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Sputter Deposition of ScAlN Thin Films Using a Sc-Al Alloy Target

Sc-Al 合金ターゲットによる ScAlN 薄膜のスパッタ堆積

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1. Introduction

Recently, ScAlN was proposed, and is paid much attention for its exceptionally strong piezoelectricity [1,2]. For example, the authors reported that high performance surface acoustic wave (SAW) resonators operating in the SHF range can be developed by using the ScAlN/6H-SiC structure[3].

Until now, most of all reported works employed co-sputtering using Sc and Al targets for the ScAlN deposition. However, co-sputtering is not suitable for mass production because of difficulty in controlling film uniformity within a wafer.

This paper describes deposition of ScAlN thin films by conventional radio frequency (RF) magnetron sputtering. Two Sc-Al alloy targets with different Sc/Al ratio were prepared, and deposited film qualities and uniformity were evaluated. Then one SAW resonators were fabricated on the ScAlN/Si structure, and the device performances were also evaluated.

2. Film Deposition

Two 4-inch Sc-Al alloy targets with chemical composition of $Sc_{0.43}$-$Al_{0.57}$ and $Sc_{0.32}$-$Al_{0.68}$ were prepared by sintering process. They were installed in an RF magnetron sputtering system (Anelva SPC350-UHV), which equip an ultra clean turbo molecular pump and a load-lock system.

The sputtering condition used for the deposition is shown in Table 1. The deposition rate was circa 0.8 μm/hour under this condition.

Deposited ScAlN films were evauated by (a) the X-ray fluorescence spectrometry for chemical composition, (b) the atomic force microscopy for surface roughness, and (c) the X-ray diffraction (XRD) for crystallographic quality.

3. Results and discussions

Figure 1 shows a measured XRD rocking curve of the (002) plane for a deposited ScAlN film when the $Sc_{0.43}$-$Al_{0.57}$ target was employed. The full width at half maxima (FWHM) was 3.25°. This indicates that the c-axis of ScAlN grains is well aligned normal to the surface. This property is necessary for developing high performance acoutic wave devices operating in the GHz range.

Table 1 Deposition Condition

Background Pressure	< 5×10^{-5} [Pa]
Total Gas Pressure	0.5 [Pa]
N_2 Flow	24.0 [sccm]
Ar Flow	12.0 [sccm]
Substrate Temparature	200 [℃]
RF Power	250 [W]
Substrate	3-inch FZ (001) Si
Pre-Sputtering	10 [min]

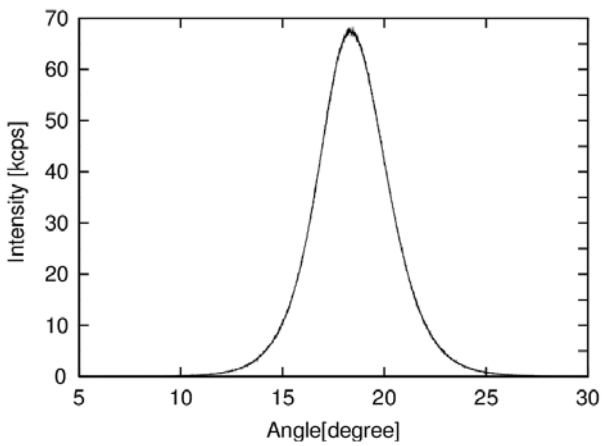

Figure 1 Rocking curve of deposited ScAlN film

Figure 2 shows how the Sc content and the FWHM of the rocking curve changed with the cumulative deposition time *T*. The Sc content of deposited films was approximately 32%, which is significantly lower than that of the target. The Sc content seems to increase gradually with *T*. Furthermore, the film quality became very bad quite often. Although the target surface was polished, the film quality could not be recovered.

