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ScAlN free–standing piezoelectric plates in the range of 30–40 MHz resonance frequency

大きな圧電性を持つ ScAlN 自立薄板を用いた 30–40 MHz 帯振動子

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1. Introduction

Ultrasonic microscopy for biological imaging uses the frequency range of 100–300 MHz. High frequency ultrasound has high spatial resolution. Higher frequency, however, induces lower deep resolution because of the large sound attenuation. In recent years, *in vivo* tissues observation by ultrasonic microscopy with 80 MHz PVDF (Polyvinylidene Difluoride) transducer was reported [1]. However, their electromechanical coupling coefficient k_t^2 of 4% is insufficient for practical applications [2].

Table I shows the k_t^2 of various piezoelectric film materials. We previously reported the ScAlN thin film (k_t^2=18.5%) and the transducer with ScAlN thick film on silica glass rod (k_t^2=11.9%) [3]. Lead–free ScAlN with large piezoelectricity is suitable for medical applications.

Fig. 1 shows the difference in the shape of the transducer using between piezoelectric single crystal plate and piezoelectric film. In a piezoelectric film, it is not difficult to fabricate a transducer with complicated surface. Piezoelectric film is attractive for a concave focus type transducer which is often used for ultrasound imaging. However, it is difficult to grow thick film on a substrate without a crack by the internal stress.

In this study, we report the fabrication of ScAlN free–standing plates with 0.105 mm and 0.117 mm thickness by using hot target sputtering growth.

Table I k_t^2 of piezoelectric film materials

	k_t^2	Reference
PVDF	4%	[2]
ScAlN thin film	18.5%	[3]
PZT(sputtering)	25%	[4, 5]
PMN–30%PT single crystal	40%	[6]
ZnO thin film	8.4%	[7]

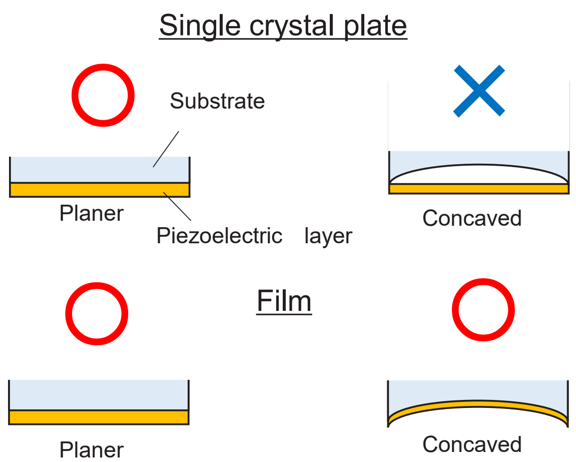

Fig. 1 Difference in the shape of the transducer fabricated between piezoelectric single crystal plate and piezoelectric film

2. Experiment

Two ScAlN thick films (plates) were grown on Ti bottom electrodes / silica glass substrates by hot target RF magnetron sputtering technique as shown in **Fig. 2** We used self–made ScAl alloy metal target fabricated by e–beam melting in vacuum. Au top electrodes were deposited on the films. The free–standing plates as shown in **Fig. 3**, were obtained by peeling off the thick films from the substrates. The real part of admittance (Y_{real}) and impedance (Z_{real}) were measured by a network analyzer.

