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Effect of film quality on PZT/PZT ultrasonic transducers

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1. Introduction

Ultrasound imaging diagnosisis is widely used in the medical field because it allows diagnosis without damaging the human body. However, conventional probes are heavy and may have difficulty detecting small abnormalities due to the high-pass effect caused by the use of large amounts of coupling agents when diagnosing curved surfaces of the living body.

A new medical ultrasound probe using sol-gel composite spraying (SCS) technology has been developed as a solution to this problem. Piezoelectric materials fabricated by the SCS method have a lower acoustic impedance and dielectric constant than bulk lead zirconate titanate (PZT) due to their porous structure. As a result, the heavy backing materials and multiple matching layers typically employed in bulk are not necessary, and lightweight, flexible probes are easier to fabricate. Probes fabricated using this method have demonstrated high fundamental performance. The performance of the fabricated probe appears to be sufficient for use in relatively shallow sites such as the carotid artery and in low attenuation sites such as the bladder [1)].

Therefore, in order to further improve the performance of this probe, we will attempt an approach to improve the film quality of the sensor. accordingly, in this paper, we fabricate PZT/PZT and study the difference in performance of piezoelectric membranes depending on the membrane quality.

2. Sample Fabrication

PZT/PZT is prepared using an a automatic spray coating. First, PZT sol-gel solution and PZT powder (HIZIRCO L) are mixed using a ball mill, and the sol-gel composite, adjusted to a viscosity suitable for spraying, is sprayed onto a square titanium substrate 3 mm thick and 30 mm long and wide using a automatic spray coating. After the spray coating, it is baked in an electric furnace at 150°C for 10 minutes to dry, followed by baking at 650°C for 5 minutes. After the substrate is cooled, film deposition, drying, and baking are repeated until the target film thickness becomes 50 μm. Polarization was performed by positive voltage corona discharge at room temperature for 5 minutes at less than 20% humidity [2)].The output voltage is approximately 43 kV. the distance between the electrode and the sample is 4 cm. The top electrode is fabricated on the sensor with silver paste by screen printing. The diameter of the upper electrode is 6 mm. This is shown in **Fig. 1**. In this study, two samples with different multiple parameters in the spraying and firing processes were prepared.

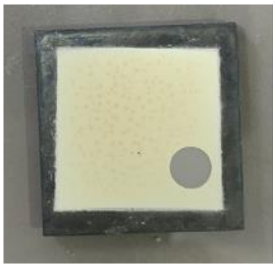

Fig. 1 Optical image of PZT/PZT sample fabricated on 3mm thick titanium substrate and Top electrode

3. Result

To confirm that the fabricated samples were working properly, piezoelectric constant d_{33} measurements and ultrasonic measurements using the pulse echo method were performed. The piezoelectric constant d_{33} was measured by a piezo d_{33} meter. The value was 37 pC/N for a sensor 47 μm thick. The ultrasonic waveform and the value of the piezoelectric constant d_{33} are measured, indicating that the sensor is working properly. **Fig. 2** shows the ultrasonic response. It can be seen that a clear ultrasonic response was obtained at room temperature. There is some noise, but this is thought to be due to the lack of impedance matching. The bandwidth was 6.1 MHz and the center frequency was 12 MHz. The sensitivity is expressed by the following equation(1).

$$Sensitivity = -(20 \log V_1/V_2 + P/R\ Gain) \quad (1)$$

The reference amplitude V_1 is 0.1 $V_{p\text{-}p}$. The signal amplitude V_2 of the reflected echo is the amplitude of the third reflected wave and P/R Gain is the gain used by the pulsar receiver. Since the amplitude V_2 is 1.74 $V_{p\text{-}p}$ and the gain used is 10, the sensitivity is 14.7.

