Staircase-like tunnel resistance increase with barrier thickness in epitaxial Fe/Mg_4Al-Ox/Fe(001) magnetic tunnel junctions

NIMS, °T. Scheike, Z. Wen, S. Kasai, H. Sukegawa, S. Mitani

E-mail: SCHEIKE.Thomas@nims.go.jp

Magnetic tunnel junctions (MTJs) are essential for spintronics applications and, thus, have been extensively studied experimentally and theoretically. While, in general the concept of giant tunneling magnetoresistance (TMR) effect is understood by the so-called coherent tunneling mechanism [1], some transport phenomena of MTJs have yet to be clarified. One is the significant TMR oscillation with barrier thickness observed even at room temperature (RT) in high quality MTJs with a period of ~0.3 nm [2]. Absent in most theoretical calculations, we aim to give further experimental inside on the behavior of the oscillations of recently reported Fe/wedged $Mg_4Al\text{-}O_x$/Fe with peak RT TMR >400% [3]. For this, we measured an array of over 450 MTJs on the same wafer and report Lorentz-like oscillation components in tunnel resistances at RT.

MTJ multilayers were deposited by magnetron sputtering and electron beam deposition on a single crystal MgO(001) substrate with the structure: substrate/Cr buffer/Fe (50 nm)/$Mg_4Al\text{-}O_x$ (wedged, d_{MAO})/Fe (5 nm)/IrMn (10 nm)/Ru cap. The barrier was sputtered from a sintered $Mg_4Al\text{-}O_x$ block. After the deposition, micrometer-scale MTJs were patterned using Ar ion milling and photolithography.

Figure 1 shows the parallel (P) and antiparallel (AP) resistance area (*RA*) vs. the barrier thickness at RT under a low bias voltage (10 mV). Each point presents one MTJ. The large difference in resistance results in large peak TMR >400%. A staircase-like increase of *RA* with increased barrier thickness is clearly observed for both resistance states, leading to the observed giant TMR oscillation. This is remarkable as usually oscillations are hidden behind the common exponential background. The steps are slightly shifted with respect to each other. When the exponential background is removed, the oscillation behavior is different from a previously assumed sine function behavior with round peak and valleys. The oscillations appear more spiked following Lorentz-like curves. This is the first reported behavior of such strong oscillations and suggest a connection with the high quality of the MTJ. This work was supported by the JSPS KAKENHI Grant Nos. 21H01750, 21H01397 and 22H04966, and partly based on results obtained from a project, No. JPNP16007, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

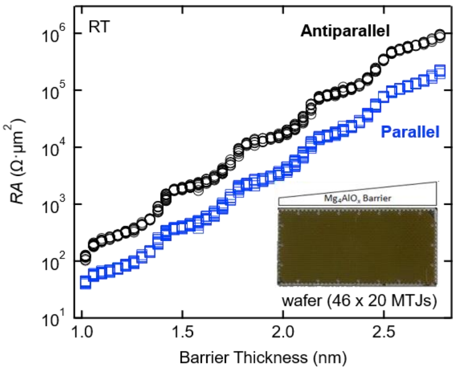

Fig. 1. Resistance area vs. barrier thickness at RT.

References: [1] W. Butler *et al.*, Phys. Rev. B **63**, 054416 (2001). [2] S. Yuasa *et al.*, Nat. Mater. **3**, 868 (2004). [3] T. Scheike *et al.*, Appl. Phys. Lett. **120**, 032404 (2022).