High quality cation-disorder $MgAl_2O_4$(001)-based magnetic tunnel junctions deposited by a direct sputtering technique

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Recently, the capability of $MgAl_2O_4$ tunnel barrier in magnetic tunnel junctions (MTJs) has been investigated for future non-volatile magnetoresistive memory applications. To date, large tunnel magnetoresistance (TMR) ratios exceeding 300% at room temperature (RT) were achieved in $MgAl_2O_4$-MTJs using a post-oxidation of an Mg-Al alloy layer [1]. However, the chemical inhomogeneity and interface roughness of the post-oxidized $MgAl_2O_4$ barriers have hindered the achievement of large TMR ratios for thinner barriers. In this study, we report very flat $MgAl_2O_4$ barrier interfaces with few misfit dislocations in Fe/$MgAl_2O_4$/Fe MTJs prepared by direct sputtering of a sintered $MgAl_2O_4$ target [2].

The MTJs with the following structure were prepared using a magnetron sputtering system: MgO(001) substrate/Cr (40)/Fe (100)/MgAl/$MgAl_2O_4$/Fe (7)/IrMn (12)/Ru (10), units in nm. The $MgAl_2O_4$ barrier was deposited using RF sputtering and was subsequently post-annealed at 500°C to improve the crystalline quality. The ultra-thin MgAl layer was inserted to tune the interface state. An annular dark-field scanning transmission electron microscopy (ADF-STEM) image shows the excellent quality of the barrier and perfect lattice-matched interfaces with the Fe electrodes (Fig. 1 (a)). The formation of the cation-disorder $MgAl_2O_4$ structure needed for high TMR ratios [1] was confirmed by the nano-electron beam diffraction (NBD) (inset of Fig. 1 (a)). A large TMR ratio of 245% at RT was observed, which exceeds those of epitaxial Fe/MgO/Fe (~180%) [3] and Fe/post-oxidized $MgAl_2O_4$/Fe (~212%) MTJs [4], and reflected the coherent tunneling through the half-metallic Fe-Δ_1 band. The bias voltage dependence of TMR (Fig. 1 (b)) shows that the TMR drops to the half of its zero-bias value at +1.2 V and −1.0 V, which are about two times larger than that of the MgO-based MTJs [5] and is similar to the post-oxidized $MgAl_2O_4$-based MTJs [4]. This is attributed to the high quality of the $MgAl_2O_4$ barrier with few misfit dislocations due to the perfect lattice matching with an Fe electrode. These results reveal that the direct sputtering is an alternative way for achieving high performance spinel barrier-based MTJs with uniform thin $MgAl_2O_4$ tunnel barriers.

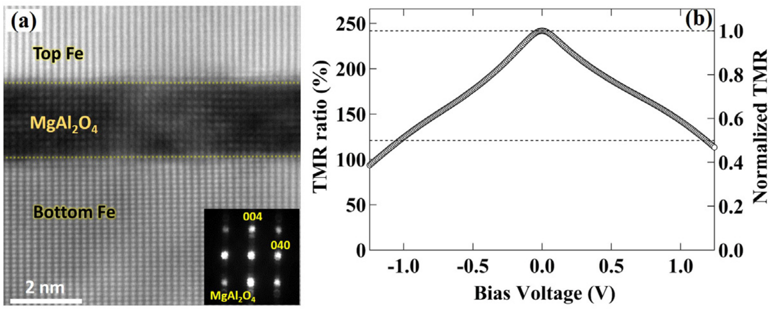

Fig. 1. (a) ADF-STEM image of an Fe/$MgAl_2O_4$ (2.10 nm)/Fe MTJ. (b) Bias voltage dependence of TMR ratio of an Fe/$MgAl_2O_4$ (1.86 nm)/Fe MTJ at RT. Inset of (a) is the NBD pattern of the barrier.

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References: [1] H. Sukegawa *et al.*, Phys. Rev. B **86**, 184401 (2012). [2] M. Belmoubarik *et al.*, Appl. Phys. Lett. **108**, 132404 (2016). [3] S. Yuasa *et al.*, Nat. Mater. **3**, 868 (2004). [4] H. Sukegawa *et al.*, Appl. Phys. Lett. **105**, 092403 (2014). [5] W. Wang *et al.*, Appl. Phys. Lett. **95**, 182502 (2009).