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Fabrication of Pb(Zr, Ti)O_3-based Bi-Material Sol-Gel Phase Ultrasonic Transducer

Pb(Zr,Ti)O_3 ベース 2 材料ゾルゲル相による超音波トランスデューサの作製

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1. Introduction

Piezoelectric devices have a characteristic called the piezoelectric effect and are used for non-destructive testing in industrial facilities such as power plants and chemical plants.[1-2] Another method using piezoelectric elements is non-destructive testing using ultrasonic transducers. Ultrasonic transducers have been used to detect cracks and corrosion in such industrial facilities. In addition, since sol-gel composites are fabricated by mixing piezoelectric elements with a sol-gel solution, the presence of micropores eliminates the need for packing agents, Kaplan, and other less heat-resistant mechanisms required by conventional transducers. Therefore, ultrasonic probes using sol-gel composites can be used for nondestructive testing under high temperature conditions, so that defects can be noticed in real time and safety is high. Pb(Zr,Ti)O_3 (PZT) material has been extensively studied and widely used as an ultrasonic transducer because of its high piezoelectricity and relatively high Curie temperature of 350℃.[3-5] Therefore, PZT is also used in this study as both sol-gel phase and piezoelectric powder phase.

In this experiment, the low-frequency ultrasonic transducer was fabricated. For this purpose, it is necessary to increase the thickness of the film. However, the thicker the film, the more brittle the durability becomes. Therefore, in this experiment, we used a composite sol-gel of PZT sol-gel and Al_2O_3 sol-gel to measure the ultrasonic waveform.

2. Fabrication method

The composite sol-gel solution, which is a mixture of PZT sol-gel solution and Al_2O_3 sol-gel solution, and PZT piezoelectric powder are crushed and mixed in a ball mill for about a day, and this is sprayed onto a titanium substrate of 30 mm square and 3 mm thick. Next, the film is dried at room temperature for 5 minutes, in a drying oven at 150°C for 5 minutes, and finally in a firing oven at 650°C for 5 minutes. This process is repeated until the film thickness reaches 200 μm. The fabrication process of the PZT/PZT+Al_2O_3 sample is shown in **Fig. 1**. For the poling process, corona discharge poling and pulse poling with a pulsar receiver were used. In corona discharge poling, the distance between the needle and the substrate was set at 35 mm, and 40 kV was applied for 5 minutes. After poling, the upper electrode was fabricated. In this study, high performance silver pencil is used for the top electrode. In this study, PZT/PZT+Al_2O_3 was fabricated. The piezoelectric constant d_{33} of the PZT/PZT+Al_2O_3 sample after poling was measured by ZJ3B piezo d_{33} meter, and it was 50.0 [pC/N] at room temperature. **Fig. 2** shows the optical image of PZT/PZT+Al_2O_3 after fabrication.

