Single-crystal Fe/MgO/Fe magnetic tunnel junctions with a room temperature magnetoresistance of 417%

NIMS, °T. Scheike, Xiang, Z. Wen, H. Sukegawa, T. Ohkubo, K. Hono, S. Mitani
E-mail: scheike.thomas@nims.go.jp

Magnetic tunnel junctions (MTJs) are important building blocks for novel spintronics applications, e.g., brain-morphic devices and magnetic logic circuits, which are in need of very large tunnel magnetoresistance (TMR) ratios possibly exceeding 1000% at room temperature (RT) for their operation [1]. Therefore, significant enhancement in experimental TMR is needed. Even in a simple Fe/MgO/Fe MTJ, there is large discrepancy between experiments (~180%) [2] and theories that predict TMR >1000%. To bridge the discrepancy, we revisited the Fe/MgO/Fe MTJ by all layer optimization for production; as a result, we achieved a TMR ratio up to 417% at RT, almost doubling previous reports of Fe/MgO/Fe [3].

MTJs were deposited using an ultrahigh vacuum magnetron sputtering with a structure of MgO(001) substrate//Cr (60)/Fe (50)[/CoFe (2.24)]/Mg (0.5)/wedge-shaped MgO (d_{MgO})/natural oxidation/Fe (5)/IrMn (10)/Ru (20) (in nm). All layer processes were tuned to improve the crystal quality of the top- and bottom-Fe/MgO interfaces. Wafers were *ex-situ* annealed in a 0.7 T magnetic field at 200°C and patterned into micrometer scale MTJs. The transport properties were investigated using a DC 4-probe method.

In Fig. 1, the RT TMR ratio and *RA* vs. d_{MgO} for the Fe/MgO/Fe MTJ after optimization is shown. The maximum TMR ratio reaches 417% at RT (see the MR loop in the inset). The TMR ratio shows oscillations with d_{MgO} and a period of 3.1 Å, similar to the previous Fe/MgO/Fe report [2]. Surprisingly, the maximum peak-to-valley difference is ~80%, which is 7 times larger than that of the reported values [2]. The obtained TMR ratio is almost twice as large as previously reported values of Fe/MgO/Fe, demonstrating that there is more room for larger TMR ratios in typical MTJs by using material optimization and interface tuning. In fact, we obtain a much larger TMR ratio of 497% using a CoFe insertion, i.e., Fe/CoFe (2.24)/MgO/Fe, as shown as the diamond of Fig. 1.

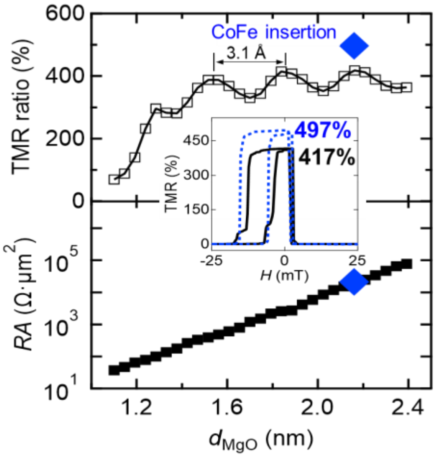

Fig. 1 TMR and *RA* vs. d_{MgO}; inset: maximum TMR loop of Fe/MgO/Fe and Fe/CoFe/MgO/Fe MTJ.

This work was partly supported by the ImPACT Program of the Council for Science, Technology and innovation (Cabinet Office, Government of Japan), JSPS KAKENHI 16H06332, TIA Kakehashi, and project JPNP16007, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

Reference: [1] Y. Cao *et al.*, iScience **23**, 101614 (2020); [2] S. Yuasa *et al.*, Nat. Mater. **3**, 868 (2004); [3] T. Scheike *et al.*, Appl. Phys Lett., in-press; arXiv: 2011.08739.