Ion beam induced a-axis in-plane oriented c-axis oriented AlN thin film growth for high-Q BAW resonator application

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Abstract— **The frequency bands are becoming heavily used because the wireless standard is increased. Therefore, the demands for high *Q* filters are increasing. In previous study, it was found that the direction of crystal growth of ZnO can be controlled by ion beam irradiation during deposition [1, 2]. We aimed to improve the mechanical Q_m factor by aligning the direction of crystal growth of AlN for in-plane direction [3].**

Keywords—ion beam, ion beam irradiation, AlN, ScAlN, piezoelectric film,

I. Introduction

Wurzite materials such as ZnO and AlN are tends to grow along the (0001) direction because the surface density energy of the (0001) plane is the lowest according to the Bravais' law. On the other hand, a-axis in-plane direction of standard AlN is random as shown in Fig. 1. We considered that a-axis in-plane alignment leads the further improvement of Q_m value (mechanical quarity factor) of the films.

In previous study, it was found that the direction of crystal growth of ZnO can be controlled by ion beam irradiation during deposition [1, 2]. We aimed to improve the mechanical Q_m factor by aligning the direction of crystal growth of AlN and ScAlN for in-plane direction by ion beam irradiation as shown in Fig. 2.

In this study, we fabricated several AlN thin films. AlN films were grown with ion beam irradiation (0.3 kV, 0.5 kV, 0.7 kV). AlN thin films grown without ion beam irradiation were prepared. We compared the in-plane a-axis orientation of the thin film grown with ion beam irradiation and the thin film grown without ion beam irradiation.

II. Experiment

AlN thin films were grown on Ti bottom electrodes/ silica glass substrates by RF magnetron sputtering system. AlN film were grown without ion beam irradiation and the others were grown with nitrogen ion beam irradiation during deposition. N_2 ion beam from ECR ion source (ARIOS, EMIS-111Q) was accelerated to the substrate. Ion beam incident angle is 20º with respect to the substrate surface. The in-plane and out-of-plane orientations of the AlN thin films were measured by the X-ray diffraction (XRD).

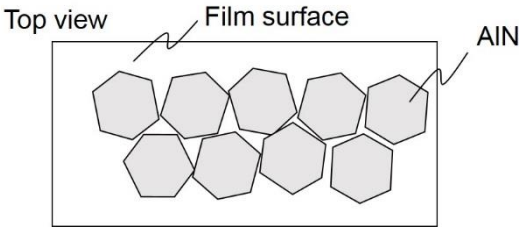

Fig. 1 AlN thin film whose a-axis in-plane direction is random

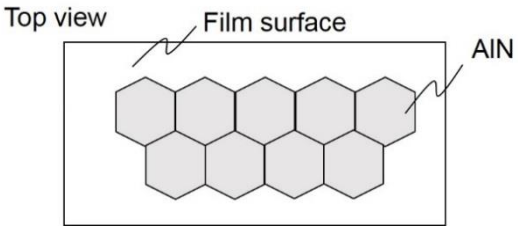

Fig. 2 AlN thin film whose a-axis in-plane direction is aligned

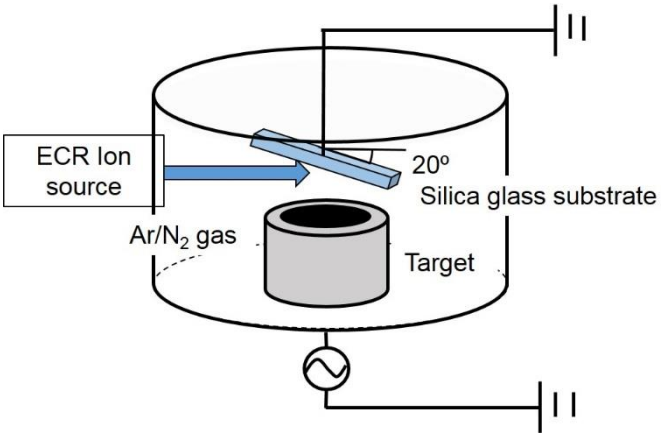

Fig. 3 Ion beam assisted RF magnetron sputtering system

III. Evaluation of the in-plane orientation of the films

The crystalline orientations of the films were examined by X–ray diffraction (XRD). Table I shows the properties of the AlN thin films.

