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Fabrication of Epitaxial Fe_3O_4 Film on Si(111) Substrate

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【Introduction】Spinel ferrites are promising materials for spintronics applications because they have useful magnetic properties and high Curie temperature. In particular, Fe_3O_4 has been expected to be the spin source in the devices such as magnetic tunnel junctions[1]. However, direct fabrication of Fe_3O_4 on Si substrates is difficult because the surface of Si is oxidized by introducing oxygen into the chamber. In this study, to prevent the oxidization of the Si surface, we inserted the γ - Al_2O_3 with spinel structure as a buffer layer and fabricated the epitaxial Fe_3O_4 films.

【Experiment】The γ -Al_2O_3 and Fe_3O_4 were grown by the molecular beam epitaxy. The sample structure was Si(111) / γ -Al_2O_3 2.4nm /Fe_3O_4 50nm /amorphous-Al_2O_3 2.0 nm. The γ -Al_2O_3 film was formed at 900℃[2], then the Fe_3O_4 film was formed by reactive deposition at 300℃ in O_2 atmosphere. The partial pressure of O_2 gas was 4.0×10^{-4} Pa. The epitaxial growth and the surface structure were observed by RHEED, AFM, XRD and TEM. The magnetic properties were measured by VSM.

【Results】The γ - Al_2O_3 film played a role of preventing the oxidization of Si surface. The RHEED pattern of γ - Al_2O_3 was clear streak pattern. Similarly, that of Fe_3O_4 was clear streak pattern and the Root Mean Square (RMS) was estimated 0.36 nm by AFM measurement. It means that both γ -Al_2O_3 and Fe_3O_4 were considered to be high-quality and flat epitaxial films. As shown in Figure 1, the Fe_3O_4 film was (111)-oriented without other orientations or phases. As shown in Figure 2, the cross-section TEM image of heterostructure taken along the Si[1−10] zone axis showed that the Fe atoms were aligned orderly and the intervals between atoms were corresponded to the spinel structure lattice parameter.

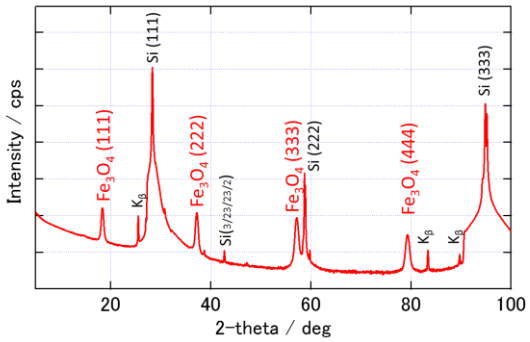

Fig.1. The X-ray diffraction of Fe_3O_4

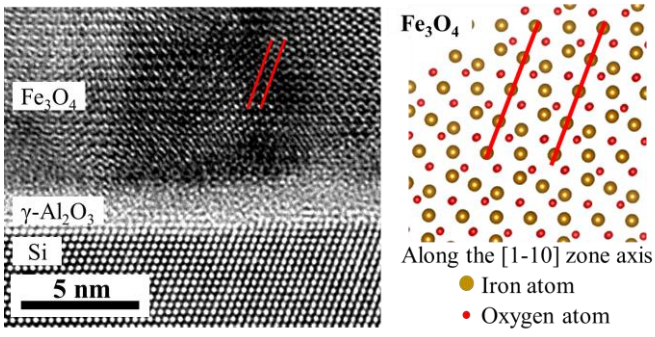

Fig. 2. The interface of Si(111)/ γ-Al_2O_3/Fe_3O_4

【Reference】

[1] T. Nagahama *et al.*, Appl. Phys. Lett. **105**, 102410 (2014).

[2] C. Merckling *et al.*, Thin Solid Films **515**, 6479–6483 (2007).