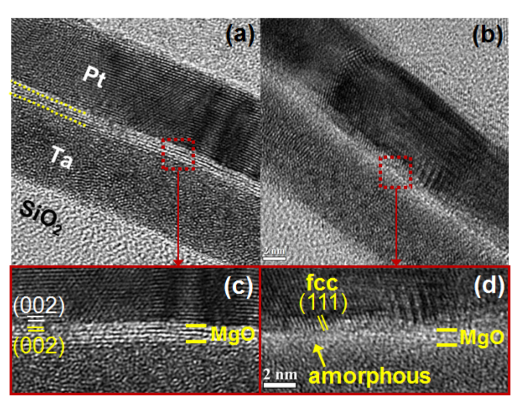

Fig. 3. Cross-sectional HR-TEM images of MTJs as a function of upper CoFeB layer thickness: (a) and (c) 1.0 nm after annealing at 275°C, (c) and(d) 1.2 nm without annealing