Table I Properties of the thin films

Film material	AlN	AlN	AlN	AlN
Ion beam accelerating voltage (kV)	–	0.3	0.5	0.7
ω-scan Rocking curve FWHM	1.3º	6.5º	2.2º	1.5º
Thickness of film (μm)	4.4	5.2	4.3	4.6
Deposition time (hours)	4	4	4	3.5

Fig. 4, 5, and 6 show the (1011) pole figures of the AlN thin films respectively. The sixth symmetry was not observed clearly in the pole figure of the AlN thin film grown without ion beam irradiation as shown in Fig.4. This indicates that a-axis in-plane direction of standard AlN is random. On the other hand, the sixth symmetry was observed in the pole figures of the AlN film grown with ion beam irradiation shown in Fig. 5, and 6, respectively.

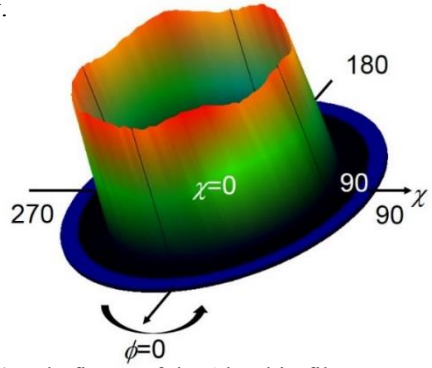

Fig. 4 (1011) pole figure of the AlN thin film grown without ion beam irradiation

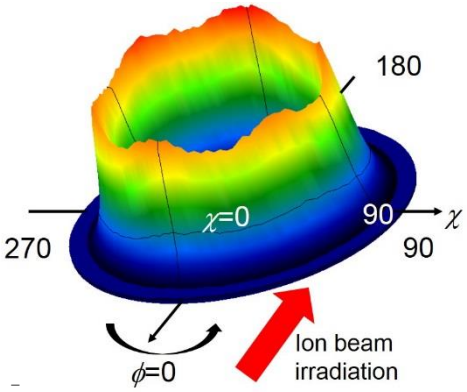

Fig. 5 (1011) pole figure of the AlN thin film grown with 0.3 kV ion beam irradiation

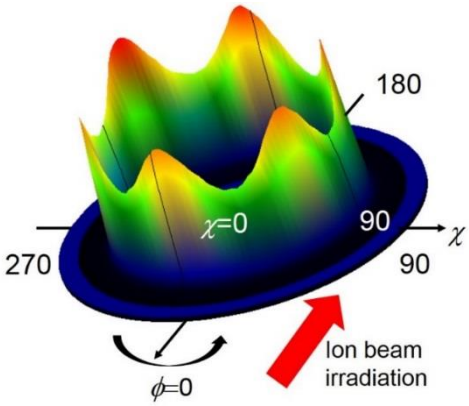

Fig. 6 (1011) pole figure of the AlN thin film grown with ion beam irradiation (0.5 kV)

The in-plane ϕ-scan curve FWHM of the $(10\bar{1}1)$ peak was measured to be 25º.

IV. Conclusion

We reported the growth of the c-axis oriented (0001) AlN films whose crystalline a-axis direction is aligned by ion beam irradiation. In the $(10\bar{1}1)$ pole figures of the films with ion beam irradiation, the poles were found every ϕ=60º around χ=62º. This results suggest that both c-axis direction (out-of -plane) and a-axis (in-plane) direction are aligned. This demonstration holds promise for increasing the Q_m factor of AlN thin film.

In the future, we will compare the Q_m factor of the film which is grown with ion beam irradiation and the film grown without ion beam irradiation.

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