VOLTAGE CONTROL Of MAGNETIZATION DIRECTION OF MULTIFERROIC THIN FILMS FOR APPLICATION TO NOVEL MAGNETIC RECORDING DEVICES WITH ELECTRIC-FIELD WRITING METHOD

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I. INTRODUCTION

Electric field writing magnetic recording is a prospective technology for future recording devices due to its lower power consumption and easier writing. For example, in the case of hard-disk drives (HDDs), magnetic field writing will gradually become more difficult due to increase of needed magnetic field. On the other hand, in the case of HDDs with multiferroic recording media which can use the electric field writing method, the power requirement is very low for switching the magnetization direction, the structure of the writing head is simple such as a needle-shape conductive element, and a very high electric field can be applied to the multiferroic layer easily due to its thinness. Therefore, in these days, control of magnetization by electric field was widely studied. In these days, suitable multiferroic materials such as Bi-based ferrite[1-3] with ferromagnetism and ferroelectristity at room temperature were reported. In this study, I propose a novel electric field writing magnetic recording technology using a multiferroic $(Bi_{1-x}Ba_x)FeO_3$ thin film with ferromagnetism and ferroelectricity for new magnetic recording devices with low power consumption.

II. RESULTS AND DISCUSSION

The multilayer of Ta(5 nm)/Pt(100 nm)/ $(Bi_{1-x}Ba_x)FeO_3$(100 nm) were deposited onto a thermally oxidized Si wafer by UHV sputtering system. The Ba concentration, x was varied at 0, 0.1, 0.2, 0.4. The Ta seedlayer, Pt underlayer, and $(Bi_{1-x}Ba_x)FeO_3$ layer were deposited at room temperature, 300 ℃, and 400-500 ℃, respectively. The film thickness and deposition temperature of Ta seedlayer and Pt underlayer were optimized to obtain strong (111) orientation of Pt underlayer[4]. The VHF (40.68 MHz) plasma irradiation process during RF (13.56 MHz) sputter deposition[5] of $(Bi_{1-x}Ba_x)FeO_3$ films was performed with the electric power of 5 W to obtain crystal grain growth of $(Bi_{1-x}Ba_x)FeO_3$ thin films at lower substrate temperature. By increasing the Ba concentration, the saturation magnetization M_s increases with maintaining the saturation electric polarization P_s, and then, in the $(Bi_{0.6}Ba_{0.4})FeO_3$ film, the clear hysteresis in the magnetization curve and ferroelectric loops was measured, and the M_s of about 60 emu/cm^3, the P_s of about 6 μC/cm^2, the coercivity H_c of about 2.5 kOe, and the squareness ratio M_r/M_s of about 0.6 were obtained, respectively (see Fig. 1). The magnetization curve of the $(Bi_{0.6}Ba_{0.4})FeO_3$ film at the measuring temperature of 250 ℃ showed clear hysteresis and the ferromagnetic transition (Curie) temperature T_c was about 400 ℃ (see Fig. 2).

The magnetization reversal with micrometer size on the $(Bi_{0.6}Ba_{0.4})FeO_3$ film by applying local electric field was demonstrated using scanning probe microscopy. Fig. 3 (a), (b), and (c) show the topographic, electric force microscopy (EFM), and magnetic force microscopy (MFM) images of the $(Bi_{0.6}Ba_{0.4})FeO_3$ film before applying DC voltage. In the case of MFM image (c), demagnetized domain structure was observed. In the case of EFM image (b), the domain structure which is same as the case of MFM image was observed. As the local electric field writing process to the $(Bi_{0.6}Ba_{0.4})FeO_3$ film, the surrounding area (3 μm square) was scanned by the conductive tip which was applied the DC voltage of +6.5 V, and the center area (1 μm square) was scanned by the conductive tip which was applied the DC voltage of -6.5 V, respectively. Fig. 3 (d), (e), and (f) show the topographic, EFM, and MFM images of the $(Bi_{0.6}Ba_{0.4})FeO_3$ film after applying DC voltage. In the center area of these images, ferroelectric and ferromagnetic single domain structure was imaged with negative electric and positive magnetic charge contrast by surrounding positive electric and negative magnetic charge contrast. This indicates that the clear ferroelectric domains with micrometer size were formed by local electric field writing, and the magnetization direction of center

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and surrounding area is upward and downward to film surface. From these results, the present multiferroic film is thought to be useful for novel magnetic recording devices driven by electric field.

