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PLASMA DIAGNOSIS OF FANING TARGETS SPUTTERING SYSTEM FOR DEPOSITION OF BA FERRITE FILMS IN Ar, Xe AND O_2 GAS MIXTURE

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ABSTRACT

The diagnosis of the plasma in the facing targets sputtering system was performed in mixture gas of Ar 0.18-0.0 Pa, Xe 0.0-0.18 Pa and O_2 0.02 Pa by using Langmiur's probe and the effect of plasma-damage to surface smoothness and magnetic characteristics of Ba ferrite films was clarified. The electron density N_e and the electron temperature T_e were evaluated at the center of the plasma and at the neighborhood of the anode ring. T_e decreased and N_e increased with increase of P_{Xe} at the center of plasma. For the measurement at the neighborhood of the anode ring, T_e was almost constant and N_e took the minimum value at P_{Xe} of 0.1 Pa, where Ba ferrite films with excellent c-axis orientation and magnetic characteristics were obtained. It was suggested that the restriction of the bombardment of recoiled particles as well as the suppress of plasma-damage were effective for obtaining good surface smoothness and excellent magnetic characteristics and it was useful for decreasing the crystallization temperature of Ba ferrite films.

INTRODUCTION

The facing targets sputtering(FTS) apparatus can achieve the deposition free from damage by γ-electron and high adatom mobility at substrate surface[1]. However, when target was composed of atoms with large atomic weight and it was larger than that of sputtering gas such as Ar, the particles recoiled at the target surface might bombard to growing film seriously. Since it may prevent the crystallite growth and sometimes they are incorporated to the film structure, the substrate temperature T_s for obtaining good crystallization might be increased. In the previous study, we succeeded to decrease the critical T_s for obtaining c-axis orientation of BaM ferrite from 550 to 475℃ by mixing appropriate amount of Xe into sputtering gas mixture instead of Ar[2]. The discharge voltage increased with the increase of the partial Xe pressure P_{Xe}, the plasma conditions might also be changed and therefore, good crystallographic and magnetic characteristics were obtained even at low T_s of 475℃ at the optimized P_{Xe} of 0.1 Pa. In this study, the diagnosis of the plasma in the facing targets sputtering system in mixture gas of Ar, Xe and

O_2 was performed by using Langmiur's probe to clarify the effect of plasma damage to surface smoothness and crystallographic and magnetic characteristics of Ba ferrite films.

EXPERIMENTAL PROCEDURE

The specimen BaM ferrite films were deposited on ZnO underlayer by using FTS apparatus as illustrated in Fig. 1. The discharge plasma in the apparatus can be confined in the space between two facing targets by applying the magnetic field perpendicularly to the target planes, the growing film and the substrate can avoid the exposure to discharge plasma, i.e. the bombardment of hot-γ electrons and negative oxygen ions with high energy[1]. However, the recoiled neutral particles with high energy occur at target surface and may severely bombard the substrate surface. Especially, since the atomic weight of Ar(40.0) is much smaller than that of Ba (137.3), Ar recoiled by Ba might not only bombard to growing films surface but also be incorporated into the films. Therefore, Xe with the atomic weight of 131.3 was mixed in the sputtering gas. The atmoic weight of Xe is much heavier than O(16.0) and Fe(55.8), and is not so different from that of Ba as shown in Fig. 2. Therefore, the energy of the recoiled particles are fairly decreased when Xe is used as the sputtering gas as shown in Fig. 3.

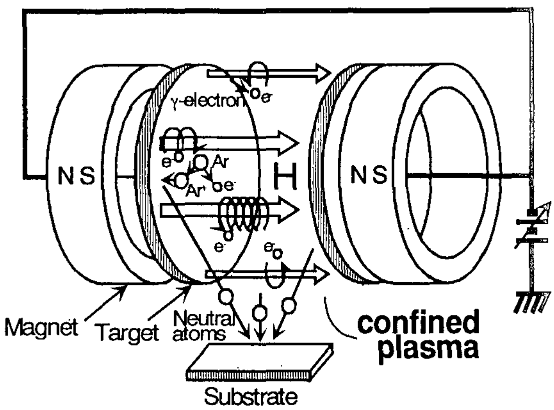

Fig. 1. Facing Targets Sputtering System.

