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Crystallographic characteristics of (11$\bar{2}$0) textured ZnO piezoelectric films fabricated by magnetron sputtering with linear erosion

直線状エロージョンマグネトロンスパッタを用いた(11$\bar{2}$0)配向 ZnO 圧電膜の結晶性

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1. Introduction

In previous studies, we have proposed shear mode devices such as shear mode film bulk acoustic resonators (FBARs) and shear horizontal surface acoustic wave (SH-SAW) devices consisting of (11$\bar{2}$0) textured ZnO piezoelectric films [1,2]. These films can be fabricated using planar RF magnetron sputtering or ion-beam evaporation.

However, there have been two problems related to the practical application, (i) highly oriented films can be obtained only in a small area, although RF magnetron sputtering is a suitable technique in a large area film deposition [3]. (ii) In addition, as shown in **Fig. 1**, crystallites c-axis in the films was oriented radially in the substrate plane [3]. Previous ion-beam evaporation studies have shown that crystallites c-axis in the ZnO films oriented toward the incident ion beam direction [4]. From these results, we consider that in the magnetron sputtering, energetic particles sputtered from the circular erosion on the cathode induces the radial orientation in the anode plane (substrate plane).

In this study, we make an attempt to realize the in-plane unidirectional orientation in large area by using sputtering cathode with linear erosion.

2. Sample fabrication

ZnO films were fabricated on the silicon substrate (4 inch diameter) using RF magnetron sputtering apparatus with linear erosion as shown in **Fig. 2**. To form the single linear erosion, a shield plate was set above the rectangular erosion area. The ZnO films were deposited at total pressure of 0.08 Pa, oxygen concentrations of 50 %, RF power of 5 kW, substrate-target distance of 60 mm and deposition time of 40 minute. The silicon substrate was set above the erosion area. The substrate was not heated during the deposition. The film thickness at the substrate center and the position 40 mm from the substrate center (X=40 mm) were 3.4 μm and 2.4 μm, respectively.

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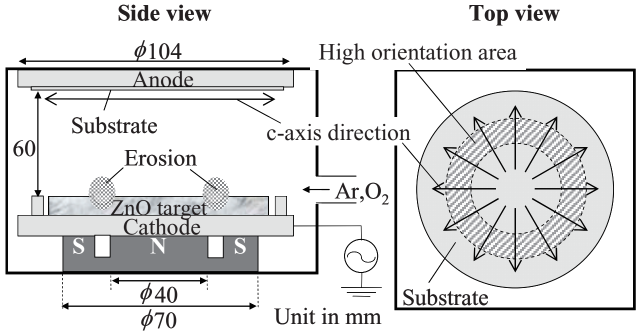

Fig. 1 Convensional RF magnetron sputtering apparatus with a circular cathode used in previous studies and c-axis direction in the anode.

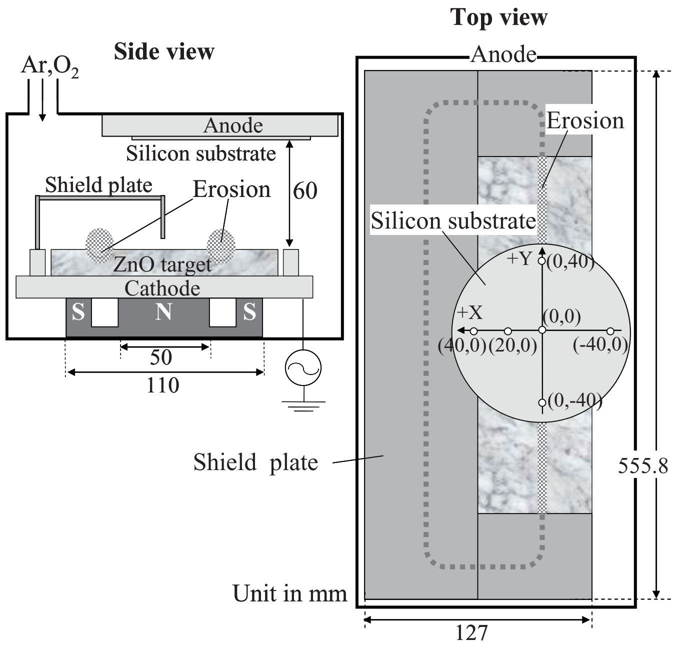

Fig. 2 New RF magnetron sputtering apparatus with a rectangular cathode and substrate configuration.

3. Crystallographic properties

Fig. 3 (a) and (b) show the XRD patterns at the positions of X=0, ±40 mm (Y=0) and Y=0, ±40 mm (X=0). As shown in **Fig. 3**, intense $(11\bar{2}0)$ peaks appeared at all positions, showing that the $(11\bar{2}0)$ textured was formed in a large area.

