3P-26

Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 507-508
6-8 December, 2010

In-plane and out-of-plane orientation control of AlN films by ion beam assisted RF magnetron sputtering

イオンビームアシスト RF マグネトロンスパッタ法による AlN 薄膜の面内面外配向制御

Masashi Suzuki†, Takahiko Yanagitani (Nagoya Institute of Technology)
鈴木 雅視, 柳谷 隆彦 (名古屋工業大学)

1. Introduction

AlN films that c-axis is parallel or tilted to the substrate is suitable for SH-SAW device and shear mode film acoustic resonator applications. A c-axis tilted AlN film expect to have large shear mode electromechanical coupling k'_{15} (k'_{15}=0.27), but excites quasi-longitudinal wave and quasi-shear wave simultaneously. On the other hand, AlN film where c-axis is parallel to the substrate can excite pure shear wave only [1]. c-axis usually orients normal to the substrate in wurtzite films such as ZnO and AlN. Previously, we have pointed out that c-axis parallel ZnO films were induced by ion-beam irradiation during deposition [2,3]. Also in AlN, Hentzell has reported AlN film having c-axis parallel orientation by a dual ion beam sputtering deposition. However, c-axis in-plane orientation is random and c-axis normal orientation still exists in these films [4].

In this study, we report on the control of in-plane and out-of-plane orientation of the films by ion beam assisted RF magnetron sputtering. Crystalline orientation and piezoelectric properties of the films are investigated.

2. Film deposition

AlN films were fabricated by ion beam assisted RF magnetron sputtering system shown in Fig. 1. Al metal target was sputtered in N_2 gas atmosphere. During deposition, the orientation control of the films was performed by 3 kV accelerated nitrogen ion beam irradiation from ECR ion source (ELIONIX, EIS-220). Three samples labeled A, B and C were prepared. Sample A was fabricated without ion beam irradiation and sample B and C were fabricated with ion beam irradiation. Silica glass (25×100×0.5 mm^3) was used as the substrate for sample A and B, and Al electrode film on silica glass is used for sample C. During all sample deposition, substrate was cooled. RF power was set to 300 W. 10 sccm pure N_2 gas with 0.52 Pa was introduced. Deposition time was 7 hours. Film thickness of sample A, B and C were 3.2 μm, 1.3 μm and 0.9 μm, respectively.

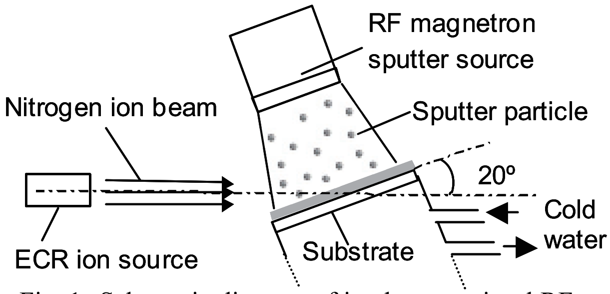

Fig. 1 Schematic diagram of ion beam assisted RF magnetron sputtering system.

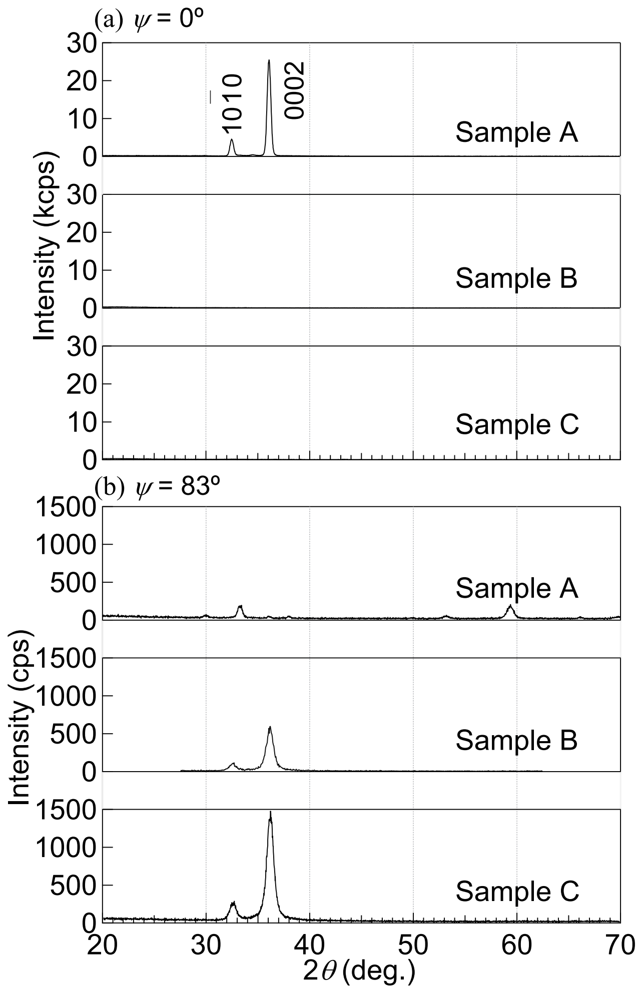

Fig. 2 XRD patterns for sample A, B and C measured by (a) normal 2θ-ω scan of ψ=0º and (b) grazing 2θ-ω scan of ψ=83º.

