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Control of Zn- or O-polar c-axis oriented ZnO films by different ion bombardment conditions to the substrate

c 軸配向 ZnO 薄膜における基板へのイオン照射を用いた Zn 面または O 面極性制御

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1. Introduction

ZnO have been used as SAW devices and high frequency transducer because of its high electromechanical coupling. However, few investigations have been reported on the polarization control of c-axis oriented ZnO films deposited by sputtering method. On the other hand, it is known that AlN films deposited by sputtering have Al-polar surface[1)]. Our other study of AlN implies that the ion bombardment during sputtering induces unusual N-polar AlN film growth[2)]. Control of Zn- or O-polar c-axis oriented ZnO films has a potential to realize new functional piezoelectric devices[3)]. For example, polarization inverted multilayered resonator provides high power and higher frequency operation.

We then considered that Zn- or O- polarization control could also be achieved by using ion bonbardment in an RF magnetron sputtering. We determined the thickness extensional mode electromechanical coupling coefficient k_t values in the Zn- or O-polar ZnO films.

2. Method

2.1. ZnO films fabrication

Two types of ZnO films labeled LP (low RF power) and HP (high RF power) were fabricated on Al film/silica glass substrates using an RF magnetron sputtering apparatus shown in Fig.1. The previous reports show that O^- negative ions generated from ZnO target during the deposition are accelerated toward the substrate and collide with the substrate surface[4)]. On the other hand, positive ion bombardment is strong in the glow discharge column. Therefore, in order to avoid the positive and negative ion bombardment, substrates were set outside of the glow discharge column, and set perpendicular to the target surface. Total gas pressure was 1.0 Pa with Ar/O_2 = 3 and substrate temperature was 250 ºC.

To investigate the contribution of O^- ion generation from ZnO target to O-polar ZnO films growth, different RF power of 100 W (sample LP) or 200 W (sample HP) was applied.

According to a 2θ-ω scan XRD pattern, both LP and HP sample showed (0002) c-axis orientation. The FWHM value of (0002) ω-rocking curve in sample LP was 4.4 º (3.5 μm), and that in sample HP was 1.9 º (3.6 μm). Both samples had relatively good crystalline orientation.

2.2. Ion bombardment measurement

The amount of ion bombardment to the substrate surface was quantitatively measured using energy analyzer with Q-mass (PSM003, Hiden Analytical) shown in Fig.1.

Figure 2 shows the positive and negative ion energy distributions on the substrate. Energy and flux of the ion bombardment in the higher RF power condition were larger than that in the lower RF power condition.

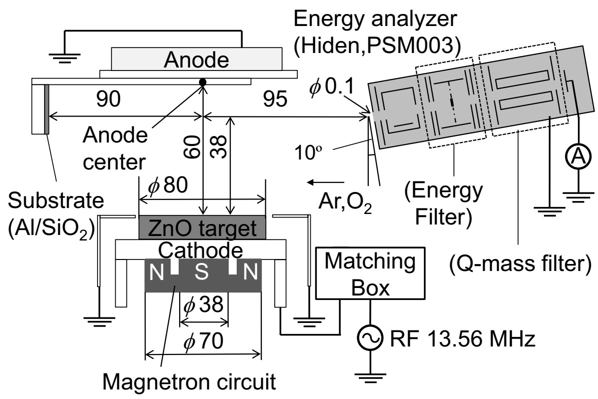

Fig.1 The ion energy and flux measurement system in an RF magnetron sputtering apparatus.

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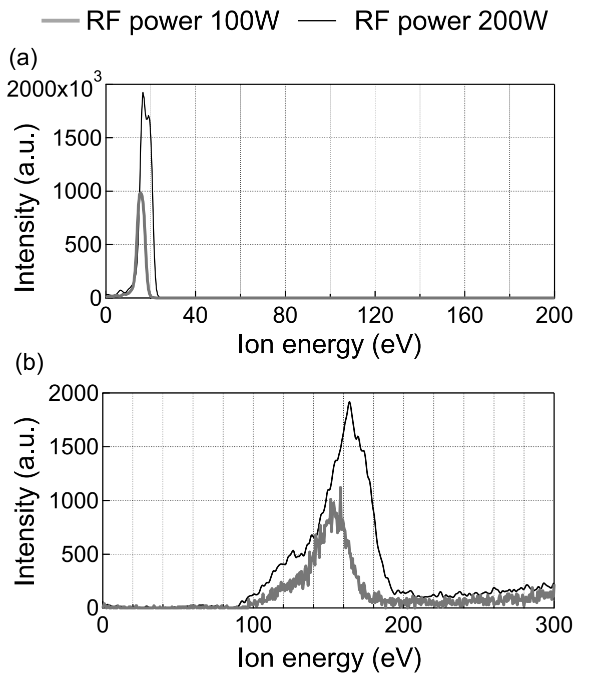

Fig.2 Energy and flux distributions of (a) O_2^+ ions and (b) O^- ions during sputtering deposition.

