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Multilayer shear mode resonator consisting of c-axis tilted ZnO films

c 軸傾斜反転配向 ZnO 多層膜の作製と横波共振子への応用

Naoki Morisato‡(Doshisha Univ.), Takahiko Yanagitani (Nagoya Insti. Tech.), Mami Matsukawa and Yoshiaki Watanabe (Doshisha Univ.)
守里直希‡，高柳真司（同志社大），柳谷隆彦（名工大），松川真美，渡辺好章（同志社大）

1. Introduction

A shear mode resonator is suitable for the sensors measuring mass loading in the liquid [1,2]. In previous study, we have reported c-axis 23º tilted ZnO films for shear mode excitation [3]. A shear mode single crystal have large electromechanical coupling coefficient k_{15}=0.38 around the c-axis tilt of 28° [3]. It is possible that a polycrystalline ZnO film with good crystalline orientation have k_{15}=0.38. But, they also excites undesired extensional mode. To permit accurate sensing, the extensional mode excitation should be suppressed.

In this study, we propose a new multilayered resonator consisting of c-axis tilted ZnO films as shown in **Fig 1**. Degree of the 3-dimensinal orientation and a cross-sectional image were measured by XRD pole figure analysis and SEM (Scanning Electron Microscope), respectively. Finally, electromechanical conversion loss characteristics were measured.

2. Resonator structure

Multilayer resonator consisiting of c-axis tilted ZnO films was fabricated, as shown in Fig 1. They were deposited by RF magnetron sputtering method. Every layer has same thickness, and the c-axis tilt direction in odd and even layers are symmetric with respect to the film surface normal. In this resonator structure, we can increase its thickness without change of thickness shear mode resonant frequency. This provides the expansion of sensing area (in 50 Ω matching) and high power operation. Moreover, longitudinal mode excitation is expected to be suppressed because thickness extensional mode resonant frequency should shifts to lower frequency region.

E-mail : yana@nitech.ac.jp

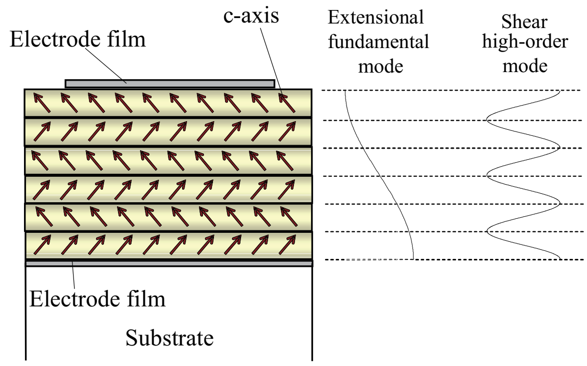

Fig. 1 Multilayered resonator consisting of c-axis tilted ZnO films.

3. Characteristics of the resonators

3.1 Resonator fabrication

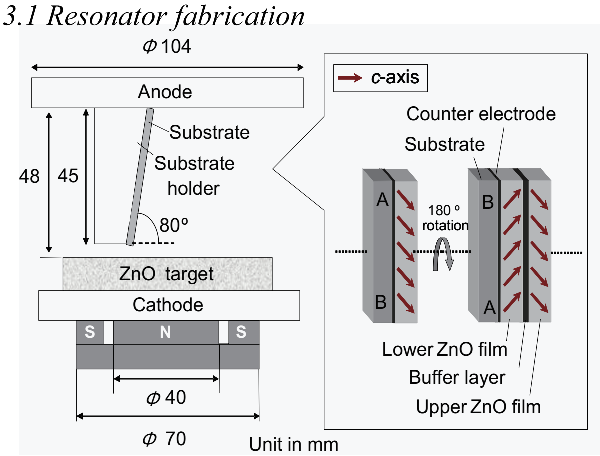

Fig. 2 RF magnetron sputtering apparatus and inclined substrate position on the anode.

1 mm thickness silica glass with evaporated aluminum electrode layer was used as a substrate. As shown in **Fig. 2**, ZnO films were fabricated using an RF magnetron sputtering system (Ulvac RFS-200) with a neodymium magnet. The ZnO films were deposited at total gas pressure of 1.0 Pa, gas composition ratio of Ar/O_2=3, substrate temperature of 400 ºC and deposition time of 1 hour. The substrate was set 80° to the ZnO target at the anode center [3]. At first, first ZnO layer was deposited, and then, second ZnO layer was deposited after turning the substrate position 180º from first deposition. The six layered ZnO structure

was fabricated by repeating these processes. Here, crystalline orientation of second ZnO layer probably deteriorates due to the local epitaxial effect of crystal grains at first ZnO layer surface. To decrease the effect, amorphous SiO_2 buffer layer was deposited between each ZnO layer.

