LARGE TUNNEL MAGNETORESISTANCE WITH A Co_2FeAl FULL-HEUSLER ALLOY ELECTRODE

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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_2YZ ($L2_1$ structure), of which structure transforms into the B2 (X_2 (Y, Z)) and then the A2 ((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 B2-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 $L2_1$ structure is hardly changed by the B2 type atomic site disorder[5)]. Recently, a large TMR of 40% at RT was also reported experimentally in the B2 type Co_2MnAl [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_2FeAl full-Heusler alloy for $x = 1$ in $Co_2(Cr_{1-x}Fe_x)Al$, which exhibits the A2 and B2 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 B2 structure. The magnetic tunnel junctions (MTJs) with a Co_2FeAl 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_2FeAl single layer films reveal that Al atoms in the Co_2FeAl are oxidized preferentially at the surfaces. On the other hand, at the interfaces in $Co_2FeAl/Al\text{-}O_x/Co_{75}Fe_{25}$ 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 $Co_2FeAl/Al\text{-}O_x/Co_{75}Fe_{25}$ for the A2 type Co_2FeAl, while it was only 27% at RT using the B2 type Co_2FeAl electrode (Fig.2). The TMR difference between the A2 and B2 type Co_2FeAl electrodes is due to the different spin polarization, which are given to be 62% and 30% for the A2 and B2, respectively by the first principle calculations. The (100) orientated B2 type Co_2FeAl 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_2FeAl electrode. We discuss about this from the point of the interface structure.

Acknowledgements

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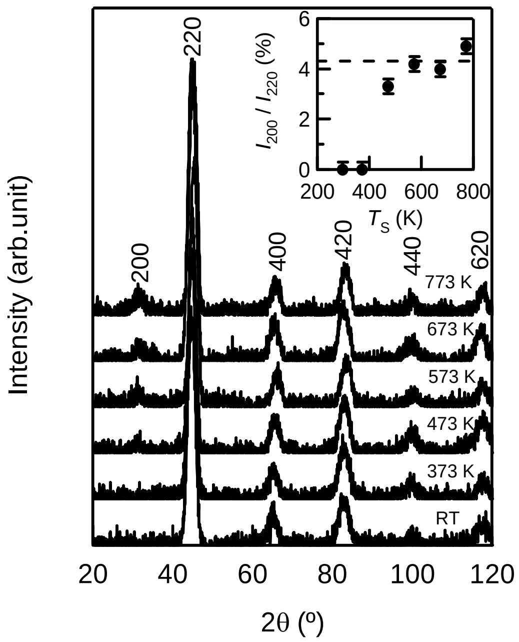

Fig. 1 X-ray diffraction patterns for Co_2FeAl (100-nm thick) films depositedon a thermally oxidized Si substrate withvarious temperatures. The inset shows substrate temperature dependence of theintensity ratios (I_{200}/I_{220}). The dotted straight line indicates the calculated values assuming the perfect *B*2 structure ordering in the films.

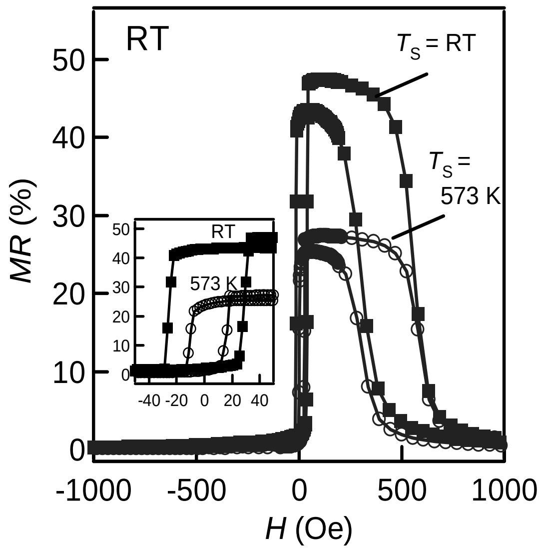

Fig. 2 Magnetoresistance curves at RT for MTJs with a Co_2FeAl film deposited at RT and 573 K. The corresponding crystal structures are the *A*2 and the *B*2 structures, respectively. The inset indicates the magnification of the magnetoresistance curves at low magnetic field region.