垂直磁気異方性を有する極薄 Co_2FeSi/MgO 積層構造の微細構造解析

Characterization of ultrathin Co_2FeSi/MgO structure with scanning transmission electron microscope

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Perpendicular magnetic tunnel junctions with half-metallic ferromagnetic (HMF) electrodes have attracted much attention as next generation non-volatile memory element since they show very high tunnel magnetoresistance ratio. To realize this device, HMF thin films are required to have perpendicular magnetic anisotropy (PMA) [1,2]. We have successfully demonstrated PMA in ultrathin Co_2FeSi (CFS)/MgO bilayers [3,4], where CFS is theoretically predicated to be HMF [5], induced by the interfacial magnetic anisotropy. To understand the origin of PMA, we have quantitively analyzed the anisotropic energy density in the stacking layer with various CFS thickness, and found that the bulk contribution drastically increased when the thickness of CFS were 0.7 nm or less. This result suggests that crystallographic properties of the CFS layers was changed at this thickness. In this presentation, we have performed cross-sectional transmission electron microscopy in the CFS/MgO to analyze the crystal structure analysis for such ultrathin CFS films.

All the stack layers were epitaxially grown with a facing targets sputtering system on MgO(001) substrates. Followed by deposition of Cr/Pd buffer layers at RT, a CFS layer was sputtered at 300ºC. Subsequently, the top of the CFS layer was exposed to pure oxygen at RT. Then, MgO and Cr were deposited. Two set of the samples with the different thicknesses of CFS layer (0.6 nm and 1.4 nm0 were prepared because the bulk magnetic anisotropy was changed at 0.7 nm. The structure of the samples was characterized by x-ray diffraction and cross-sectional scanning transmission electron microscope (STEM). The contrasts, which depens on the mean atomic number, were observed by a bright field (BF) – STEM. The composition distributions were examined under a STEM - energy dispersive X-ray spectroscopy (EDS).

Figure 1 shows the BF-STEM images. For both samples, continuous layers of CFS were observed between Pd and MgO layers. The composition distributions were analyzed as follows by STEM-EDS images. Most of Co and Fe signals were observed in the CFS layer. However, Si signals were widely distributed in the stacks. This observation implies the interdiffusion of Si during the deposition.

The atomic distance in CFS layers was investigated from the images of BF-STEM. Table 1 summarizes the atomic distance in CFS layer. The horizontal atomic distance in 0.6 nm and 1.4 nm thick CFS layers did not show significant difference. The origin of the drastic change of the bulk contribution cannot be explained by this analysis. In addition, in the 1.4 nm thick CFS layer, the horizontal and the vertical atomic distance were almost the same. These results implies the epitaxial relationship is Pd(001)[100]/CFS(001)[001] in ultrathin CFS regions, which are different from the CFS crystals far from the interface.

This work was supported by NIMS microstructural characterization platform as a program of "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology(MEXT), Japan, Grant Number A-19-NM-0111. The authors would like to thank Mr. Shirokura, Tokyo Tech.

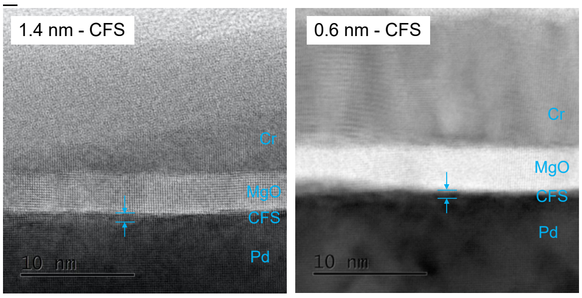

Fig.1: The images of BF-STEM

Table 1: The summary of the atomic distance

CFS thickness (nm)	Horizontal (nm)	Vertical (nm)
1.4	0.20	0.19
0.6	0.19	-

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