Extended Abstracts of the 2017 International Conference on Solid State Devices and Materials, Sendai, 2017, pp995-996

PS-12-14

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

Yuki Goto[1], Masato Araki[1], Takashi Yanase[2], Shimada Toshihiro[2], and Taro Nagahama[2]

[1] Graduate School of Chemical Sciences and Engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan
[2] Graduate School of Engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan

Abstract

The Fe/MgO/Fe magnetic tunnel junctions are key technology in spintoronics due to large TMR effect. However, lattice mismatch of 4% between Fe and MgO is a source of the spin flip scattering at interface defects. One of the solutions is the enlargement of the lattice constant of Fe by alloying with other element. In this study, Sn was doped into Fe because it has a larger atomic radius than Fe. As a result, 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.

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 spintornics 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 degradation 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 spintornics 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: $\sim 10^{-8}$ 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.

In figure 1, the XRD profiles of $Fe_{1-x}Sn_x$ films (x=0, 0.17, 0.25, 0.3) were shown. For x=0, pure Fe, the profile exhibited only (002) peak. We could not find (001) peak due to extinction rule. However, for $x \neq 0$, (001) peaks were observed, which indicated that the alloys have bcc based structure with higher order structure like $D0_3$ or B2 struc-

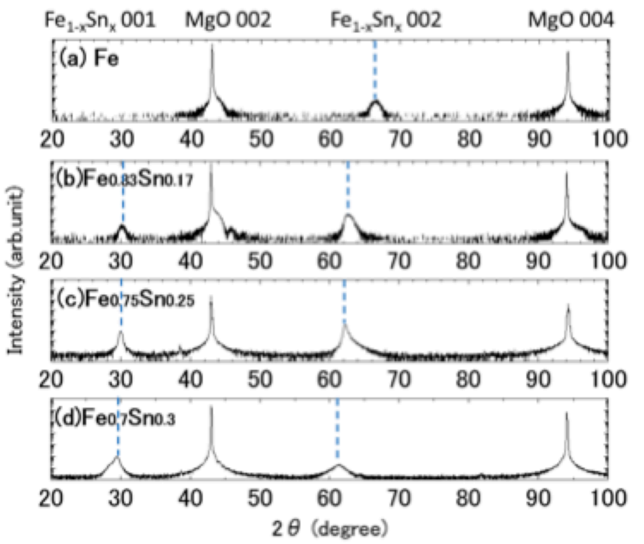

Figure 1. XRD patterns for $Fe_{1-x}Sn_x$ films with various compositions.

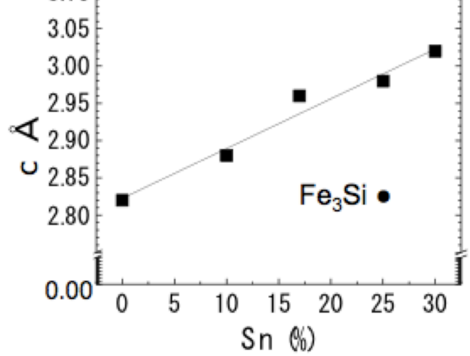

Figure 2. Lattice constant of $Fe_{1-x}Sn_x$ as a function of the Sn compositions.

tures. The lattice constants of c axis, which were enlarged by doping Sn atom, were estimated from (002) peaks for various composition in figure 2. The lattice constant increased with increasing of Sn composition linearly, following Vegard's law. Notice that the value is larger than that of Fe_3Si.

Figure 3 shows magnetic hysteresis curves for various Sn compositions. All the hysteresis curves showed in plane magnetization. The saturation magnetization decreased with Sn composition and the coercive fields were almost independent of the compositions. For x=0.25, in another word Fe_3Sn, the hysteresis loop was different from others. That implied that the Fe_3Sn was the stoichiometric metallic composition with $D0_3$ structure as same as Fe_3Si, although the stable structure of Fe3Sn is $D0_{19}$, hexagonal structure[2].

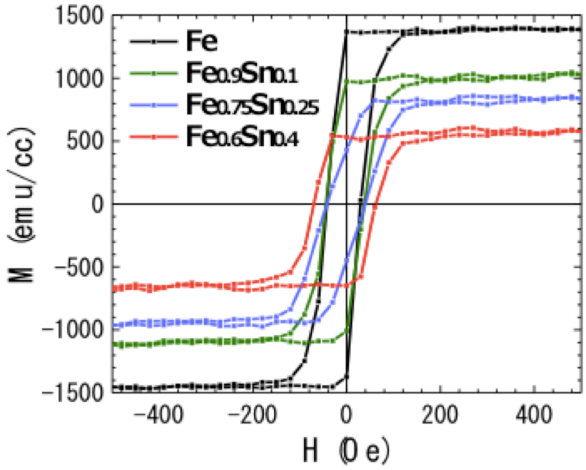

Figure 3. Magnetic hysteresis curves for various Sn compositions.

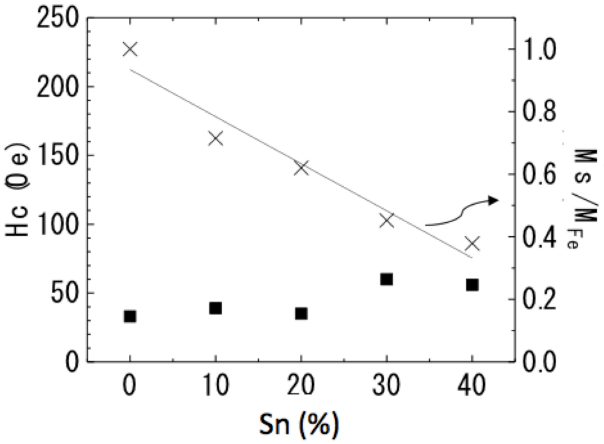

Figure 4. Coercive field and saturation magnetization as functions of the Sn composition.

3. Conclusions

$Fe_{1-x}Sn_x$ epitaxial films with B2 structure were fabricated. The lattice constant extended following Vegard's law, therefore we could control the lattice constant form 0.288 to 0.302 nm. Saturation magnetization decreased linearly with the composition of Sn. $Fe_{0.75}Sn_{0.25}$ exhibited peculiar hysteresis curve.

Acknowledgements

This work was partly supported by the OPEN FACILITY, Hokkaido University Sousei Hall.

References

[1] K. Hamaya *et al*., Phys. Rev. B **83**, 144411 (2011)., Y. Maeda *et al*., Appl. Phys. Lett. **91**, 171910 2007

[2] G. Trumpy, E. Both, C. Djega-Mariadassou, P. Lecocq, Phys. Rev. B 2, 3477 (1970).