Spin dependent transport in $Co_2FeAl/MgAl_2O_4/CoFe$ epitaxial magnetic tunnel junctions with and without CoFe insertion

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For the application in magnetic random-access memory (MRAM) devices, magnetic tunnel junctions (MTJs) with large tunnel magnetoresistance (TMR) in combination with low junction resistance area product (*RA*) and small TMR-bias voltage dependence are desired. It is generally known that these features are significantly affected by the ferromagnet/barrier interfaces. Therefore, insertion of certain materials at the interfaces have shown to be useful in altering transport properties of MTJs. Previously, we have found an increase (strong decrease) of TMR (*RA*) by insertion of a thin CoFe layer in Co_2FeAl/inserted CoFe (0 or 1 nm)/$MgAl_2O_4$/CoFe(001) MTJs [1]. Here, we study the origin of the change by analyzing their microstructure and conductance temperature dependence.

MTJ multilayers were fabricated on MgO(001) single-crystal substrates by magnetron sputtering at a base pressure of 4×10^{-7} Pa. The stacking structure is: buffer layer [Cr (40)/$Co_{50}Fe_{50}$ (CoFe, 5–25)]/Co_2FeAl (5)/CoFe insertion (d_{CoFe} = 0 or 1)/Mg (0.45)/$Mg_{16.5}Al_{83.5}$ (0.9)/plasma oxidation/CoFe (5)/IrMn (12)/Ru-cap (12) (thickness in nm) [1]. An $MgAl_2O_4$ barrier forms after plasma oxidation of the Mg/MgAl bilayer. High-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) and energy dispersive X-ray spectrometer (EDS) were observed using a Titan G2 80–200 aberration-corrected STEM. Transport properties of the MTJs were measured using a conventional DC 4-probe method after patterning.

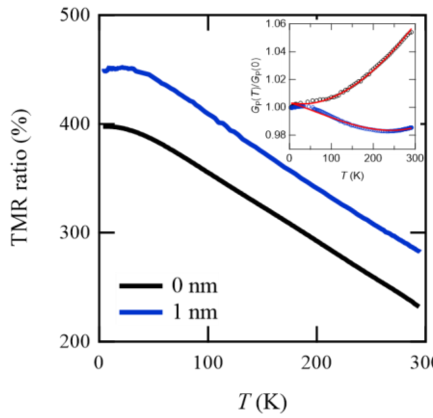

Fig. 1 TMR vs. temperature; inset: G_P vs. temperature (red line: fit).

STEM analysis of the MTJs with and without CoFe insertion revealed no significant difference in barrier thicknesses, crystallinities, and sharpness of interfaces of the two MTJs. The temperature dependences of TMR [= $100\times(G_P - G_{AP})/G_{AP}$, where $G_{A(AP)}$ is conductance in parallel (antiparallel) magnetization state] for both MTJs is shown in Fig. 1. They also show no significant different slope. The main difference is found in the temperature dependence of G_P (see inset). After the CoFe insertion the slope of G_P changes which is opposite to the typically observed monotonic increase. We successfully employed a model by Hu *et al.* which includes inelastic and elastic tunneling contributions to fit our data (red lines in inset) [2]. The model suggests a change of tunneling contributions by the CoFe insertion. This work was partly funded by ImPACT Program of Council for Science, Technology and Innovation, and JSPS KAKENHI No.16H03852.

Reference: [1] Scheike *et al.*, APL **105**, 242407 (2014); [2] B. Hu *et al.*, PRB **94**, 094428 (2016).