REFERENCES

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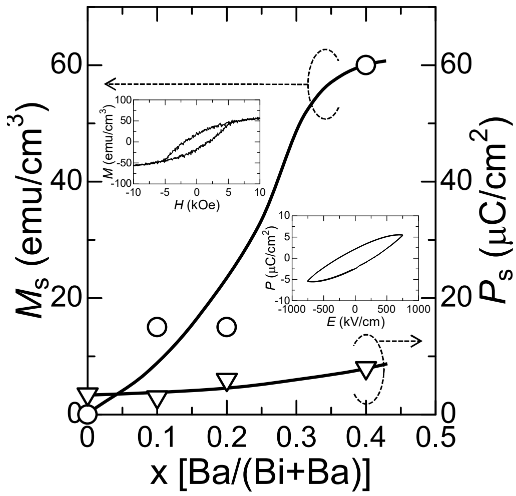

Fig. 1 Dependence of saturation magnetization and saturation electric polarization on Ba concentration for $(Bi_{1-x}Ba_x)FeO_3$ films.

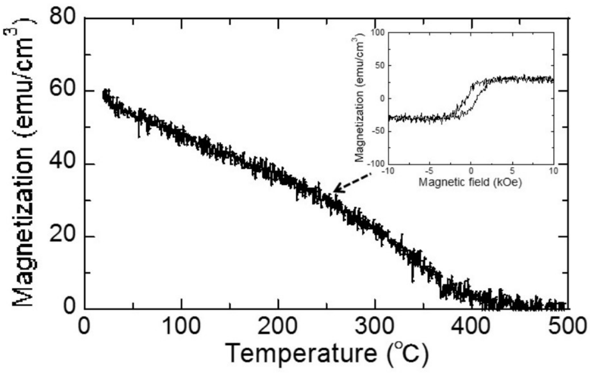

Fig. 2 Dependence of saturation magnetization on measuring temperature and the magnetization curve at the measuring temperature of 250 ℃ for $(Bi_{0.6}Ba_{0.4})FeO_3$ film.

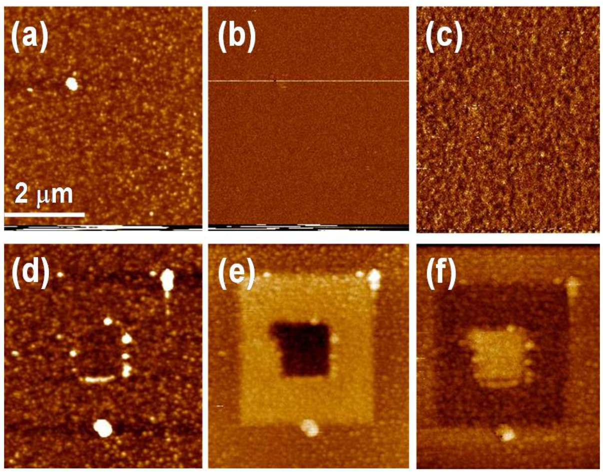

Fig. 3 (a) topographic, (b) EFM, and (c) MFM images of $(Bi_{0.6}Ba_{0.4})FeO_3$ film before applying DC voltage, and (d) topographic, (e) EFM, and (f) MFM images of $(Bi_{0.6}Ba_{0.4})FeO_3$ film after applying DC voltage.