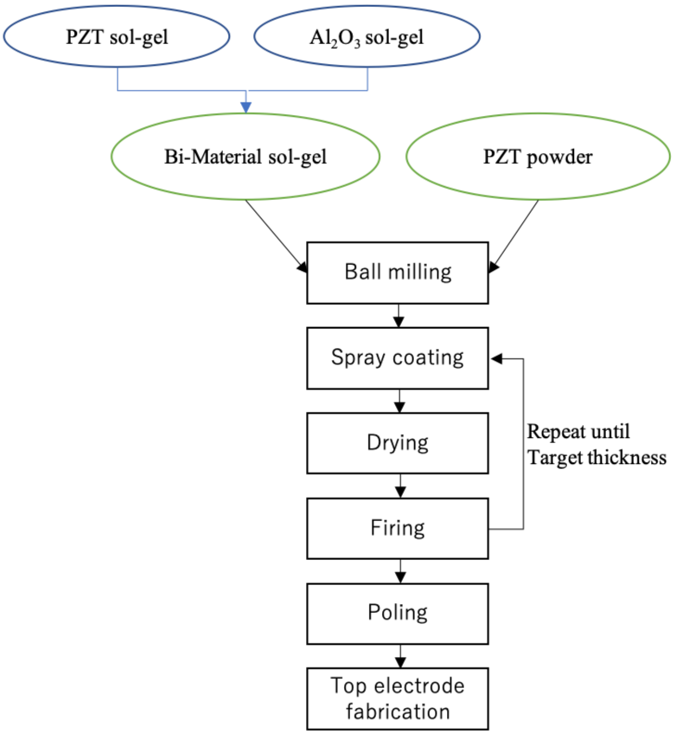

Fig1. Fabrication process of PZT/PZT+Al_2O_3 sample

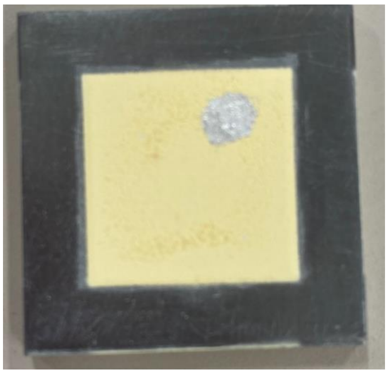

Fig.2 Optical image of PZT/PZT+Al_2O_3 film on 3mm thick titanium substrate.

3. Experimental Results of PZT-based Sol-gel Composites

In this experiment, PZT/PZT+Al_2O_3 films were prepared by automatic spray method, poled at room temperature, and the waveform of ultrasonic response was observed. A digital oscilloscope was used to record the waveforms, and by mixing PZT sol-gel and Al_2O_3 sol-gel to create a two-material sol-gel layer, we were able to fabricate a 200 μm film without the film cracking. The piezoelectric constant d_{33} value of the sample polarized at room temperature was 50 [pC/N]. The graph of the observed ultrasonic response is shown in **Fig. 3**. A clear reflection wave could be seen at room temperature. In order to investigate the frequency characteristics, we performed a Fourier transform (FFT) of the observed ultrasonic response. The FFT-transformed graph is shown in **Fig. 4.** The results showed that the center frequency was about 5 MHz, which is relatively low. However, the film quality of PZT/PZT+Al_2O fabricated in this study was poor, so the reproducibility needs to be confirmed in the future.

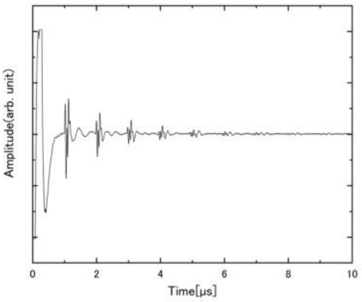

Fig.3 Ultrasonic response of PZT/PZT+Al_2O_3 ultrasonic transducer poled by positive corona discharge at room temperature (film thickness: 200 μm)

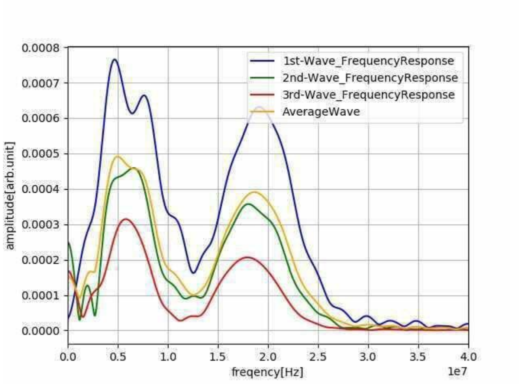

Fig.4 Frequency characteristics of PZT/PZT+Al_2O_3 ultrasonic transducer poled by positive corona discharge at room temperature (film thickness 200 μm)

4. Conclusion

In order to obtain a low-frequency ultrasonic transducer, PZT/PZT+Al_2O_3 films with a thickness of 200 μm were fabricated, and positive corona discharge poling was performed at room temperature. The ultrasonic measurement was performed in pulse echo mode and the reflected waves were observed at room temperature. The frequency characteristics of the observed ultrasonic response were investigated by FFT conversion, and it was confirmed that the center frequency was relatively low at about 5 MHz. However, in this experiment, the number of samples was only one and the film quality was poor. In the future, we would like to improve the film quality by improving the experimental method and increase the number of samples to improve the reproducibility.

References

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