The partial Xe and Ar pressures were changed in the range of 0.18-0.00 Pa and 0.00-0.18 Pa, respectively, and the O_2 pressure was set at constant value of 0.02 Pa as shown in Fig. 4. Table 1 lists the various de-

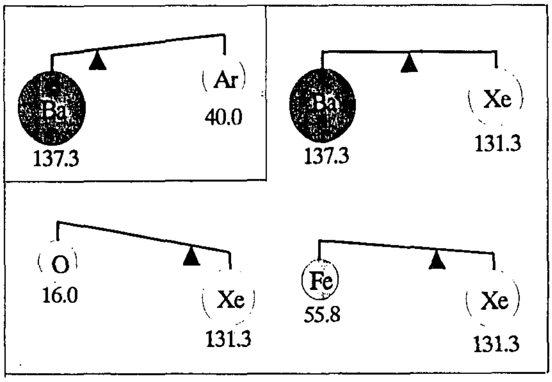

Fig. 2. Atomic weight and size of Ar, Xe, O, Ba and Fe.

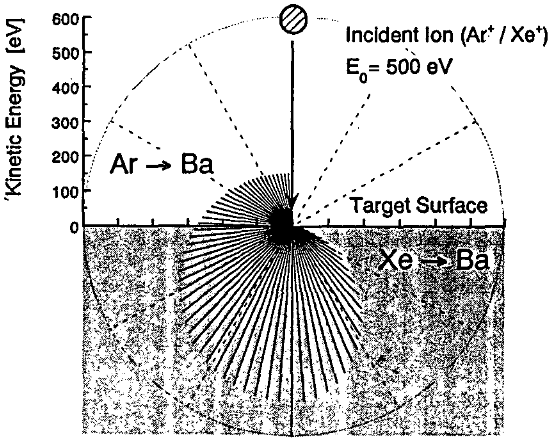

Fig. 3. Kinetic energy of recoiled Ar and Xe atoms scattered by Ba atom at target surface.

position conditions of Ba ferrite and ZnO layers. The sintered Ba ferrite plates with composition of BaO·6.5(Fe_2O_3) were used as targets and the glow discharge was sustained by using power supply at dc current of 0.1 A. The discharge voltage increased from 490 to 700 V with the increase of P_{Xe} and then the plasma became wider at higher P_{Xe}. The surface smoothness was observed and evaluted by the scanning electron microscopy(SEM) and the atomic force microscopy(AFM). The magnetic characteristics were determined by the vibrating sample magnetometer(VSM) and torque meter. The diagnosis of the plasma in mixture gas of Ar, Xe and O_2 was performed by using a single type of Langmiur's probe method. The electron density N_e and the electron temperature T_e were evaluated at the center of the plasma and at the neighborhood of the anode ring.

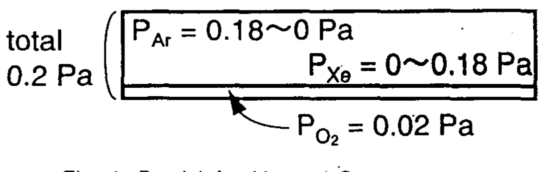

Fig. 4. Partial Ar, Xe and O_2 pressures.

Table 1 : Deposition conditions for each layers.

	ZnO	BaM ferrite
target	pure Zn(4N)	BaO·6.5Fe_2O_3
substrate	SiO_2/Si	ZnO/SiO_2/Si
substrate temp.	300℃	600℃
film thickness	400nm	500nm
input power	70W	56~80W

RESULTS AND DISCUSSION

Figure 5 shows the SEM images of the films deposited at P_{Xe} of (a) 0.0, (b) 0.02, (c) 0.10 and (d) 0.18 Pa. The center-line surface roughness evaluated by AFM was 22.0, 8.9 and 10.3 nm for (b), (c) and (d), respectively. The films revealed the best surface smoothness and possessed the best c-axis orientation in X-ray diffraction diagrams[3].

