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Deposition of c-axis parallel oriented ZnO film on rotated silica glass pipe for SH-SAW pipe sensor

円管構造 SH-SAW センサに向けた c 軸平行配向 ZnO 薄膜の石英ガラス管回転成膜

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1. Introduction

Shear horizontal surface acoustic wave (SH-SAW) sensors have been researched for measurement of liquid conductivity and viscosity[1]. c-Axis parallel $(11\bar{2}0)$ oriented ZnO film can excite the SH-SAW[2]. In our previous study, c-Axis parallel oriented ZnO film was obtained on a glass plate by an RF magnetron sputtering[2]. We also demonstrated the SH-SAW excitation[3].

The viscosity and conductivity of the liquid on the propagation path changes the velocity and amplitude of the SH-SAW. To detect the small changes of them, the long-distance propagation is required. Multiple wave roundtrips of SAW on a pipe surface leads to the long-distance propagation[4]. Therefore, They improve the measurement sensitivity. ZnO films can be grown on curved surface by a sputtering deposition. Thus, c-axis parallel oriented ZnO film on the pipe is suitable for a high-sensitive liquid sensor.

The film growth of $(11\bar{2}0)$ oriented ZnO on the entire pipe surface is necessary in order to propagate SH-SAW with the roundtrips. In previous study, we demonstrated the ZnO film growth on the glass pipe with 6.0 mm diameter with an automatic rotation system[5]. However, the highly oriented film was not obtained on the entire pipe surface. In this study, the deposition conditions of the c-axis parallel $(11\bar{2}0)$ oriented ZnO such as a rotation speed of the pipe were investigated.

2. Deposition at different rotation speeds

ZnO film was grown on the entire pipe surface of the substrate by a sputtering system as shown in **Fig. 1(a)**. The outside diameter and inside diameter were, 6.0 and 4.1 mm, respectively. The length of silica glass pipe was 50 mm. **Fig. 1(b)** shows a detail of the pipe substrate installation. Irradiation of highly energetic negative ions from the ZnO sputtering target induced the growth of the c-axis parallel orientation[6]. The highly oriented film was obtained above the target erosion area. A 6.0 mm slit was set under the pipe substate in order to prevent the ZnO film being grown at the side surface. Deposition conditions were set to the RF power of 100 W, gas pressure of 0.1 Pa, Ar/O_2 ratio of 1/3. Deposition time was set to 24 h. The film thickness of 3.0 μm was expected in this deposition time.

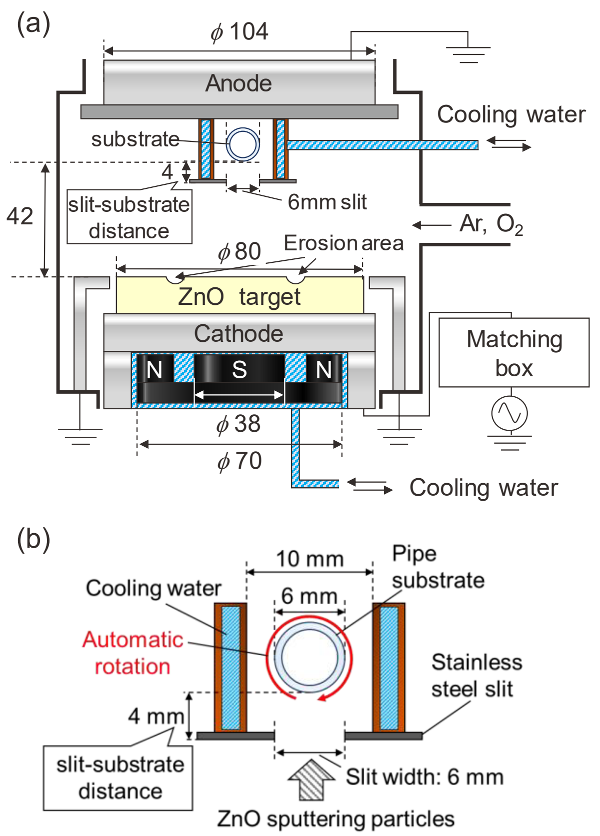

Fig. 1 (a) RF magnetron sputtering apparatus and (b) installation of a pipe substrate.

The crystalline orientations of the ZnO films were evaluated by X-ray diffraction (XRD) analyses. **Fig. 2** shows integrated intensity of 2θ-ω XRD peaks in the Sample I. When the pipe substrate was rotated at 1.6 rpm, the c-axis normal orientation (0002) was oriented preferentially. This is because the rotation speed of the substrate is high, so it is considered that insufficient negative ion hit

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the pipe substrate. In Sample II, the ZnO films were deposited with the rotational speed of 0.25 rpm. **Fig. 3** shows integrated intensity of 2θ-ω XRD peaks in the Sample II. When the pipe substrate was rotated at 0.25 rpm, the c-axis parallel orientation was oriented preferentially. From this result, it is necessary to rotate the substrate as slowly as possible to deposit the c-axis parallel orientation.

