Thermally stable perpendicular magnetic anisotropy features of Ta/TaOx/Ta/CoFeB/MgO/W stacks via TaOx Underlayer insertion

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1. Introduction

Spin-Transfer-Torque Magnetoresistive Random Access Memory (STT-MRAM) has garnered considerable attention as a promising next generation nonvolatile memory due to extremely low power consumption, and high-speed performance.[1-2] In particular, STT-MRAM, including out-of-plane magnetized tunnel junctions (p-MTJ) is highly promising, because it suggests it is possible to achieve the thermal stability factor Δ, which determines memory retention and write current density (Jc).[3] A critical issue for Ta/CoFeB/MgO stacks, which is one of key structures for p-MTJ, is PMA feature degradation during annealing temperatures greater than 300 °C, which is equivalent to the annealing temperature used in a standard CMOS integrated process. Therefore, we describe an effective Ta atom diffusion sponge approach to create thermally stable Ta/CoFeB/MgO stacks that involves use of a TaO_x underlayer.

2. Experimental Details

Two stack samples were prepared by utilizing a radio-frequency magnetron sputter-system. One sample was Si/SiO2/Ta (1)/Co2Fe6B2 (1.2)/MgO (2)/W (3) [Sample A] while the other was Si/SiO2/Ta (1)/TaOx (1)/Ta (1)/Co2Fe6B2 (1.2)/MgO (2)/W (3) [Sample B]; numbers in parentheses refer to the thickness of each layer in nanometers. The TaOx layer was grown by mixing an extremely small amount of O2 gas (1 % of Ar) into the Ar gas atmosphere during Ta sputtering. To monitor diffusion of Ta atoms toward the CoFeB layer or TaOx under-layer, a post-annealing process was carried out for both samples; this involved incubation at 250 °C and 350 °C for 1 hour under vacuum at a pressure below ~1 x 10-3 Torr and a perpendicular magnetic field of ~2 kOe. Finally, in-plane and out-of-plane magnetic properties were measured by vibrating sample magnetometry (VSM) and XPS measurements were taken.

3. Results and Discussion

The insertion of TaO_x layer clearly shows the enhanced annealing stability for Ta/CoFeB/MgO stacks, which was confirmed by hysteresis loops. This behavior can be explained by the fact that TaO_x layer suppressed Ta diffusion into the CoFeB/MgO interface. This diffusion behavior was confirmed by XPS depth profile analysis.

Moreover, the role of TaOx layer for the diffusion-suppresser was explained and also confirmed by XRD analysis.

4. Conclusion

In conclusion, we evaluated a simple TaOx underlayer approach as an alternative solution to stabilize the PMA features of CoFeB/MgO free layer stacks. Different oxygen amounts in the TaO_x underlayer had a significant impact on magnetic responses, likely due to variation of pre-existing grain boundaries. XPS analysis indicated that the TaOx underlayer functioned as a diffusion sponge due to partial impregnation of Ta atoms into this layer during thermal annealing; this was supported by XRD analysis. Our approach represents a useful and simple route for generation of highly stable free layer stacks.

5. References

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