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Negative ions generation of the arc-melted and hot press sintered ScAl alloy targets in ScAlN film growth

溶融及び焼結 ScAl 合金ターゲットからの負イオン照射が ScAlN 薄膜成長へ及ぼす影響

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1. Introduction

FBAR (Film Bulk Acoustic Resonator) has become commonplace for the frequency filter used in smartphones. AlN films were used for piezoelectric material of FBAR because of their high acoustic velocity and high quality factor. High piezoelectricity in ScAlN films have attracted much attention as FBAR material [1]. In previous studies, we reported that negative ion generation occurs during the sputtering growth when Sc ingots are introduced on the sputtering target [2]. We also reported the degradation of the crystallinity of ScAlN films due to the O^- and CN^- ion generation from sputtering target [3]. The suppression of the negative ion generation caused by Sc target is required for ScAlN film growth with Sc high concentration.

In this study, we measured the energy distributions of negative ions generated from ScAl alloy target on the anode. Two types of ScAl alloy targets (Sc: 43 atom%) which were fabricated by different process: arc-melting and sintering were compared. Additionally, the c-axis orientation and electromechanical coupling coefficient k_t^2 of ScAlN films fabricated using these different targets were also compared.

2. ScAl alloy sputtering targets

We prepared 2 types of ScAl alloy sputtering target. One was fabricated by arc-melted Sc and Al in vacuum. The other was fabricated by sintered metal powder produced by gas atomization. The impurities in these sputtering targets was evaluated by an infrared absorption spectroscopy. The arc-melted ScAl alloy target contained 900 ppm oxygen and 50 ppm carbon. The sintered ScAl alloy target contained 8000 ppm oxygen and 300 ppm carbon.

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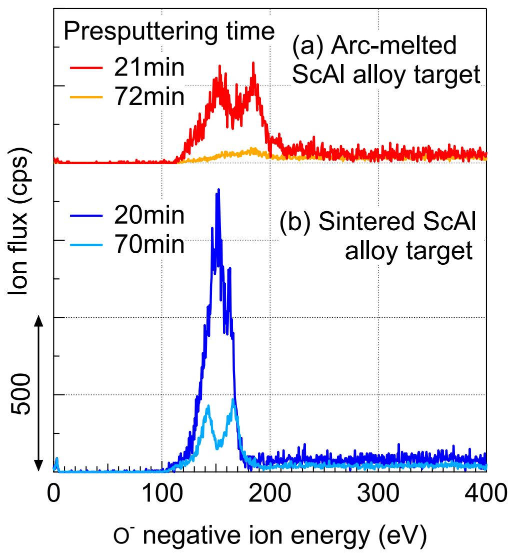

Fig. 1 Energy distribution and ion flux of O^- negative ion generated on the ScAl alloy target.

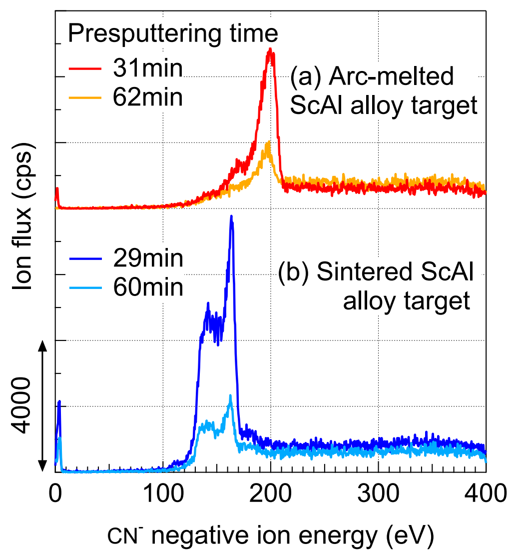

Fig. 2 Energy distribution and ion flux of CN^- negative ion generated on the ScAl alloy target.

