Fabrication of Fe-C soft magnetic thin films by facing-targets sputtering method

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INTRODUCTION

Soft magnetic thin films are required in small electric components such as radio-frequency thin film inductors. Fe-C thin films that have high saturation magnetic flux density of about 2 T and low coercivity below a few Oersteds are one of the candidates for soft magnetic materials for the thin film devices.[1)] In order to put Fe-C thin films in practical use, we need to investigate the relationship between sputtering conditions and thin film properties, such as crystallographic and magnetic properties. In the present paper, we describe the fabrication of the Fe-C thin films by facing-targets sputtering (FTS) method at room temperature and the investigation of the influence of the sputtering conditions such as an input power and a sputtering gas pressure on the magnetic properties and the film structure.

EXPERIMENTAL

Fe-C films were fabricated by a FTS apparatus with two targets of Fe with C chips at room temperature. Before sputtering, the chamber was evacuated to less than 6×10^{-7} mTorr. Sputtering was performed in pure Ar and films of about 300 nm in thickness were deposited on fused quartz substrates (10×10×0.5t mm) under the input power ranging from 50 W to 800 W and the sputtering gas pressure ranging from 1.0 mTorr to 5.0 mTorr. The carbon contents were about 20%. Crystal structure was investigated by X-ray diffraction and transmission electron microscopy. Magnetic properties were measured by a vibrating sample magnetometer. Surface morphology was investigated using an atomic force microscope. Permeability along a magnetic hard axis was measured by PMF-3000(Ryowa Electronics Co., Ltd.).

RESULTS AND DISCUSSION

Figure 1 shows a TEM image of a typical Fe-C film. The image reveals that nanocrystals are dispersed in a amorphous-like matrix. Mossbauer spectroscopy exhibited that Fe crystals coexist with amorphous-like Fe-based ferromagnets. Figure 2 shows a sputtering-gas pressure dependence of 110 diffraction peak angle 2θ when an input power was varied 100 W to 800 W. For each input power, 2θ increased with increasing the sputtering gas pressure. When 2θ is larger or smaller than about 44.5°, the films showed a tensile stress or a compressive stress, respectively. Figure 3 shows the change in easy axis coercivity H_{ce} by varying the input power and sputtering gas pressure. Low H_{ce} was obtained in the limited range of input power and sputtering gas pressure, and the sample deposited at 600 W and 3.0 mTorr showed the lowest H_{ce} about 2.4 Oe. These might be resulted from the crystal structure and stress state of the films. The films with the low coercivity exhibited stress-free or small compressive stress.

CONCLUSIONS

Nanocrystalline Fe-C thin films were deposited by FTS method. Soft magnetic properties were obtained for films with small internal stress. Carbon-doping decreased crystallite size, but the stress in the film must be controlled to obtain soft magnetic properties, such as low coercivity and high permeability.

REFERENCES

1) H. Kawano, T. Morikawa, K. Matsumoto, and K. Shono, *Trans. Magn. Soc. Japan*, **2**, 23, (2002).

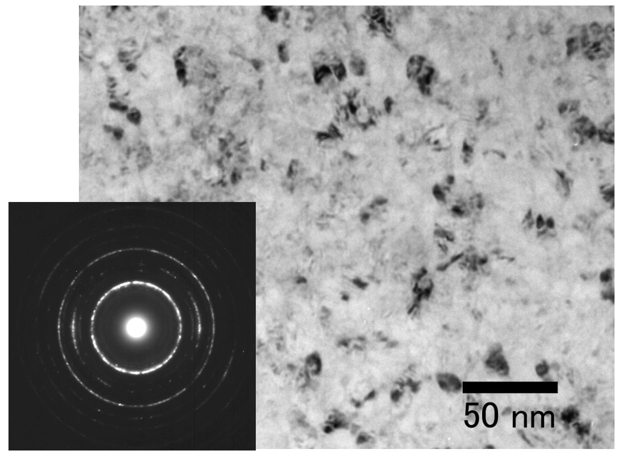

Fig. 1 TEM plane image and electron diffraction pattern of Fe-C thin film.

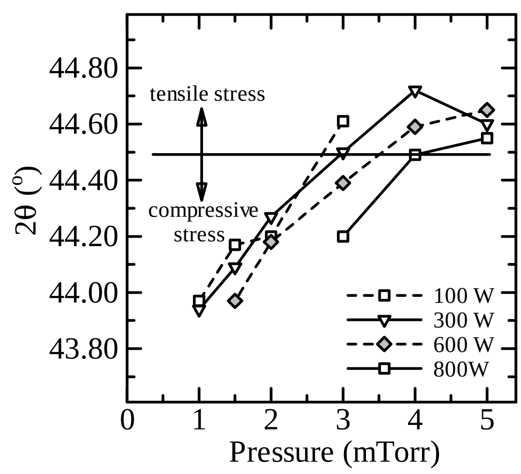

Fig. 2 Sputtering gas pressure dependence of Fe-C thin film's angle of diffraction for each input powers.

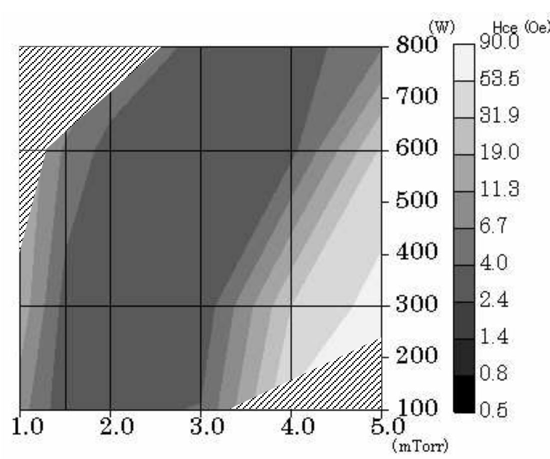

Fig. 3 Change in H_{ce} by varying input power and sputtering gas pressure. Data are not available in shaded area.