Tunnel Magnetoresistance in Magnetic Tunnel Junctions with the MgO Barrier Prepared with Off-Axis Sputtering

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The high tunnel magnetoresistance (TMR) ratio in magnetic tunnel junctions (MTJs) is strongly required in spintronic devices such as magnetoresistive random access memories, magnetic sensors, and so on. In the MTJs with oxide barriers, the defects in the barrier due to O^- ion bombardment should play one of the significant roles on the deterioration of TMR ratios. [1] Off-axis sputtering technique with the cathode orthogonal to substrate surface could reduce the damage on the oxide barrier due to the bombardments, whereas there were few investigations using the off-axis sputtering reported, to our knowledge. In this report, the CoFeB/MgO/CoFeB-based MTJs, the conventional type of MTJs, prepared using off-axis sputtering were investigated to examine whether this technique is useful for exploration of oxide barrier materials.

The MgO (10)/Ta(1) films and MTJ multilayer films composed of Ta(5)/ Ru(10)/ Ta(5)/ CoFeB(10)/ MgO(2)/ CoFeB(4)/ Ta(3)/ Ru(5) (thickness in nm) were prepared with DC/RF magnetron sputtering on Si/SiO_2 substrates. The MgO layer was deposited with the off-axis sputtering cathode. MTJ stacking was patterned into rectangular-shaped pseudo-spin-valve (PSV) with 40×2, 20×2, and 15×3 μm^2 so that bottom and top CoFeB layers can show different switching fields. Ex-situ post-annealing was carried out to crystallize CoFeB and MgO. Structural and transport properties were evaluated by x-ray diffraction (XRD) and 4-probe method, respectively.

The x-ray intensities of MgO (200) peaks for the 10-nm-thick MgO films increased with decreasing Ar gas pressure. This trend is different from that conventional sputtering technique, *i.e.*, the off-axis sputtering does not need to increase Ar gas pressure to suppress O^- ion bombardments. [2] TMR ratio of 42% was obtained in the as-prepared MTJs. The TMR ratio increased with increasing post-annealing temperature; it was reached to 330% by the post-annealing at 450°C, which was higher than that of PSV previously prepared using conventional cathodes in our group. Therefore, the off-axis sputtering technique could be a beneficial tool to explore the various oxide barriers. In addition, the x-ray analysis for the sputtered MgO films with O_2 flow indicated that O_2 flow is effective for further improving crystallinity. The TMR properties of MTJs prepared using the reactive off-axis sputtering of MgO will also be discussed.

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References [1] K. Ono *et al.*, Jpn. J. Appl. Phys. **50**, 023001 (2011). [2] J. Jia *et al.*, Appl. Phys. Lett. **103**, 013501 (2013).