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Film growth of ZnO with suppressing ion bombardment to substrate during sputtering deposition and effect of piezoelectric property
スパッタ成膜中に基板へ照射されるイオンの抑制をした ZnO 薄膜の形成と圧電性への影響

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1. Introduction

(0001) oriented ZnO films can excite longitudinal wave. On the other hand, $(11\bar{2}0)$ oriented ZnO films can excite shear waves. (0001) oriented ZnO film is preferentially grown by a conventional sputtering deposition. The growth of the (0001)-oriented grains is, however, hindered by the bombardment with high-energy O^- negative ions flying from near the sputtering target, resulting in a growth of $(11\bar{2}0)$ oriented ZnO film[1)]. Therefore, the control of negative ion bombardment is important for the determination of the crystalline orientation. In previous study, we investigated the methods of increasing negative ion bombardment for the growth of $(11\bar{2}0)$ oriented ZnO films[2)]. Conversely, the suppression of the negative ion bombardment is required for the growth of (0001) oriented films. In this study, we demonstrated the ion bombardment suppression by applying voltage to grids set between a substrate and a sputtering target. ZnO films were prepared by a sputtering deposition with the suppression system. The effects of the suprresion on the piezoelectric property were investigated.

2. Fabrication of suppression system

An ion suppression system was placed on a ZnO target in an RF magnetron sputtering apparatus, as shown in **Fig. 1**. Positive ion bombardment is suppressed by applying a positive voltage V_{G1} to the electrode G1. On the other hand, negative ion bombardment is suppressed by applying a negative voltage V_{G2} to the electrode G2. If V_{G1} or V_{G2} are low, these ions pass through G1 or G2, resulting in observation of ion current I at the electrode G3. I is positive when the positive ions pass througt G1. I is negative when the negative ions pass througt G2. Ions are not bombarding to G3 when I is 0 μA.

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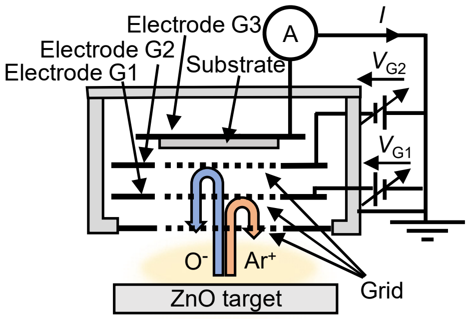

Fig. 1 Ion suppression system in a sputtering apparatus.

3. Suppression of ion bombardment

The ion currents I were measured during sputtering deposition. The deposition conditions were set to RF power of 50 W with 13.56 MHz, gas pressure of 0.1 Pa, and O_2/Ar of 3/1. In this deposition condition, large amount of negative ions bombard to the substrate. **Figure. 2 (a)** shows I and the differential of I with respect to V_{G1} as a function of V_{G1}. V_{G2} was fixed to -300 V in this measurement. I decreased with positively increasing V_{G1}. Because I approached 0 μA at V_{G1} of 100 V, the positive ion bombardment was almost suppressed by applying 100 V to G1. The differential of I with respect to V_{G1} indicates the positive-ion-energy distribution. It was found that the positive-ion energy was 20–60 eV. **Figure. 2 (b)** shows I and the differential of I with respect to V_{G2} as a function of V_{G2}. V_{G1} was fixed to 100 V in this measurement. I decreased with negatively increasing V_{G2}. Because I approached 0 μA at V_{G2} of -300 V, the negative ion bombardment was almost suppressed by applying -300 V to G2. The negative-ion-energy was estimated as 100–250 eV from the differential of I with respect to V_{G2}. While it was higher than the positive-ion energy, the amount of negative ions was smaller than the amount of positive ions from absolute values of I in Fig. 2. From these results, both positive and negative ion bombardment were suppressed by appling 100 V to G1 and -300 V to G2.

