LARGE TUNNEL MAGNETORESISTANCE WITH A Co$_2$FeAl FULL-HEUSLER ALLOY ELECTRODE

K. Inomata$^{1,2}$, S. Okamura$^1$, and N. Tezuka$^{1,2}$

$^1$Department of Materials Science, Graduate School of Engineering, Tohoku University, Aoba-yama 6-6-02, Sendai 980-8579, and $^2$CREST, Japan Science and Technology Agency, 4-1-8 Honcho Kawaguchi, Saitama 332-0012, Japan

inomata@material.tohoku.ac.jp

Highly spin-polarized ferromagnets are the key materials for technological development of spintronics devices. Half metallic ferromagnets (HMFs) are 100% spin-polarized due to the unusual band structures, having a band gap for one spin band and being metallic for another spin band at the Fermi energy ($E_F$), while normal transition metal ferromagnets (Fe, Co, and Ni) possess the spin polarization of 40~50%. Consequently, HMFs are expected to provide the huge tunnel magnetoresistance (TMR) and current perpendicular-to-plane giant magnetoresistance (CPP-GMR). There are many half metallic full-Heusler alloys$^{1,2}$, which are in a chemical form of X$_2$YZ ($L_2$$_1$ structure), of which structure transforms into the B$_2$ (X$_2$(Y, Z)) and then the A$_2$ ((X, Y, Z)) structures with increasing temperature, where (Y, Z) and (X, Y, Z) mean that the Y and Z atoms, and X, Y, Z atoms are randomly substituted, respectively. The structural transformations have been believed to reduce the spin polarization, because the spin polarization is predicted to be very sensitive to the atomic site disorder in HMFs. On the other hand, we have reported the relatively large TMR at RT of 18% and 27% using Co$_2$(Cr, Fe)Al Heusler alloys with the B$_2$ structure$^{3,4}$. This result aroused the possibility that the B$_2$-type Co$_2$(Cr, Fe)Al Heusler alloys may have a large spin polarization. Afterwards, the first principle calculations were carried out, and demonstrated that the large spin polarization in Co$_2$(Cr, Fe)Al Heusler alloys with the $L_2$$_1$ structure is hardly changed by the B$_2$ type atomic site disorder$^5$. Recently, a large TMR of 40% at RT was also reported experimentally in the B$_2$ type Co$_2$MnAl$^6$. Thus, full-Heusler alloys are promising materials for obtaining the large TMR due to the disorder tolerance.

In this work, we focus on the Co$_2$FeAl full-Heusler alloy for $x = 1$ in Co$_2$(Cr$_{1-x}$Fe$_x$)Al, which exhibits the A$_2$ and B$_2$ structures when deposited on a thermally oxidized Si substrate with room temperature (RT) and an elevated temperature above 473K, respectively as shown in Fig.1, in which the (200) is the superlattice line of the B$_2$ structure. The magnetic tunnel junctions (MTJs) with a Co$_2$FeAl full-Heusler alloy electrode were investigated, which were fabricated by the deposition of the films using an ultrahigh vacuum sputtering system, followed by the photo lithography and Ar ion etching. The TMR was measured by the four point method. X-ray photoelectron spectroscopy (XPS) depth profiles in the Co$_2$FeAl single layer films reveal that Al atoms in the Co$_2$FeAl are oxidized preferentially at the surfaces. On the other hand, at the interfaces in Co$_2$FeAl/Al-O$_x$/Co$_{75}$Fe$_{25}$ MTJs, the ferromagnetic layers are hardly oxidized during plasma oxidation for a formation of Al oxide barriers. The TMR of 47% and 74% at RT and 5K, respectively were obtained in a MTJ with the stack of Co$_2$FeAl/Al-O$_x$/Co$_{75}$Fe$_{25}$ for the A$_2$ type Co$_2$FeAl, while it was only 27% at RT using the B$_2$ type Co$_2$FeAl electrode (Fig.2). The TMR difference between the A$_2$ and B$_2$ type Co$_2$FeAl electrodes is due to the different spin polarization, which are given to be 62% and 30% for the A$_2$ and B$_2$, respectively by the first principle calculations. The (100) orientated B$_2$ type Co$_2$FeAl electrode fabricated on a heated MgO (100) substrate, on the other hand, exhibited nearly the same
TMR as that obtained using the A2 type Co$_2$FeAl electrode. We discuss about this from the point of the interface structure.

Acknowledgements

This study was financially supported by IT-Program RR2002 from MEXT.

References


Fig. 1 X-ray diffraction patterns for Co$_2$FeAl (100-nm thick) films deposited on a thermally oxidized Si substrate with various temperatures. The inset shows substrate temperature dependence of the intensity ratios ($I_{200}/I_{220}$). The dotted straight line indicates the calculated values assuming the perfect B2 structure ordering in the films.

Fig. 2 Magnetoresistance curves at RT for MTJs with a Co$_2$FeAl film deposited at RT and 573 K. The corresponding crystal structures are the A2 and the B2 structures, respectively. The inset indicates the magnification of the magnetoresistance curves at low magnetic field region.