CoFeB/$MgAl_2O_4$/CoFeB magnetic tunnel junctions with a large magnetoresistance over 240% at room temperature

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Recently large tunnel magnetoresistance (TMR) ratios exceeding 300% have been reported in epitaxial $MgAl_2O_4$ spinel-based (Mg-Al-O) magnetic tunnel junctions (MTJs) [1,2]. In Mg-Al-O MTJs, excellent bias voltage dependence of a TMR ratio is observed due to good lattice matching with CoFe based alloys. However, polycrystalline Mg-Al-O MTJs with CoFeB failed to show a large TMR ratio due to the difficulty to obtain a crystalline Mg-Al-O layer on CoFeB [3]. This situation made it difficult to provide industry viable spinel-MTJs that can be grown on any kind of underlayers. In this study, we demonstrated a large TMR ratio over 240% through the achievement of a highly-(001) textured CoFeB/Mg-Al-O/CoFeB structure [4]. Here, we used an MgO insertion to promote the crystallization of Mg-Al-O.

We prepared MTJ stacks with Si/SiO_2 substrate/Ta (5)/Ru (10)/Ta (5)/$Co_{20}Fe_{60}B_{20}$ (CoFeB) (5)/$Co_{75}Fe_{25}$ (CoFe) (1)/MgO (0–0.7)/Mg-Al-O (1.2)/CoFeB (3)/Ta (5)/Ru (5), (thickness in nm) using magnetron sputtering. The Mg-Al-O layer was deposited by RF sputtering from sintered targets with Mg_2Al-O_x and $MgAl_2$-O_x compositions. The stacks were patterned into elliptical MTJ pillars with a size of 200x400 nm^2 using typical microfabrication techniques. The MTJs were post-annealed at 500°C.

A scanning transmission electron microscopy (STEM) image of the stack with MgO (0.7 nm)/$MgAl_2$-O_x revealed formation of a highly (001) textured CoFe(B)/Mg-Al-O/CoFe(B) structure as shown in Fig. 1. The misfit dislocations were not observed within the grains, suggesting the good lattice-matching. By using the MgO insertion, TMR ratios more than 100% were achieved at room temperature for both the Mg_2Al-O_x and $MgAl_2$-O_x cases. The largest TMR ratio of 242% was observed in an MTJ with MgO (0.7 nm)/Mg_2Al-O_x. We also confirmed good bias voltage dependence of TMR due to the achievement of the lattice-matching. This study demonstrates the industrially viability of polycrystalline spinel-MTJs for spintronic devices with a large TMR signal output. This work was partly supported by the ImPACT Program of Council for Science, Technology and Innovation, Japan, and JSPS KAKENHI No. 16H03852.

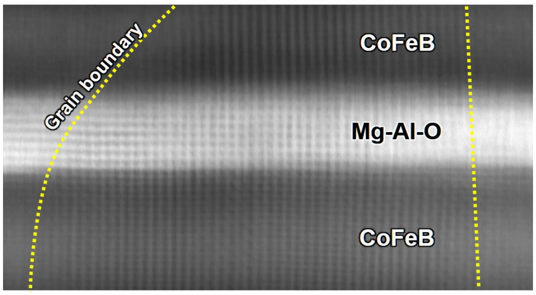

Fig. 1. Cross-sectional STEM image of CoFeB/CoFe/MgO (0.7 nm)/$MgAl_2$-O_x (1.2 nm)/CoFeB structure.

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