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Effects of highly energetic negative ions generated from Sc grains during sputtering deposition on electromechanical properties of ScAlN film

スパッタ成膜中に Sc 金属から発生する高速負イオンが
ScAlN 薄膜の圧電性に及ぼす影響

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1. Introduction

Because of their high piezoelectricity, ScAlN films are well-researched for various acoustic wave devices. A single sputtering source with a ScAl alloy metal target was used as one of the deposition technique. Although the stability of the composition is high, the large-size target of ScAl is difficult to prepare and expensive. In previous study, we demonstrated Sc ingot sputtering deposition in which Sc ingots were set on an Al metal target[1)]. Sample preparations with different Sc concentrations are easy by using this method. Oxidization of Sc ingots is, however, seriously problem. Compared with ScAl alloy sputtering, the c-axis orientation was degraded by bombardment with O^- negative ions generated from the Sc ingots. In this study, we investigated the detailed effects of the O^- ion bombardment on the electromechanical coupling.

2. Energy Distributions of Negative Ions

During a sputtering deposition, if the target contains oxygen, O^-negative ions generates around the target. Then, these negative ions are accelerated to the substrate by the negatively biased target and bombard the substrate surface, resulting in the degradation of c-axis orientation in wurtzite films[2)].

The amount of ion flux and ion energy which enter the substrate during the deposition by using an energy analyzer with a Q-mass spectrometer, as shown in **Fig. 1**. An Al metal disc (80 mm diameter) with total weights of Sc ingots of 0, 0.8, and 2.4 g was used as sputtering targets.

Figure 2 shows the ion energy distributions of O^- in each Sc ingot condition. The amount of O^- during the deposition without the Sc ingot was small. The amount of the O^- at 100-200 eV was increased as increasing Sc ingots. This results show the oxidization of the Sc ingots. The O^- ion flux was observed after 60 minutes of the discharge start. The inside of Sc ingots may be oxidized.

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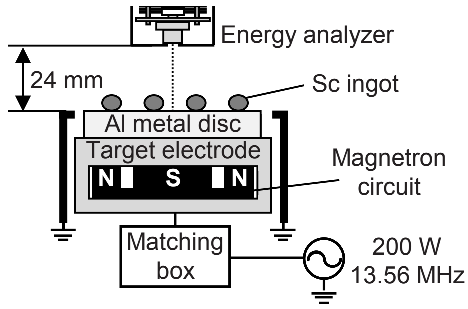

Fig. 1 Measurement system of the O^- energy distributions in an RF magnetron sputtering apparatus.

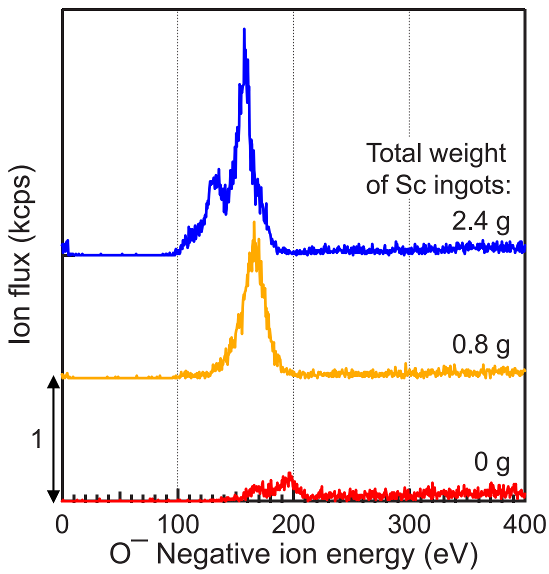

Fig. 2 Energy distributions of O^- entering the substrate during the sputtering deposition.

3. ScAlN Film Growth

ScAlN film samples were grown on Ti/silica glass substrates by an RF magnetron sputtering in the same conditions of the O^- ion energy measurement. The substrate was set at the surface of the energy analyzer in Fig. 1. Total weights of the Sc ingots on the Al target were 0, 0.8, 1.6, 2.4, and 3.2 g, resulting in Sc concentrations of 0, 4, 10, 21, and 30% in ScAlN films.

The crystalline orientations were determined by XRD analyses. **Figure 3** shows 2θ–ω scan XRD patterns of the samples. The intensity of the AlN(002) peak was slightly increased as increasing the Sc ingots. However, no AlN(002) peak was observed at 3.2-g Sc ingots.

