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Dependence of magnetic properties of MgO/CoFeB/Ta stacks on CoFeB and Ta thicknesses

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Abstract

We investigate the dependence of magnetic properties of MgO/CoFeB/Ta stacks on CoFeB and Ta thicknesses. 2 nm-thick CoFeB film shows increase of saturation magnetic moment per unit area (m_S) by annealing whereas thicker CoFeB film (> 5 nm) shows smaller increase of m_S, suggesting higher B composition in thicker CoFeB layer after annealing. m_S of 10 nm-thick CoFeB film after annealing increases with increasing Ta capping layer thickness from 1 nm to 5, 10 nm. The results suggest that B composition in CoFeB layer after annealing depends on both the CoFeB and Ta capping layer thicknesses.

1. Introduction

CoFeB-MgO based magnetic tunnel junction (MTJ) is an appealing system as a building block in spintronics based logic-in-memory and spin-transfer-torque magnetoresistive random access memory [1] owing to its large tunnel magnetoresistance (TMR) ratio [2][3]. As reported previously, in order to obtain high TMR ratio in CoFeB-MgO system, one needs to extract B from CoFeB layer by annealing to crystallize CoFeB into CoFe. Moreover, it was reported that interfacial magnetic anisotropy at CoFeB-MgO interface [4], which allows for achievement of CoFeB-MgO MTJ with perpendicular magnetic easy-axis [5], depends on B composition of CoFeB layer [6]. Therefore, it is important to control B composition in CoFeB layer for the improvement of properties of MTJ. It is expected that B composition in CoFeB layer after annealing depends on both CoFeB thickness and capping layer thickness, because B is absorbed by an adjacent layer such as Ta [7]. In this study, we investigate CoFeB and Ta capping layer thicknesses dependence of magnetic properties of MgO/CoFeB/Ta stacks.

2. Experimental procedure

A stacking structure, from substrate side, Ta(5)/MgO(1)/$Co_{20}Fe_{60}B_{20}$(t = 2 – 30)/Ta(t_{Ta} = 1-10) is deposited on thermally oxidized Si substrate by rf magnetron sputtering. (numbers in parenthesis are thicknesses in nanometers). Composition of CoFeB denotes that in the sputtering target. Magnetization measurement is done for 10 mm × 10 mm chips. Some of them are annealed in vacuum under a magnetic field of 0.4 T along film normal direction at temperature (T_a) of 300°C, 350°C, and 400°C. By using vibrating sample magnetometer, magnetic moment is measured as a function of magnetic field (H) along in-plane and out-of-plane directions

3. Results

Magnetic moment per unit area versus H curves (m-H curves) along in-plane and out-of-plane directions for CoFeB film with t = 10 nm at as-deposited state are shown

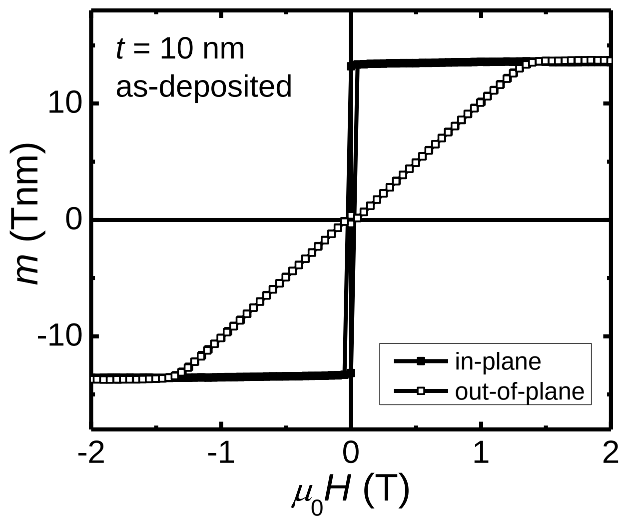

Fig. 1 Magnetic moment per unit area versus magnetic field curves (m-H curves) of 10 nm-thick CoFeB film at as-deposited state. Blank (bold) symbol corresponds to out-of-plane (in-plane) m-H curve.

in Fig. 1. Saturation magnetic moment per unit area (m_S) for CoFeB films with various t at as-deposited and annealed states at 300, 350, and 400°C are evaluated from the m-H curves. Normalized m_S of CoFeB films with various t is plotted with respect to T_a in Fig. 2 where m_S for annealed