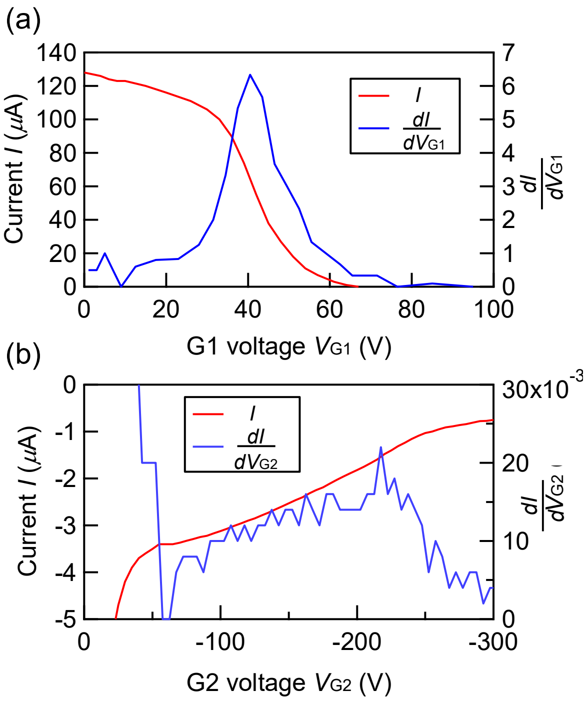

Fig. 2 Ion current I and differential of I with respect to applying voltage as a function of voltage (a) V_{G1} and (b) V_{G2}.

4. Film growth of ZnO by suppression system

Three ZnO films were prepared by the sputtering deposition with the suppression system. V_{G1} and V_{G2} were set as shown in **Table I**. Al/silica glass substrate was placed on G3.

Figure 3 shows XRD patterns of the ZnO samples. A $(11\bar{2}0)$ peak was observed in sample C, wherease a (0001) peak was observed in sample B. Therefore, Negative ion suppression leads to (0001)-oriented-grain growth. Forthermore, a strong (0001) peak was observed in sample A. The positive-ion suppression was found to be also effective. **Figure 4** shows time responses of HBARs with the sample A and C. The HBAR with sample C excited pure shear wave, whereahse the HBAR with sample A excited both longitudinal and shear wave. Because the c-axis-tilted grains were includeed in sample A, the quasi-shear mode was observed. The amplitude of longitudinal wave in sample A was larger than that in sample B. From these results, (0001) oriented ZnO films were obtained with the suppression of the ion bombaedment to the substrate.

Table I V_{G1} and V_{G2} applied in ZnO film deposition.

	V_{G1}	V_{G2}	Suppression
Sample A	100 V	-300 V	Positive and Negative ions
Sample B	0 V	-300 V	Negative ions
Sample C	0 V	0 V	———

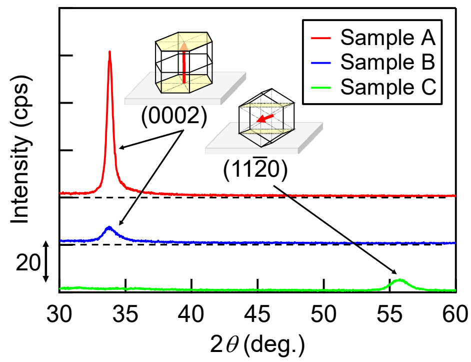

Fig. 3 2θ-ω scan XRD of the all samples.

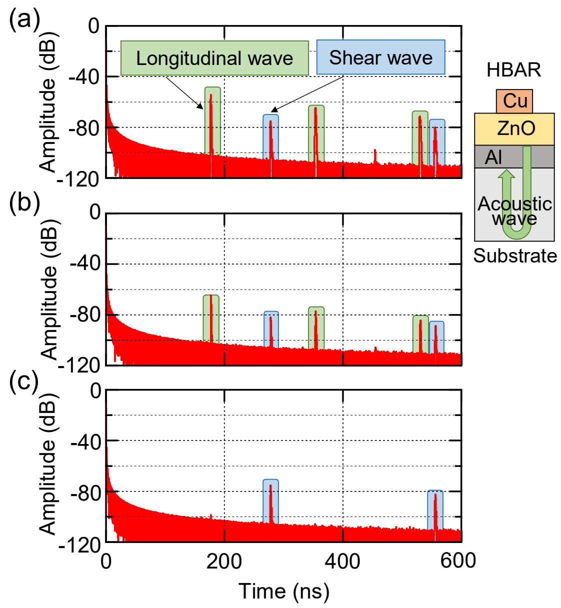

Fig. 4 Time responses of HBARs with (a) sample A and (b) sample C.

5. Conclusion

Ion bombardment to a substrate during sputtering deposition was suppressed by applying voltage to grids set between the substrate and the sputtering target. The negative ion bombardment was suppressed by applying -300 V to the grid. On the other hand, positive ion bombardment was suppressed by applying 100 V to the grid. (0001) orientated ZnO film was obtained by the suppression of ion bombardment, and londitudinal wave excitation was observed by a HBAR with the ZnO film. Not only negative ion suppression, but also positive ion suppression is important for the film growth of (0001) oriented ZnO. It is expected to investigation of the ion-suppression effect on ScAlN films.

References

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