3.2 Crystallographic properties

The crystalline orientation of the samples were determined by XRD pole figure analysis. **Figure 3** shows (0002) pole figure measured at position 6 mm from the substrate edge (target side). Two concentrated poles observed at ϕ=88º and ϕ=282º indicate that c-axis tilt direction in the fifth and sixth layers are symmetric with respect to the film surface normal. The ψ angle of poles diffracted from the sixth layer (22º) and the fifth layer (21º) corresponds to the c-axis tilt angle of the each layer. Degree of pole concentration indicates the degree of crystalline orientation.

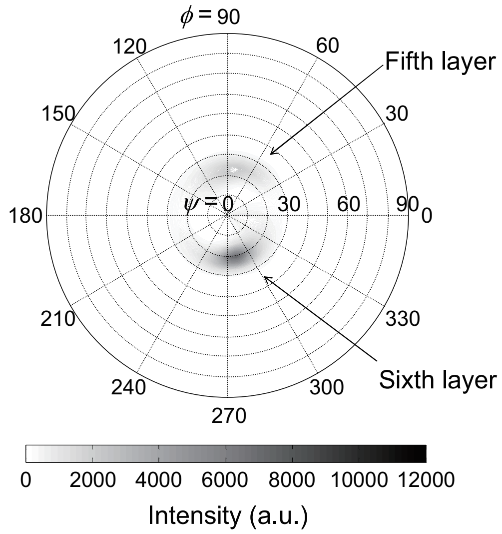

Fig. 3 (0002) pole figure of sixth ZnO layer.

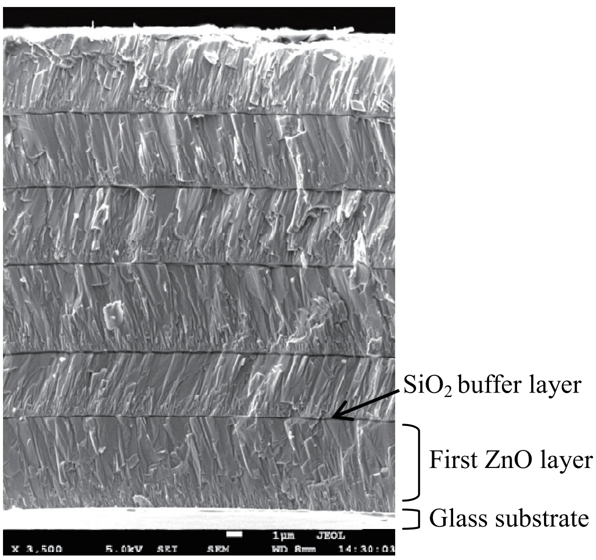

Fig. 4 FE-SEM image of cross section of six layered ZnO films.

Figure 4 shows FE-SEM image of the cross section of the six layered ZnO films. c-axis tilted ZnO films are reproducibly formed. As the film grows, the crystal grains become dense (geometrical selection).

3.3 Resonator conversion losses

A copper film was evaporated as a top electrode at position 6 mm from the substrate edge. The extensional and shear mode conversion loss curves in six layered resonator are shown in **Fig 5**. Extensional mode conversion loss exhibits a minimum at a fundamental mode (L_1). The minimum value found to be 17.7 dB at 101 MHz. Shear mode conversion loss exhibits a minimum at a sixth order mode (S_6). The minimum value found to be 4.5 dB at 288 MHz. A extensional mode resonant frequency is shifted to lower frequency. Therefore, extensional mode is suppressed around shear mode resonant frequency (288 MHz).

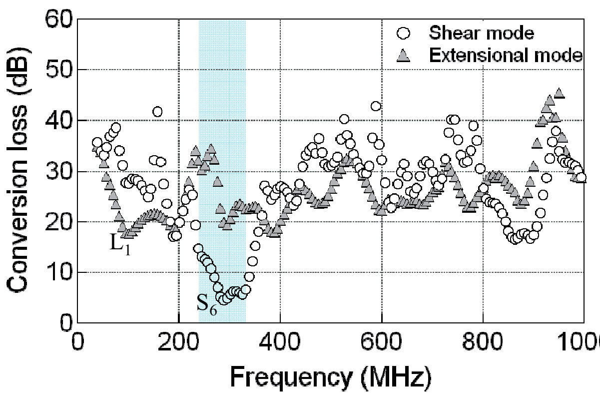

Fig. 5 Extensional and shear mode conversion losses of resonator.

4. Conclusions

The six layered resonators consisting of highly oriented c-axis tilted ZnO films was fabricated. In the sixth order mode shear mode resonant frequency, high efficient shear mode excitation with relatively suppressed extensional mode excitation was observed.

References

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