2.3. Polarization determination in the ZnO films

First, top gold electrode films were formed onto the film samples and the composite resonator was fabricated.

Next, the polarization of the films was determined by the sign of piezoelectric response to compression stress.

When the top electrode is pressed by an oscilloscope probe, positive or negative charges appear on the top electrode owing to the piezoelectricity of the films. The polarization of the films can be then determined by the signs of these charges. Negative charge corresponds to Zn-polar surface, and positive charge corresponds to O-polar surface.

Figure 3 shows a result of the compression test. The compressive response of sample LP was negative, and that of sample HP was positive. Cosequently, sample LP has Zn-polar, and sample HP has O-polar.

The results of ion energy and flux distributions and polarization determination imply that the ion bombardment to the substrate induces unusual O-polar ZnO film growth.

Figure 4 shows experimental and theoretical conversion losses of the resonators. Fundamental mode (0.75 GHz) and third-overtone mode (2.3 GHz) was strongly excited in both samples. k_t values were then determined 0.21 in sample LP, and 0.22 in sample HP, respectively.

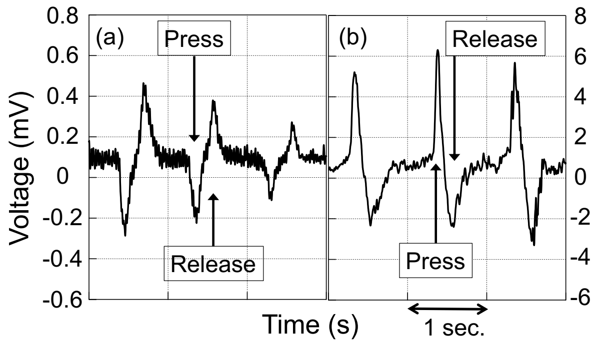

Fig.3 Piezoelectric response due to the compression stress applied to the top electrode in the ZnO films deposited by (a) RF power 100 W (sample LP) and (b) RF power 200 W (sample HP).

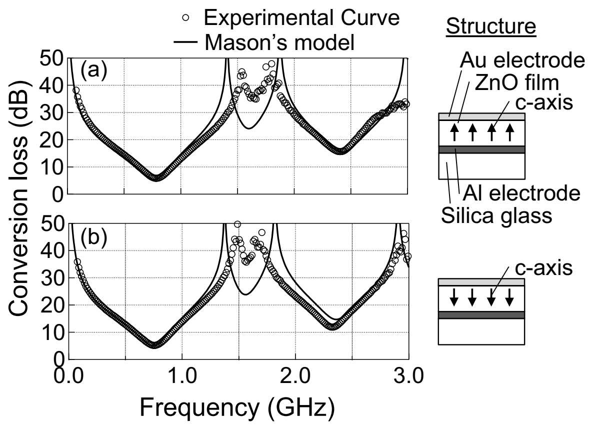

Fig.4 Frequency responses of longitudinal wave conversion loss in the ZnO films deposited by (a) RF power 100 W (sample LP) and (b) RF power 200 W (sample HP) and the structure of the composite resonators.

3. Conclusions

The ion bombardment to the subatrate during RF sputteing induces O-polar ZnO films growth. Zn-polar ZnO films was grown under weak ion bombardment conditions. Note that k_t values in the Zn- and O-polar ZnO films were found to be comparable.

References

1. J. D. Larson III, S. Mishin, and S. Bader: Proc. IEEE Ultrason. Symp. (2010) 719.
2. M. Suzuki, N. Suganuma, T. Yanagitani and H. Odagawa: Proc. of Piezoelectric Materials & Devices Symp. (2012) 53.
3. K. Nakamura: J. Acoust. Soc. Jpn. **56**, (2000) 579.
4. S. Takayanagi, T. Yanagitani, M. Matsukawa, and Y. Watanabe: Proc. of Piezoelectric Materials & Devices Symp. (2012) 13.