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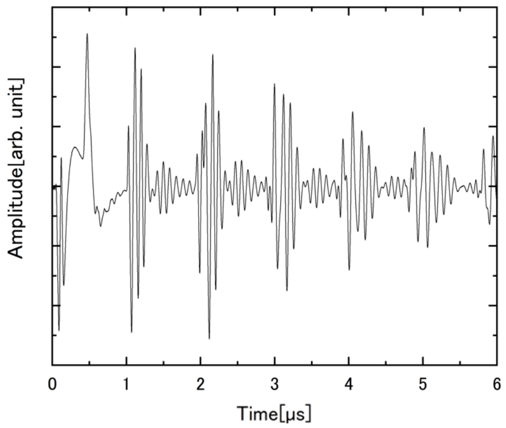
Fig.2 ultrasonic response of PZT/PZT samples fabricated on 3mm titanium substrate using new parameters

The relative permittivity was calculated from the sample's d_{33} and capacitance. The area of the electrode was 28.3 mm^2, the film thickness was 47 μm , and the capacitance was 1.62 nF, so the relative permittivity was calculated to be 3.04×10^2.



Here, we compare the performance with the previous study[3)]. The thickness of the L/PZT film in the previous study was about 50μm, with a d_{33} value was 41.7. This is higher than the value measured in the present study. Next, considering that the reference amplitude V_1 was calculated to be 0.2 $V_{p\text{-}p}$ in the previous study, the sensitivity was almost the same. However, a simple comparison cannot be made because of the different conditions of the upper electrode. The relative permittivity was 593, which was higher than the 3.04×10^2 in the present study. A lower relative permittivity results in higher reception performance. Therefore, the PZT/PZT film fabricated in this study may be effective for sensor applications.

Next, images of the piezoelectric film surface and cross-section were captured by scanning electron microscope (SEM) to evaluate film quality. A photograph of the samples from which the SEM images were taken is shown in **Fig. 3**. This sensor used to photograph the surface. The substrate is SUS foil and the thickness of the sensor is 47 μm. SEM images of the surface of the sensor before and after the parameter change are shown in **Fig. 4**. The image is multiplied by 20,000. The porosity of the cross-section does not change much, but the surface porosity is lower in the sensor made by the method after the parameters change than in the sensor made by the method before the parameters change.

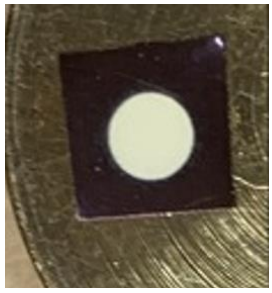


Fig.3 The sample fabricated on SUS foil and 47μm of film thickness for scanning SEM

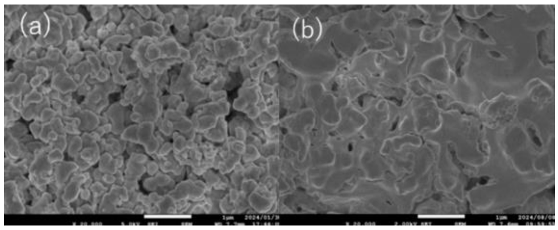


Fig.4 SEM image of the surface (a)before parameter change and (b) after parameter change

4. Conclusion

In this study, PZT/PZT ultrasonic transducers were fabricated on titanium substrates by varying the preparation parameters, including thermal sintering parameters, compared to the conventional method in order to investigate the change in performance of PZT/PZT ultrasonic transducers as the film quality changed. The d_{33} and ultrasonic response were measured to compare with the sensors created using the proposed method with those created with the conventional method. As a result, No significant difference in d_{33} and ultrasonic sensitivity was observed. In this case, the piezoelectric film was fabricated on a 3mm titanium substrate for comparison. Since the adjusted parameters were based on the fabrication that the piezoelectric film would be fabricated on a flexible substrate, it is possible that the parameters were not fully optimized for the substrate used in this study. In the SEM images, no difference was observed in the cross section, but on the surface, the porosity of the proposed method was smaller than that of conventional method.

References

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