Fig. 4 shows the $(11\bar{2}0)$ XRD pole figure at the position of (20, 0). Two highly concentrated $(1\bar{2}10)$ and $(\bar{2}110)$ poles appear around $\phi = 0°$, $\psi = 60°$ and $\phi = 180°$, $\psi = 60°$, respectively. This indicates that crystallites c-axis are oriented parallel to the substrate plane and normal to the direction of linear erosion. To evaluate the degree of crystal orientation in the in-plane and out-of-plane direction, FWHM values of the ϕ-scan and ψ-scan profile curves were measured from $(1\bar{2}10)$ or $(\bar{2}110)$ poles. The c-axis direction, ϕ-FWHM and ψ-FWHM at each position are summarized in **Fig. 5**. In the figure, direction, width and length of arrows indicate c-axis direction, ϕ-FWHM and ψ-FWHM, respectively.

The c-axes are oriented normal to the direction of linear erosion in substrate plane at each position. However, the ϕ-FWHM value seem to be large around the erosion area, which indicates radial spread of c-axes in the substrate plane. This results may be show that incident angle of energetic particles affects the in-plane c-axis alignment in the film. Namely, the lack of unidirectional alignment of c-axis in the plane is caused by the normal incident energetic particles to the substrate plane.

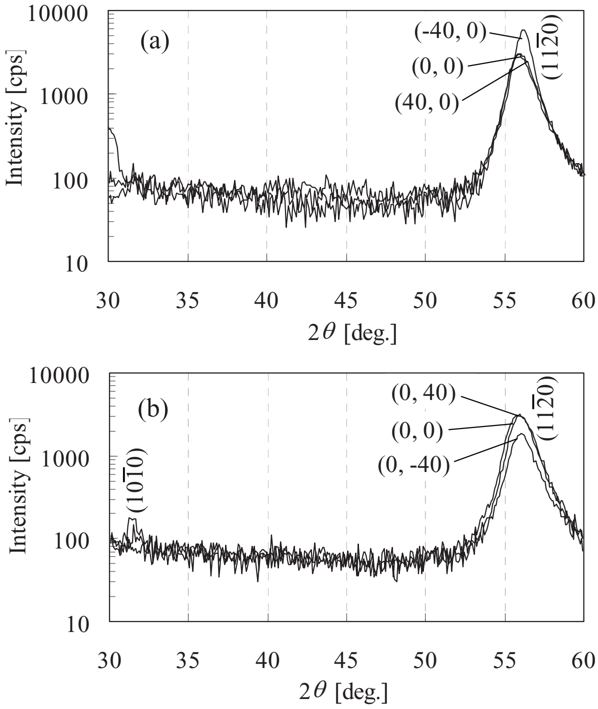

Fig. 3 XRD patterns of the sample (a) at X=0, ±40 mm (Y=0 mm) and (b) at Y=0, ±40 mm (X=0 mm).

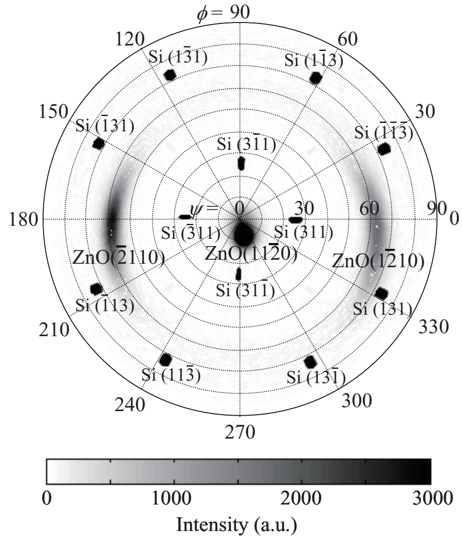

Fig. 4 $(11\bar{2}0)$ ploe figure of the sample at (20, 0).

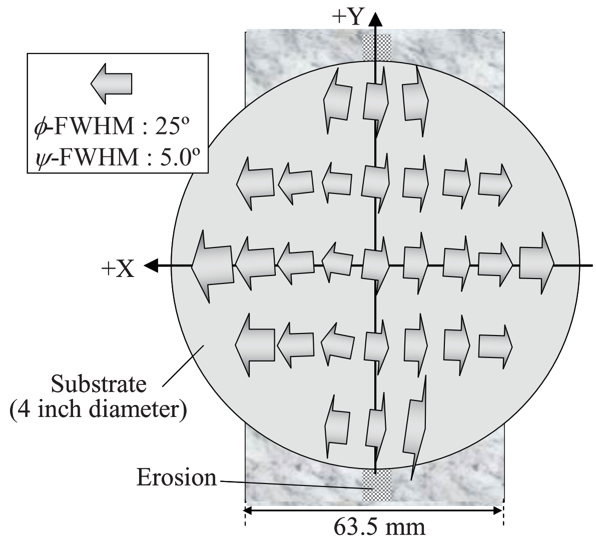

Fig. 5 Distributions of c-axis direction, ϕ-FWHM and ψ-FWHM in the sample.

4. Conclusions

To fabricate the $(11\bar{2}0)$ textured films in a large area, sputtering deposition with linear erosion was proposed. Large area deposition was proven by the results of detailed pole figure analysis.

References

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