3. Negative ion bombardment at anode

The O^- and CN^- negative ion bombardments were measured during RF magnetron sputtering using an energy analyzer with Q-mass (PSM003, Hiden Analytical). Fig. 1 and 2 show the ion energy distribution and ion flux of O^- and CN^- during the sputtering growth, respectively. The O^- ion flux generated at sintered ScAl alloy target were much larger than that at the arc-melted ScAl alloy target in Fig. 1, as expected. However, no apparent differences were found in CN^- ion flux between the two targets, although sintered target contained 6 times higher concentration of carbon than arc-melted did, as shown in Fig. 2. In addition, O^- and CN^- ion generation decreased when presputtering time is extended. These results show that 1 hour presputtering is effective for the suppression of the negative ion generation.

4. ScAlN films growth

We fabricated 2 types of ScAlN films using the sintered or the arc-melted ScAl alloy target by RF magnetron sputtering. The ScAlN films were grown on (0001) oriented Ti electrode films (RC FWHM 2.4–2.5°)/silica glass substrate (25 × 25 × 0.54 mm^3). The crystal orientation of the ScAlN films were measured using X-ray diffraction ω rocking curve FWHM (PANalytical, X'Pert Pro MRD). Rocking curve FWHM of the ScAlN films grown by arc-melted ScAl alloy targets was 1.7°, and that by sintered ScAl alloy target was 1.4°, as shown in Fig. 3. High crystal orientation was observed at the samples fabricated using two targets.

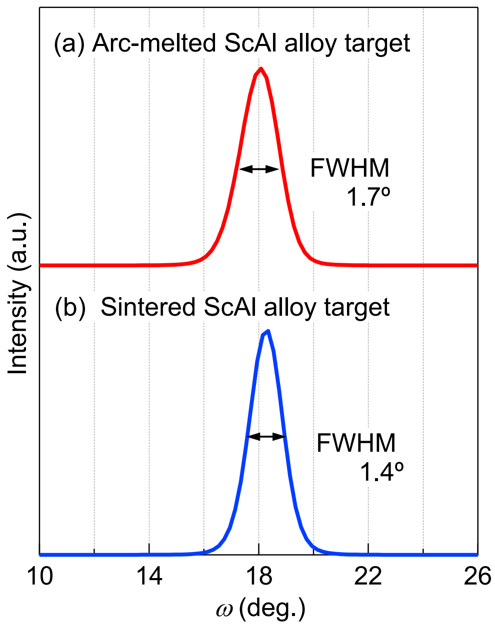

Fig. 3 X-ray rocking curves of ScAlN films fabricated by using two types of ScAl alloy targets: (a) arc-melting or (b) sintering.

The k_t^2 were determined by comparing the experimental and theoretical conversion losses of HBAR. The experimental conversion loss curves were measured by a network analyzer (E5071C, Agilent Technologies). The k_t^2 in the arc-melted target and the sintered target were determined to be 20.6% and 20.1%, respectively, as shown in Fig. 4. No apparent differences were found in the k_t^2 between the two targets.

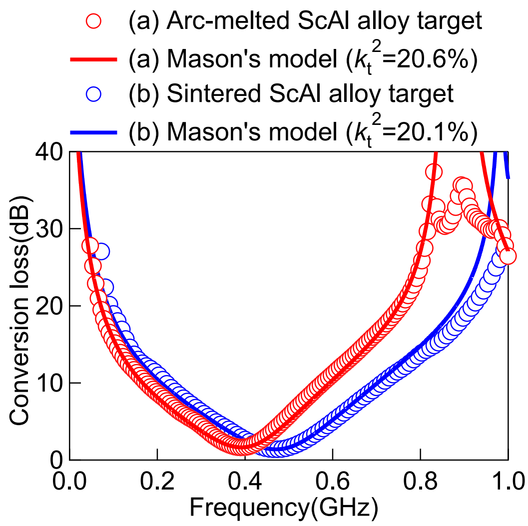

Fig. 4 Experimental conversion loss curves of ScAlN films fabricated by using two types of ScAl alloy targets: (a) arc-melting or (b) sintering.

4. Conclusion

We demonstrated that the amount of CN^- ions generation was one tenth of that in Sc ingot sputtering. Although the different amount of O^- and CN^- ions were generated in the two targets, it does not significantly affect the results of the crystallization and k_t^2 of the ScAlN films.

Acknowledgment

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