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

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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 Sc0.43-Al0.57 and Sc0.32-Al0.68 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 evaluated 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 Sc0.43-Al0.57 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 acoustic wave devices operating in the GHz range.

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 Sc0.32-Al0.68 target was used. The Sc content of the...
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.

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).

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.

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References