The conversion losses (CLs) of the samples were measured by a network analyzer with HBARs consisting of Cu electrode/ScAlN film/Ti electrode/silica glass substrate. **Figure. 4** shows the frequency responses of the longitudinal mode conversion losses. The CL of the fundamental mode L_1 at 0.8-g Sc ingots was lower than that at 0-g Sc ingots. Therefore, the electromechanical coupling was improved by Sc doping. However, the CLs of L_1 were not decreased by increasing Sc ingots. The CL of the second mode L_2 was low at 2.4-g Sc ingots. It indicates the polarity inversion of ScAlN during the Sc ingot deposition[3)].

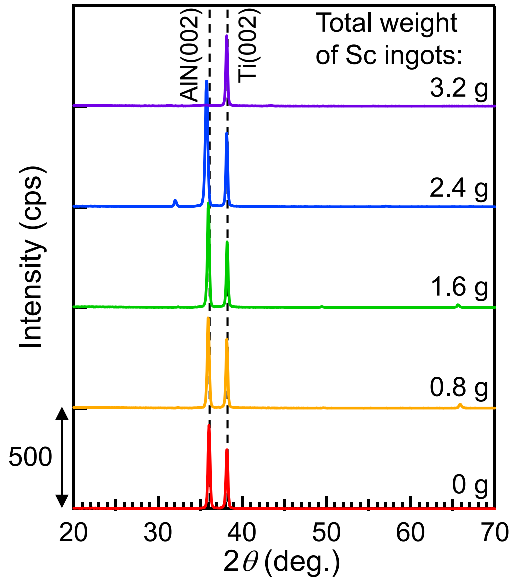

Fig. 3 2θ–ω scan XRD patterns of the ScAlN samples.

4. Discussion

The amount of the O^- negative ions was increased as increasing Sc ingots, resulting in the degradation of the AlN(001) orientation with 3.2-g Sc ingots. Although the intensity of the AlN(002) peak was slightly increased until 2.4-g Sc ingots, The piezoelectric property was not improved. The polarity inversion ScAlN film was grown at 2.4-g Sc ingots. In our previous experiment, the polarity-inverted layer was grown with an oxide ($Al_{0.1}Si_{0.2}O_{0.7}$) ingot[3)]. The polarity of ScAlN film was inverted during the deposition with 2.4-g Sc ingots because the substrate was bombarded with the large amount of O^-. The decrease of the O^- bombardment is required for the Sc ingot sputtering[1)].

5. Conclusions

The effects of the O^- bombardment on the crystalline orientations and piezoelectric properties in the Sc ingot sputtering. The large number of O^- negative ions was generated with increasing Sc ingots. Therefore, the crystallization and the CL of the ScAlN film were degraded. We will discuss about the suppression of the negative ion generation.

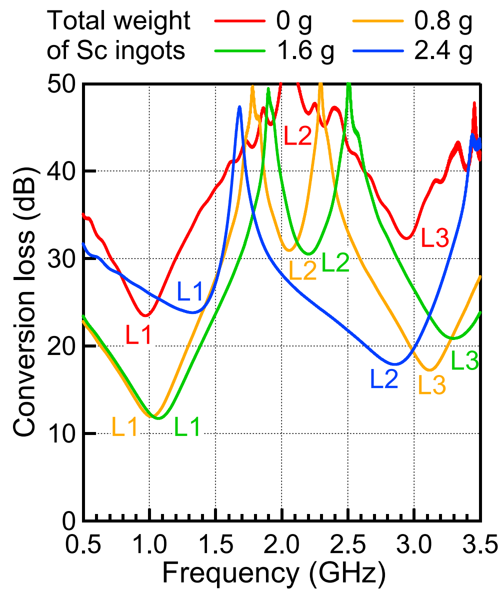

Fig. 4 Frequency responses of the longitudinal-mode conversion losses of ScAlN film samples with the Sc ingots of 0, 0.8, 1.6, and 2.4 g as the sputtering target.

References

1. S. Takayanagi, and T. Yanagitani: Proc. 2017 IEEE Int. Ultrasonics Symp., 2017, p. 1.
2. S. Takayanagi, T. Yanagitani, and M. Matsukawa: Appl. Phys. Lett. **101** (2012) 232902.
3. M. Suzuki, T. Yanagitani, and H. Odagawa: Appl. Phys. Lett. **104** (2014) 172905.