----

yana@nitech.ac.jp

3. Crystalline orientation

Fig. 2 (a) and (b) shows XRD patterns at $\psi = 0^{\circ}$ and $\psi = 83^{\circ}$ for sample A, B and C, respectively. ψ - angle shows the angle between 2θ -ω scan plane and substrate normal as shown in Fig. 4. Intense (0002) peak was observed at $\psi = 0^{\circ}$ in sample A, whereas, no peak was observed at $\psi = 0^{\circ}$ but (0002) peak was observed at $\psi = 83^{\circ}$ i. e. grazing X-ray incident measurement in sample B and C. Fig .3(a), (b) show (0002) pole figures of sample A and sample B, respectively. (0002) pole concentrated at $\psi = 2^{\circ}$ and in sample A. On the other hand, (0002) pole concentrated at $\psi = 83^{\circ}$ in sample B. These results show that in the case that deposition was performed by only RF magnetron sputter source, c-axis in the film was normal to the substrate plane. In contrast, c-axis parallel orientation was formed in the film deposited using ion beam irradiation. As shown on Fig. 4, the direction of c-axis corresponded with the ion beam direction. and out-of-plane orientation was random. The crystalline orientation in sample C fabricated on Al electrode was almost same as sample B.

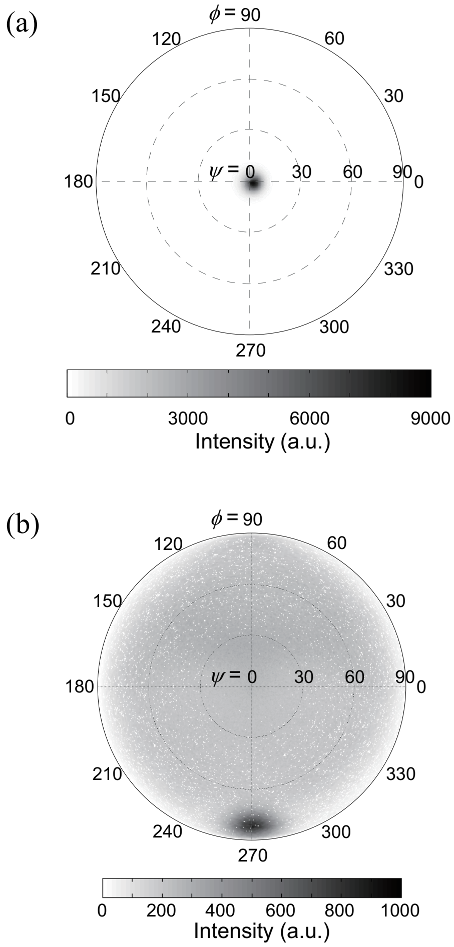

Fig. 3 (0002) pole figure of (a) sample A and (b) sample B.

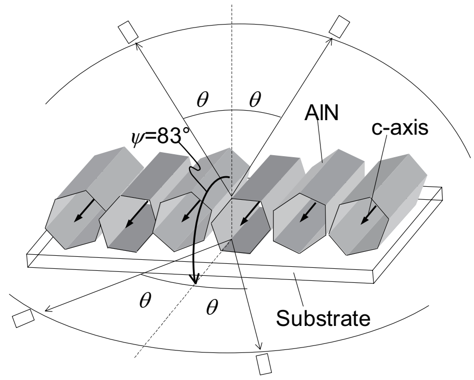

Fig. 4 Diagram of crystalline orientation of sample B and C. Also described in the X-ray 2θ-ω scan plane and ψ angle.

4. Piezoelectric properties

A composite resonator structure was fabricated by evaporating top electrode Cu (0.15 μm) on sample C to measure piezoelectric properties of AlN film. Fig. 4 shows the impulse response of the resonator measured by network analyzer. Pure shear wave echoes were observed at 275 ns interval because of silica glass thickness of approximately 0.53 mm and shear wave velocity of 3770 m/s. Other echo signal was not observed in Fig. 4, and this shows that resonator excited shear wave only. Shear wave resonance frequency was found to be 2.2 GHz, and k'_{15} was determined to be 0.05 by a conversion loss characteristic obtained from the Fourier transform of the first echo.

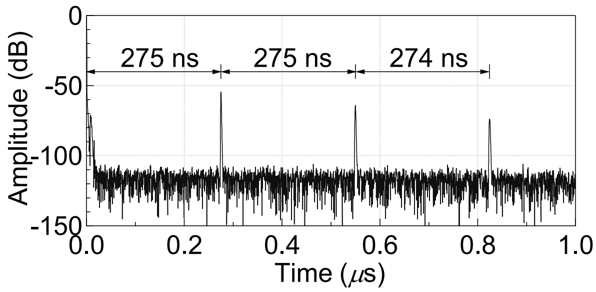

Fig. 5 The impulse response of the resonator (Sample C).

5. Conclusion

The orientation that c-axis is parallel to the substrate is induced by the ion beam irradiation during deposition. In the film sample, c-axis unidirectionally oriented for in-plane direction but randomly oriented for out-of-plane direction. This film excited 2.2 GHz shear wave without excitation of longitudinal wave. k'_{15} was determined to be 0.05.

Reference

1. J. S. Wang, et. al. : IEEE. Ultrason. Symp., (1983) 144.
2. T. Yanagitani. et. al. : J. Appl. Phys. **102** (2007) 044115.
3. T. Yanagitani. et. al. : IEEE TUFFC., **54** (2007) 1680.
4. H. T. G.. Hentzell, et. al. : J. Appl. Phys. **58** (1985) 556.