$Mg_{1-x}Ti_xO$-based magnetic tunnel junctions with CoFeB electrodes

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The MgO-based magnetic tunnel junctions (MTJs) are the building blocks in magnetic random access memory (MRAM) [1]. Future development of gigabit-scale MRAM requires perpendicular MTJs with large tunneling magnetoresistance (TMR) ratio and resistance-area product (*RA*) lower than 10 Ωμm^2 [2], which is very challenging for the MgO barrier considering its large band gap. Here we report on the polycrystalline MTJs using $Mg_{1-x}Ti_xO$ (x = 0.05 and 0.1) barriers that were found to show comparable TMR ratio to that of MgO-based MTJs, especially at low *RA*, and have relatively lower barrier heights.

MTJ stacks of Ta(5)/ Ru(10)/ Ta(5)/CoFeB(5)/MgO or $Mg_{1-x}Ti_xO$ (0-1.8)/ CoFeB(4)/ Ta(5)/ Ru (5, in nm) were prepared by using a magnetron sputtering system, with x = 0.05, and 0.1. The MTJ devices were fabricated by electron beam lithography, photolithography, and argon-ion milling. The MTJs were then post-annealed at 300°-450°C. The electrical measurements were performed by the four-probe method at room temperature.

The introduction of Ti into MgO was found to reduce the TMR ratio of MTJs for high *RA* range, as shown in Fig. 1. In general, the TMR ratio was found to monotonically decrease with increasing Ti concentration for the whole range of post-annealing temperature. As the *RA* decreases below 10 Ωμm^2, the TMR ratio of MgO-based MTJs decreases rapidly and becomes lower than that of $Mg_{1-x}Ti_xO$-based MTJs (Fig. 2). Detail transmission electron microscopy (TEM) characterization found that a very thin MgO barrier have some pinholes with more dislocations at the interface while a very thin $Mg_{1-x}Ti_xO$ barrier have much less dislocations and atomically sharp interfaces. This result demonstrates the potential of $Mg_{1-x}Ti_xO$ barrier for spintronics applications that need low *RA* MTJs.

References

1) S. Yuasa and D.D. Djayaprawira, *J. Phys. D: Appl. Phys.*, **40**, R337 (2007).
2) S. Yuasa *et al*, *Proc. IEEE Int. Electron Devices Meeting*, 311 (2013)

Acknowledgements

This work was partly supported by ImPACT Program of Council for Science, Technology and Innovation.

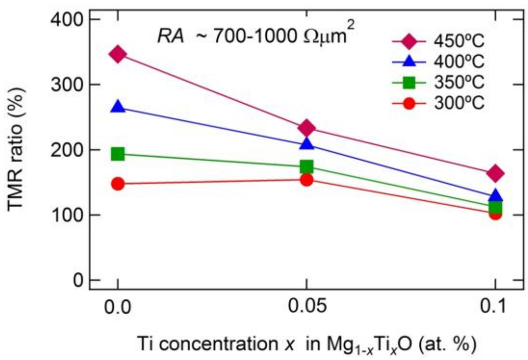

Figure 1. The TMR ratio of MgO and $Mg_{1-x}Ti_xO$-based MTJs for different post-annealing temperatures.

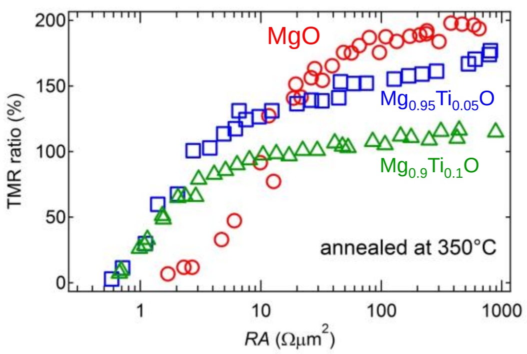

Figure 2. TMR ratio vs *RA* for MTJs post-annealed at 350°C