Fabrication of $Fe_{1-x}Sn_x$ epitaxial films on MgO(001) substrates

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1. Introduction

Since Magnetic tunnel junctions (MTJs) are the most important part in the spintronics, the researchers are tackling on the developments of them extensively. Although, the Fe/MgO/Fe junctions are mainstream in the spintronics due to large TMR effect, there is lattice mismatch of 4% between Fe and MgO. Such mismatch generates the interface defects that could be the source of the spin-flip scatterings, which are responsible for the decrease of the TMR at high bias voltage. To control the lattice constant, alloying Fe with other element is one of the solutions. For example, Fe_3Si is the intermetallic compound with $D0_3$ structure based on bcc, however, the lattice constant is smaller than Fe [1].

In this study, $Fe_{1-x}Sn_x$ was examined as a spintronics material. Sn is the material in group 4 as same as Si, moreover atomic radius is larger than Si. Therefore we can expect the enlargement the lattice constant by alloying with Fe. It could improve the lattice mismatch with MgO.

2. Experiments

The samples were grown on MgO (100) substrate by molecular beam epitaxy method (Base Pressure: ~10^{-8} Pa). The film structures were MgO (100) substrate/MgO(20 nm)/ $Fe_{1-x}Sn_x$(30 nm)/AlO(2 nm). $Fe_{1-x}Sn_x$ layer was deposited at a temperature of 100℃ on MgO substrate prebaked at 800℃, then the films were annealed at 300℃ for 30 min. The AlO layer was evaporated to prevent surface oxidation.

The epitaxial growth was confirmed by reflective high-energy electron diffraction (RHEED). The crystal structure was observed by X-ray diffraction (XRD) and transmission electron microscope (TEM). The magnetization curves were measured by vibrating sample magnetometer (VSM).

3. Results and discussions

The $Fe_{1-x}Sn_x$ exhibited streak patterns in RHEED for the composition of $0<x<0.4$, indicating the epitaxial growth in bcc-based structure. However, for the composition of x=0.5, we could not observe the epitaxial growth.

In figure 1, the XRD profiles of MgO substrate and $Fe_{1-x}Sn_x$ films (x=0, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5) were shown. For x=0 and x=0.1, the profile exhibited only (002) peak. We could not find (001) peak due to extinction rule. However, for x=0.2~0.4, (001) peaks were observed, which indicated that the alloys have bcc based structure with higher order structure like $D0_3$ or B2 structures.

Figure 2 shows transmission electron microscope (TEM) image of the Fe_3Sn/MgO interface and the electron diffraction pattern of Fe_3Sn layer. We can see that the Fe_3Sn grow epitaxially on the MgO substrate. That implied that we succeeded to alloying Sn with Fe with maintaining body center cubic (bcc) structure. In particular, B2 type Fe_3Sn which is metastable phase was realized by epitaxial growth, although the stable structure of Fe3Sn is $D0_{19}$, hexagonal structure [2].

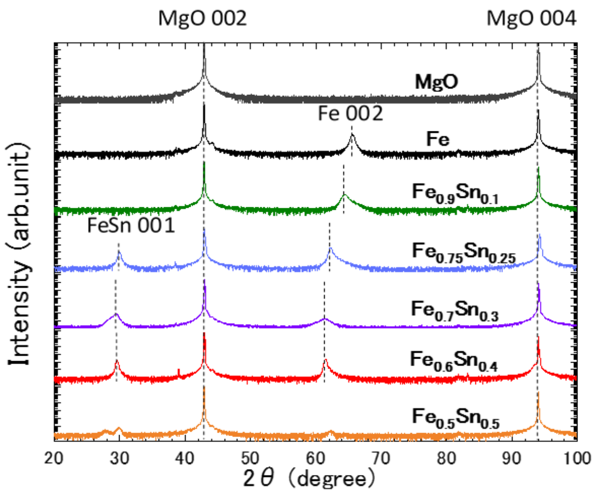

Figure 1. XRD patterns for $Fe_{1-x}Sn_x$ films with various compositions.

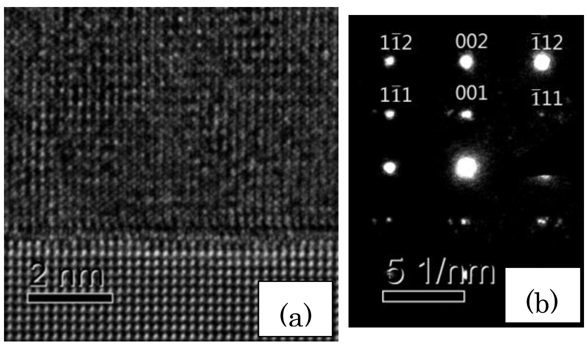

Figure 2. TEM image of the Fe_3Sn/MgO interface (a), and the electron diffraction pattern of Fe_3Sn layer (b).

References

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