Figure 3 shows that the result when the $Sc_{0.32}$-$Al_{0.68}$ target was used. The Sc content of the

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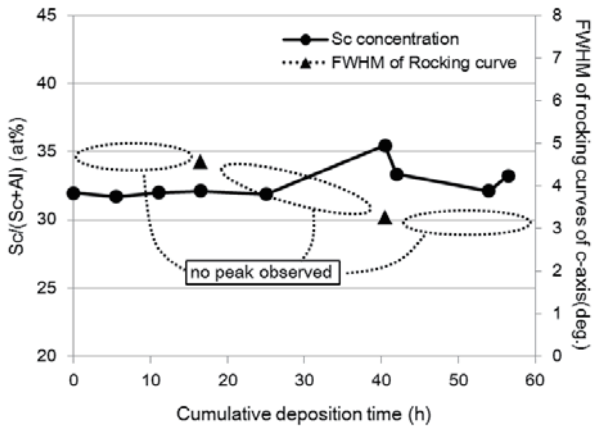

Fig. 2 Variation of Sc content and FWHM of the XRD rocking curve with the cumulative deposition time (Target: $Sc_{0.43}$-$Al_{0.57}$)

deposited film was approximately 22%, which is significantly lower than that of the target. In this case, the FWHM becomes better with an increase in *T*. The FWHM for *T* = 15 h was 2.84°, and surface roughness (*R*a) was as low as 2.4 nm.

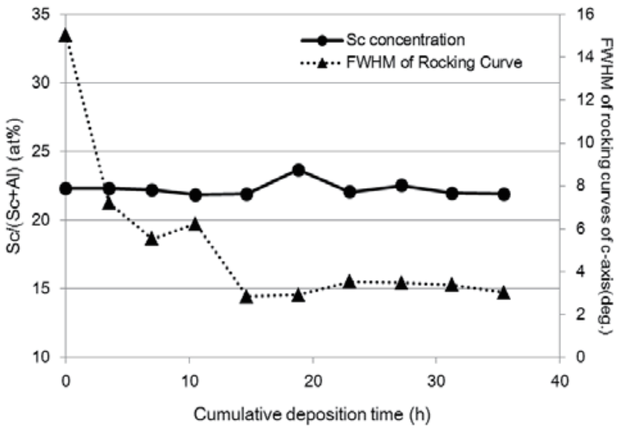

Fig. 3 Variation of Sc content and FWHM of the XRD rocking curve with the cumulative deposition time (Target: $Sc_{0.32}$-$Al_{0.68}$)

We measured uniformity of the Sc content in the deposited surface, and the variation was small for all cases.

Next, One port SAW resonators were fabricated on the ScAlN/Si structure. They have 80 IDT fingers and 40 reflector fingers, and the IDT periodicity and aperture were 2.7 µm and 54 µm, respectively. Al electrode thickness was 270 nm.

Figure 4 shows the measured input impedance. It is seen that both the resonance frequency and resonance quality factor *Q* decreased and the electromechanical coupling factor K^2 increased with an increase of the Sc content. From the fitting, K^2 and *Q* were estimated as 2.7% and 305 for the $Sc_{0.43}$-$Al_{0.57}$ case (*T*=16.5 h) while they were 1.3% and 910 for the $Sc_{0.32}$-$Al_{0.68}$ case (*T*=15 h).

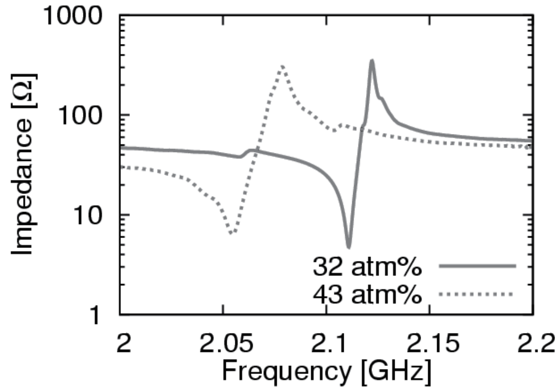

Fig. 4: Measured impedance of fabricated one-port SAW resonators

4. Conclusions

ScAlN films were prepared by the RF magnetron sputtering using two Sc-Al alloy targets with the different Sc/Al ratio. Although highly c-axis oriented ScAlN films were realized, the film quality became worse when the cumulative deposition time became large and the Sc/Al ratio was high.

One-port SAW resonators were fabricated on the ScAlN/Si structure and their performances were discussed.

As a next step, we will develop high performance SAW devices using high velocity substrates such as diamond or SiC instead of Si.

Acknowledgements

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