CoFeB films is normalized by that for as-deposited CoFeB film. CoFeB film with t = 2 nm shows increase of m_S upon annealing, which agrees with reduction of B composition in CoFeB layer. On the other hand, CoFeB film with thicker t (> 5 nm) shows much smaller increase of m_S than that for 2 nm-thick CoFeB film, suggesting higher B composition in thicker CoFeB film. The higher B composition in thicker CoFeB film can be related to the amount of B that Ta capping layer can absorb. To examine the relationship between the amount of B absorbed in Ta capping layer and Ta capping layer thickness, T_a dependence of m_S for 10 nm-thick CoFeB film with t_{Ta} of 1, 5, and 10 nm is studied. Figure 3 shows T_a dependence of m_S of 10 nm-thick CoFeB film with various Ta capping layer thicknesses. m_S at as-deposited state is almost independent of t_{Ta}. In contrast,

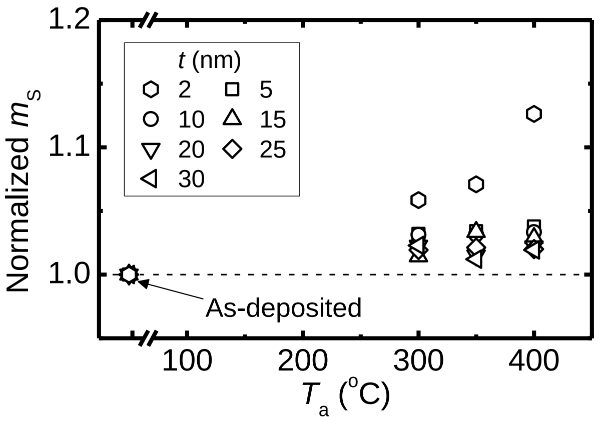

Fig. 2 Normalized saturation magnetic moment per unit area (m_S) for CoFeB films with various CoFeB thicknesses as a function of annealing temperature where m_S for annealed CoFeB films is normalized by that of as-deposited state.

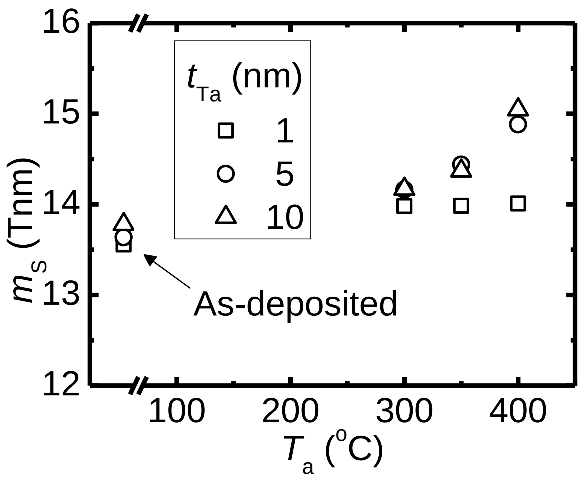

Fig. 3 m_S for 10 nm-thick CoFeB films with Ta capping layer thicknesses of 1, 5, and 10 nm is plotted against annealing temperature.

increase of t_{Ta} from 1 nm to 5 and 10 nm results in increase of m_S after annealing at 350 and 400°C. In addition, no significant difference of m_S of 10 nm-thick CoFeB film between t_{Ta} of 5 and 10 nm, suggesting that there is the limit for the amount of B that thick Ta capping layer can absorb.

4. Conclusion

We study magnetic properties of MgO/CoFeB/Ta stacks with various CoFeB and Ta thicknesses annealed at temperature up to 400°C. A study of CoFeB thickness dependence of saturation magnetic moment per unit area (m_S) reveals that thicker CoFeB film (> 5 nm) shows smaller increase of m_S than that of 2 nm-thick CoFeB film after annealing, suggesting that B composition is higher in thicker CoFeB film after annealing. Ta capping layer thickness dependence of m_S is also studied to clarify the relationship between amount of absorbed B by Ta capping layer and Ta capping layer thickness. m_S for 10 nm-thick CoFeB after annealing at 350°C and 400°C increases with increase of Ta capping layer from 1 nm to 5 and 10 nm. The m_S in 10 nm-thick CoFeB is virtually the same at the Ta capping layer thickness of more than 5 nm, suggesting that there is the limit for the amount of B that thick Ta capping layer can absorb.

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