3. Deposition by improving the slit-substrate distance

In previous study, there was a slit-substrate distance of 4 mm, which could have been an obstacle to negative ion bombardment with the pipe substrate. Therefore, ZnO films were deposited on a part of the pipe substrate in the case where the slit-substrate distance was lost in Sample III. In Sample IV, the ZnO films were deposited with the slit-substrate distance of 4 mm. **Fig. 4** shows 2θ-ω XRD patterns of the Sample III and IV. Because the slit-substrate distance was lost, a preferentially $(11\bar{2}0)$ peak was observed in the Sample III. Substrate settings which increase the ion bombardment are required.

4. Conclusion

Deposition methods of the c-axis parallel oriented ZnO film on the silica glass pipe surface were investigated. Highly crystallized and oriented film was grown by rotating the pipe substrate as slowly as possible. Bombardment of highly energetic negative ions from the ZnO sputtering target is necessary to obtain the $(11\bar{2}0)$ orientation. Because the slit-substrate distance was lost, a preferentially $(11\bar{2}0)$ peak was observed. Further investigations of substrate settings for the pipe substrate were required. In addition, the SAW propagation properties of the pipe structure sensor with the c-axis parallel oriented ZnO film were expected.

References

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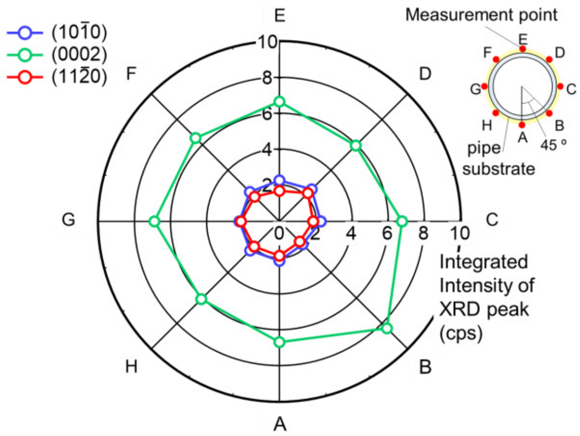

Fig. 2 Integrated intensity of $2\theta-\omega$ XRD peaks of the sample I deposited with the rotational speed of 1.6 rpm.

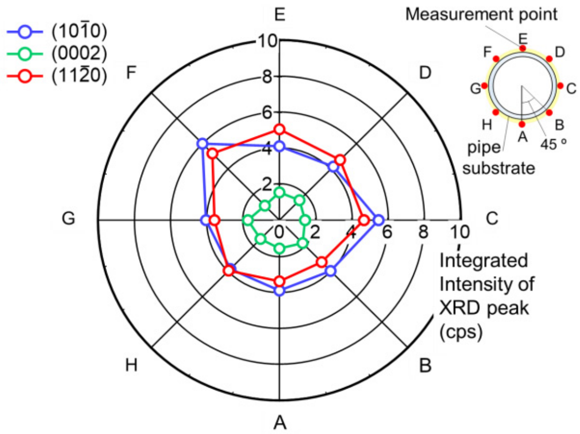

Fig. 3 Integrated intensity of $2\theta-\omega$ XRD peaks of the sample II deposited with the rotational speed of 0.25 rpm.

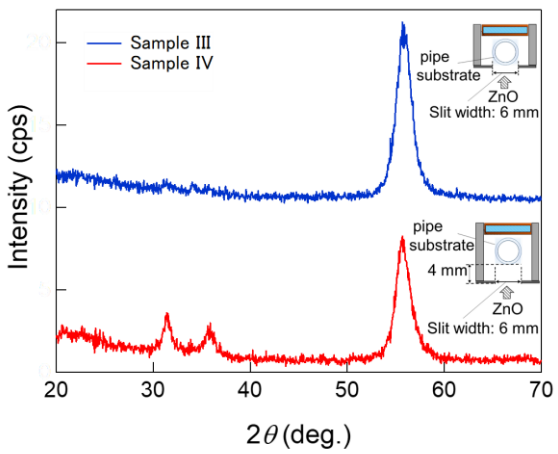

Fig. 4 $2\theta-\omega$ XRD pattern of the ZnO samples on the 6-mm-diameter pipes with the slit-substrate distance of 0mm and 4mm.