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Magnetic states of Co and Mn at the Co_2MnSi/MgO interfaces studied by x-ray absorption spectroscopy and soft x-ray magnetic circular dichroism

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Introduction

Co-based full Heusler alloys Co_2YZ such as Co_2MnGe (CMG) and Co_2MnSi (CMS) are promising candidates for ferromagnetic electrodes in magnetic tunnel junctions (MTJ), because theories have predicted that they are perfect half-metals [1]. A numerical study in Ref. 2 suggests that lattice distortions and the existence of impurities at the interfaces make the spin polarization small. Hence, the quality of the interface is a key to obtain higher tunnel magnetoresistance (TMR) ratio, and it is highly important to characterize the interfacial magnetic and electronic states of Heusler alloy/MgO MTJs interfaces.

In this report, we have studied the magnetic states and the electronic structures of Mn and Co atoms in CMS facing to the MgO barrier by using x-ray absorption spectroscopy (XAS) and soft x-ray magnetic circular dichroism (XMCD). In order to extract the information about the interfacial magnetic and electronic states, we have investigated the film-thickness dependence of XMCD

Experimental

The fabricated sample layer structure (from the substrate side) was as follows: MgO (001) single crystal substrate/MgO buffer layer (10 nm)/CMG (30nm)/MgO barrier (2 nm)/AlO_x (1nm) capping layer. XMCD measurements were made at BL-16A.

Result and discussion

In Fig. 1(a), in the Mn $L_{2,3}$ XAS spectra for samples with different compositions of Mn, a shoulder-like structure was observed in the higher energy region of the Mn L_3 peak. The Mn L_2 peak was split into a doublet. These features are characteristic of bulk CMG and CMS [3]. Because the probing depth of XAS and XMCD around $h\gamma$ ~600-800 eV is several nm. The XAS and XMCD for these samples reflect a bulk-like feature in addition to interfacial feature. As Mn concentration increases in CMS films, XMCD intensity decreases as shown in Fig. 1(a) and (b).

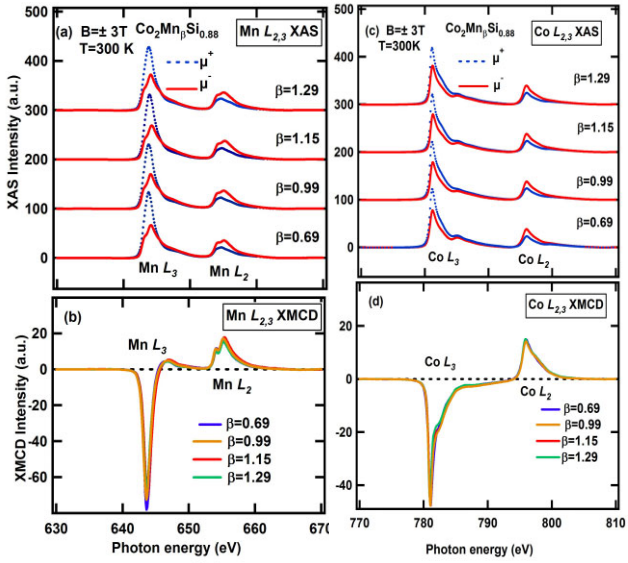

Figure 1(d) displays the Co $L_{3,2}$-edge XMCD spectra. For all the samples, a shoulder-like structure was observed in the higher energy region of the Co L_3-edge XAS as shown in Fig. 1(c). This feature is common to bulk samples [3]. The XMCD signals very slightly decreases as the Mn composition increases. We could not find CoO-like multiplet structure [4] for all the samples.

Figure 1: Mn and Co $L_{3,2}$-edge XAS [(a), (c)] and Mn and Co $L_{3,2}$-edge XMCD ($\Delta\mu = \mu_+ - \mu_-$) [(b), (d)] of $Co_2Mn_\beta Si_{0.88}$ facing MgO at 300 K and $B = \pm 3$ T. μ_+ (blue dotted line) and μ_- (red solid line) are the absorption coefficients for photon helicity + and -, respectively.

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