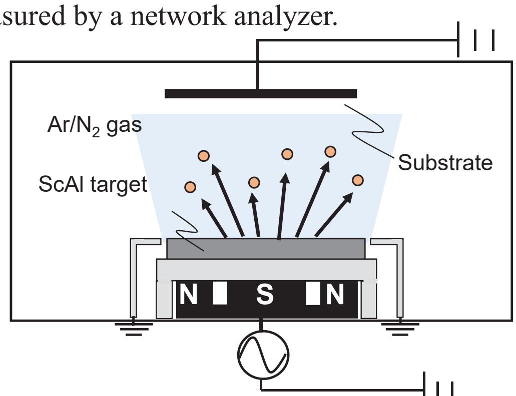

Fig. 2 The hot target RF magnetron sputtering system

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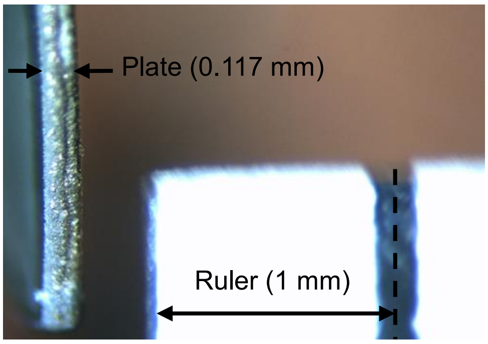

Fig. 3 ScAlN free–standing plate (0.117 mm)

3. Results and discussion

Fig. 4 shows the X–ray diffraction (XRD) pattern of the 0.105 mm thick ScAlN free–standing plate. The rocking curve FWHM (0002) peak of the plate was measured to be 2.6°. **Fig. 5** shows the experimental frequency response of the admittance, the real part of the admittance, and the real part of the impedance of the 0.105 mm thick plate. In **Table II**, the properties of the two plates are summarized. The k_t^2 was measured by a resonance anti–resonance method using the peak of Y_{real} and Z_{real} [8]. The k_t^2 of each plate was determined to be 12.4% at 43 MHz and 13.6% at 38 MHz. These k_t^2 values were much larger than that of PVDF membrane.

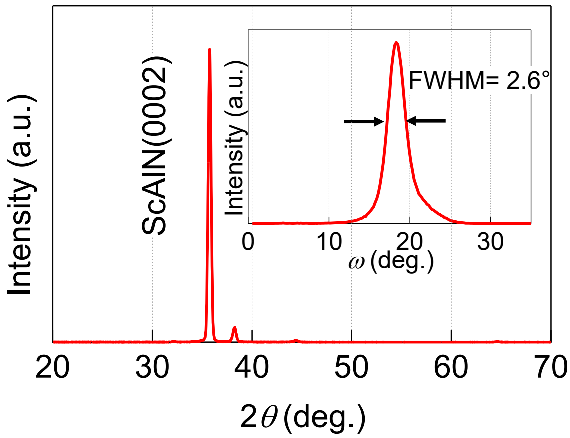

Fig. 4 XRD pattern of the ScAlN free–standing plate (0.105 mm)

4. Conclusion

We first reported ScAlN free–standing piezoelectric plates in the range of 30–40 MHz resonance frequency. The k_t^2 values of both plates are larger than that of PVDF membrane. Therefore, the lead–free ScAlN transducer has a bright promise for ultrasound biological imaging.

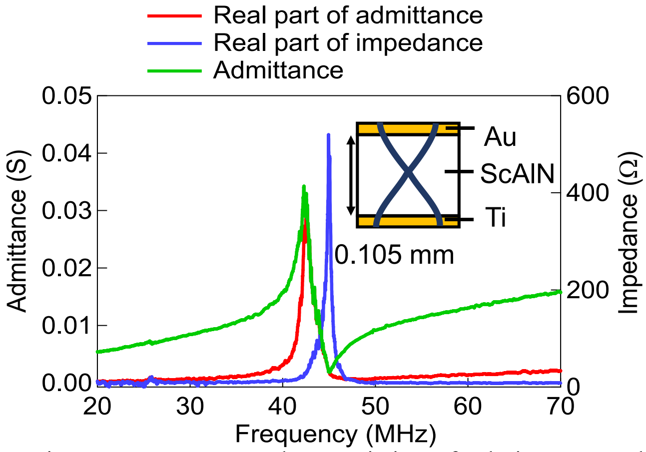

Fig. 5 Frequency characteristics of admittance, real part of admittance and impedance of the ScAlN free–standing plate (0.105 mm)

Table II Properties of the ScAlN free–standing plates

	ScAlN plate A	ScAlN plate B
Film thickness	0.105 mm	0.117 mm
Rocking curve FWHM	2.6°	4.7°
Resonance frequency	43 MHz	38 MHz
k_t^2	12.4%	13.6%

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