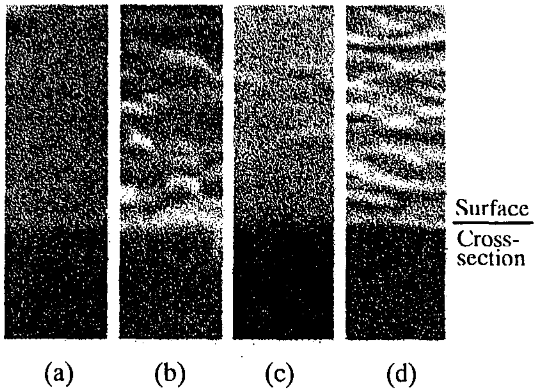

Fig. 5. SEM observations of BaM ferrite films deposited at various depositon conditions

The best magnetic characteristics was also obtained at P_{Xe} of 0.1 Pa. Figure 6 shows the ∈ dependences of the saturation magnetization $4\pi M_s$ and the perpendicular anisotropy constant K on P_{Xe}. $4\pi M_s$ took the maximum value of 5.1 kG at P_{Xe} of 0.1 Pa. This value was larger than that of bulk BaM ferrite of 4.8 kG. K also took the maximum value of 3.21×10^5 Jm^{-3} and the calculated anisotropy constant K_{u1} was 4.23×10^5 Jm^{-3}. It was larger than that of bulk BaM ferrite of 3.30×10^5 Jm^{-3}. It was noted that excellent surface smoothness and magnetic characteristics were obtained at the same P_{Xe} of 0.1 Pa.

Figure 7 shows the dependences of the electron density N_e and the electron temperature T_e on P_{Xe} of which the values were evaluated at the center of the plasma. T_e decreased and N_e increased with the increase of

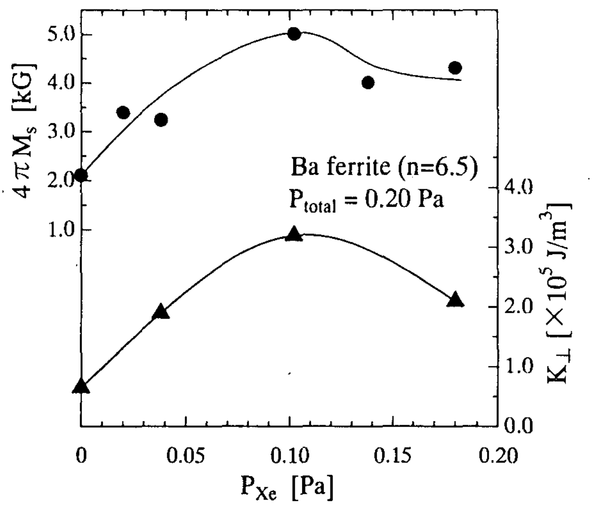

Fig. 6. P_{Xe} dependences of saturation magnetization of $4\pi M_s$, perpendicular and in-plane coercivities, H_c and H_c.

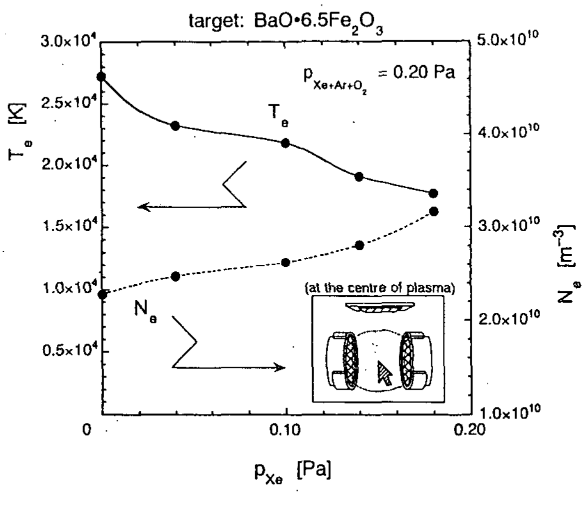

Fig. 7 P_{Xe} dependences of electron deinsity N_e and plasma temperature T_e for the measurement at the center of plasma.

