Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp424-425

Crystallographic Properties of $L1_0$ Ordered FeNi Thin Films Fabricated by Sputtering and Rapid Thermal Annealing

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Abstract

An $L1_0$ ordered FeNi phase was successfully obtained in FeNi thin films fabricated by sputtering and rapid thermal annealing on amorphous and single crystal substrates. Crystallographic properties of films were investigated by grazing incidence X-ray diffraction measurements using the synchrotron radiation. Order parameter of FeNi with rapid thermal annealing revealed the maximum at the annealing temperature of 300 - 350 ˚C, which just corresponds to the order-disorder transformation temperature.

1. Introduction

Large uniaxial magnetic anisotropy materials are extremely promising for the application for high-density magnetic storage devices or permanent magnets. In particular, an $L1_0$ ordered FePt alloy reveals extremely large magnetic anisotropy, therefore numerous studies on the fabrication of FePt films have been reported[1-5]. However, it is an essential problem that Pt is a noble metal, thus development of a material revealing large magnetic anisotropy without any noble elements is strongly needed. In previous papers, we reported successful fabrication of $L1_0$-FeNi films by alternative monatomic layer deposition using molecular beam epitaxy[6-10]. Fabricated films showed a large K_u of 7.0×10^6 erg/cc and the relationship between K_u and order parameter (S) was clarified. However, from the viewpoint of practical use, fabrication by a simpler method such as sputtering is needed. On the other hand, a rapid thermal annealing (RTA) process is known as a useful method to fabricate $L1_0$ ordered structure because the process keeps the strain enough in the film during deposition. In fact, highly $L1_0$ ordered FePt thin films with a strong (001) texture were successfully fabricated on amorphous substrates simply by co-sputtering and RTA at a low temperature[11]. In this paper, we successfully formed $L1_0$ ordered FeNi phase by RTA for sputtered FeNi films on amorphous and single crystal substrates. Sputtering and RTA conditions were varied, and crystal structures were precisely investigated by X-ray diffraction (XRD) using the synchrotron radiation.

2. Experiment

FeNi films were deposited by co-deposition of Fe and Ni using magnetron sputtering on thermally oxidized Si substrates or MgO(001) single crystal substrates at room temperature. The base pressure of magnetron sputtering chamber was less than 5×10^{-6} Pa and Ar gas pressure was set to 0.2 Pa during the sputtering. After deposition, FeNi films were annealed in vacuum for several hours by using an RTA system with an infrared lamp. The heating rate was 50 ˚C/s, and the annealing temperature was varied from 250 to 400 ˚C. The film composition of an FeNi film was evaluated by an electron probe microanalyzer to be $Fe_{48}Ni_{52}$ at%. Crystallographic properties of films were investigated by grazing incidence XRD measurements using the synchrotron radiation at SPring-8 (BL46XU). S of $L1_0$-FeNi films was evaluated from the peak intensity of XRD pattern.

3. Results and Discussions

XRD patterns of FeNi films drastically changed depending on the condition of RTA. Superlattice peaks indicating the formation of $L1_0$-FeNi phase were clearly ob-

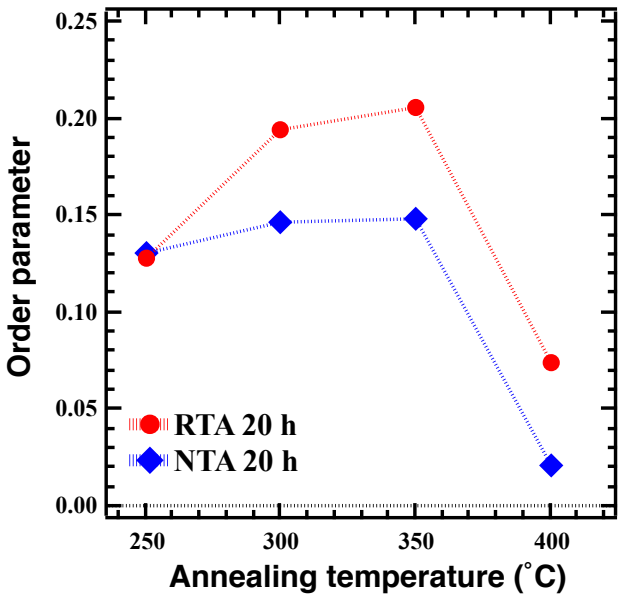

Fig. 1 The order parameter S evaluated for FeNi thin films (30 nm) fabricated on MgO(001) substrates as a function of annealing temperature. RTA and NTA indicate FeNi films with rapid and normal thermal annealing, respectively.

served for FeNi films grown on both thermally oxidized Si and MgO substrates with the RTA treatment. Figure 1 shows *S* evaluated for FeNi thin films (30 nm) fabricated on MgO(001) substrates as a function of annealing temperature. *S* of FeNi with RTA were higher than those with normal thermal annealing (NTA) for all the annealing temperatures. In addition, *S* of FeNi with RTA revealed the maximum at 300 - 350 ˚C, which just corresponds to the order-disorder transformation temperature. This result indicates that an FeNi film with much volumes of $L1_0$-FeNi phase would possibly be obtained by the optimization of the fabrication condition.

4. Conclusions

An $L1_0$ ordered FeNi phase was successfully obtained in FeNi thin films fabricated by sputtering and rapid thermal annealing on both thermally oxidized Si and MgO substrates. Crystallographic properties of FeNi films were investigated by grazing incidence X-ray diffraction measurements using the synchrotron radiation. Order parameter of FeNi with rapid thermal annealing revealed the maximum at the annealing temperature of 300 - 350 ˚C, which just corresponds to the order-disorder transformation temperature. This result indicates that an FeNi film with much more volumes of $L1_0$-FeNi phase would possibly be obtained by the optimization of the fabrication condition.

Acknowledgements

This work was partially supported by the Elements Strategy Initiative Center for Magnetic Materials under the outsourcing project of MEXT.

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