P_{Xe} and the increase of N_e seemed to be caused by the large charge transfer collision cross section of Xe. Since the T_e was gradually decreased with increase of P_{Xe}, Xe was effective to decrease the plasma temperature.

Figure 8 shows the P_{Xe} dependences of N_e and T_e of which the values were evaluated at the neighborhood of the anode ring. Although T_e was almost constant over the whole range of P_{Xe}, N_e slightly decreased and took a minimum value at P_{Xe} of 0.1 Pa and increased at P_{Xe} higher than 0.1 Pa. There seemed to be many recoiled Ar and it ionized atomsphere gases in the region outside of the plasma at P_{Xe} from 0.0 to 0.04 Pa. It seemed that since the lamour radius rc equal to $m_i v_i/eB$ of Xe ion was larger than that of Ar ion, the diamter of discharge plasma was extended to the direction perpendicular to the applied field with increase of P_{Xe} higher than 0.1 Pa. The schematic illustration of plasma exposure to substrate at various P_{Xe} were shown in Figure 9. Since the substrate surface free from plasma damage and free from recoiled particles was realized, the best surface smoothness, excellent crystallographic and magnetic characteristics were obtained at P_{Xe} of 0.1 Pa.

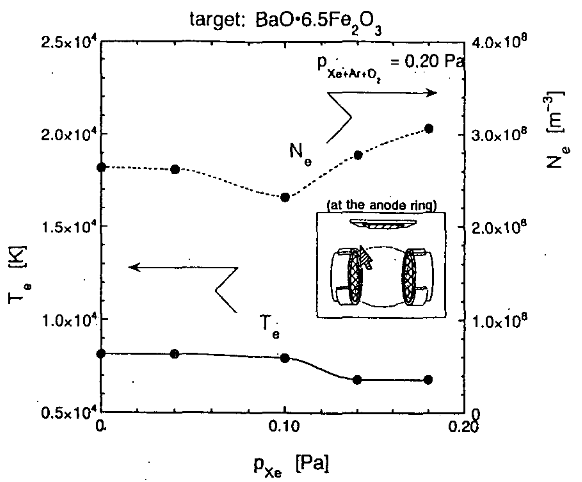

Fig. 8. P_{Xe} dependences of electron deinsity N_e and plasma temperature T_e for the measurement at the neighborhood of anode ring.

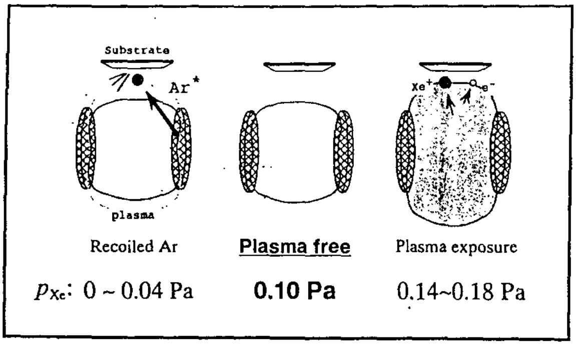

Fig. 9. Schematic illustration of situation of plasma at various P_{Xe}

CONCLUSIONS

The diagnosis of the plasma in the facing targets sputtering system was performed in mixture gas of Ar 0.18-0.0 Pa, Xe 0.0-0.18 Pa and O_2 0.02 Pa by using Langmiur's probe. The electron temperature T_e decreased and the electron density N_e increased with increase of P_{Xe} at the center of plasma. For the measurement at the neighborhood of the anode ring, T_e was almost constant and N_e took the minimum value at P_{Xe} of 0.1 Pa, where Ba ferrite films with excellent surface smoothness, c-axis orientation and magnetic characteristics were obtained. It was suggested that the perfect plasma confinement and the restriction of the bombardment of recoiled particles were effective for obtaining good surface smoothness and excellent magnetic characteristics and it was useful for decreasing the crystallization temperature of Ba ferrite films.

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