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Fabrication of $LiNbO_3/Al_2O_3$ Ultrasonic Transducer

$LiNbO_3/Al_2O_3$超音波トランスデューサの作製

Naoki Zaito[1‡], Hiroaki Akatsuka[1], Naoki Kambayashi[1] and Makiko Kobayashi[1]
([1]Kumamoto Univ.)
財頭　直希[1‡]，赤塚　大晃[1]，神林　尚樹[1]，小林　牧子[1] ([1]熊本大学)

1. Introduction

In recent years, non-destuctive testing (NDT) has been requird in the industrial field from the viewpoint of safety and economy[1-2], and is used to detect defects in the early stage of equipment before serious problem.

The sol-gel composite ultrasonic tranceducer does not require couplant and backing material that was previously required. Therefore, it is possible to measure at high temperture. In addition, it is possible to carry out even the measurement of a curvrd surface. So this traceducer is suitable as an NDT apllication in the industrial field.

$LiNbO_3$ (LN) is a piezoelectric material with a high Curie temperature, which about 1200℃. Past studies have confirmed that LN/$Bi_4Ti_3O_{12}$ (LN/BiT) composites show clear reflected waves at high temperatures of 700℃. However, the temperature required for poling was very high at 900℃.[3] Therefore, it is difficult to manufacture and there is a risk of burns. Furthermore, it has been reported that LN/$Pb(Zr,Ti)O_3$ (LN/PZT) was poled at 550℃.[4] But LN/PZT contain lead and there is concern aobut adverse effects on the human body and the environment.

Al_2O_3 has some good characteristics as a sol-gel solution. The first, it is cheap and easy to obtain. The second, it is easy to make. And it is very important feature that it does not contain lead. Past $Bi_4Ti_3O_{12}/Al_2O_3$ compsites studies have allowed poling at room temperature.[5,6] From the results, it was considered that the poling temperature was affected by using the sol-gel solution of Al_2O_3.

In this study, the LN/Al_2O_3 sol-gel composites are poled at a temperature lower than the conventional LN poling temperature.

2. Sample Fabrication

LN/Al_2O_3 was formed by sol-gel spray technology. **Fig. 1** shows the sample fabrication procedure. The proprietary Al_2O_3 sol-gel solution and commercially available LN powder were mixed for one day using a ball mill. The sol-gel composite adjusted to a suitable viscosity is formed on a 3mm thick Inconel substrate by automatic spray coating.

After film formation with a spray device, it is fired at 150℃ for 5 minutes. Next, it is fired at 650℃ for 5 minutes. After cooling the substrate, film formation, drying, and firing were repeated until the film thickness reached the target thickness of 50 μm. By repeating this operation 7 times, the target film thickness of about 50 μm was reached.

In the poling process, the substrate was heated in a furnace at 400℃ for 15 minutes, and then poling for 10 minutes in humidity less than 20 %. The output voltage from the power supply was about 40kV. In this study, the distance between the tip of the needle and the substrate was 30mm. This distance is provided to prevent dielectric breakdown due to arcing.

The electrodes were manufactured by the sputtering deposition method. The sputtering deposition method can uniformly produce a thin film with high adhesive strength. Using this method, Ti/Cu was deposited as an electrode. The reason for covering Ti on copper is to prevent oxidation of copper.

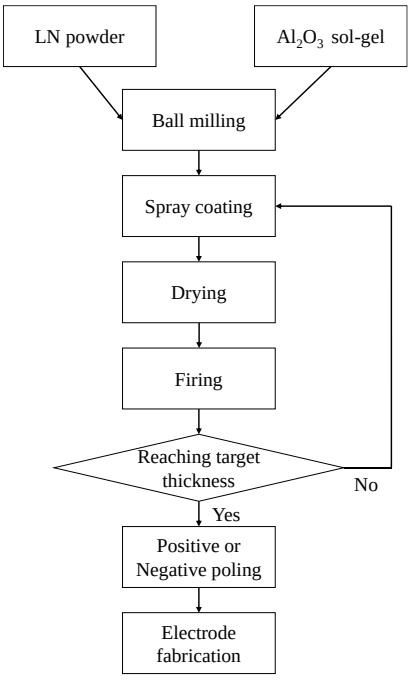

Fig. 1　Samples fabrication procedure

Two sample were prepared from the above procedure. One was positive poling and the other was negative poling. An optical image of the LN/ Al_2O_3 samples is shown in **Fig. 2**.

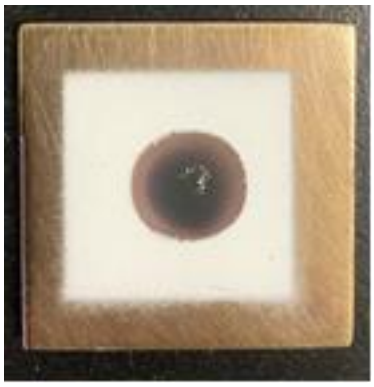

Fig. 2 Optical image of LN/Al_2O_3 film with Ti/Cu electrode on 3mm thick Inconel substrate

3. Experimental results

The absolute value of the piezoelectric constant d_{33} was about 0.4 [pC/N]. The relative permittivity obtained from the capacitance measurement was around 5.5. Those values were lower than the bulk LN because of porosity and Al_2O_3. Ultrasonic response of LN/Al_2O_3 was measured in pulse echo mode. The date was saved by a digital oscilloscope at room temperature. From **Figs. 3** and **4**, it was found that the ultrasonic response was clearly shown at room temperature. It can also be seen that the SNR is very high. These results indicate that the poling was effectively performed.

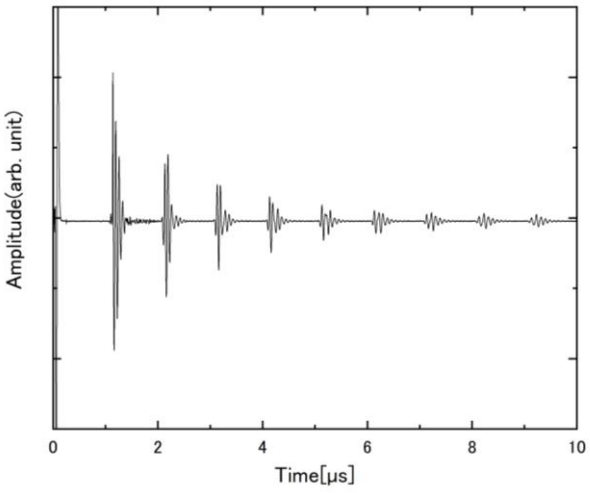

Fig. 3 Ultrasonic response of LN/Al_2O_3 with positive poling process

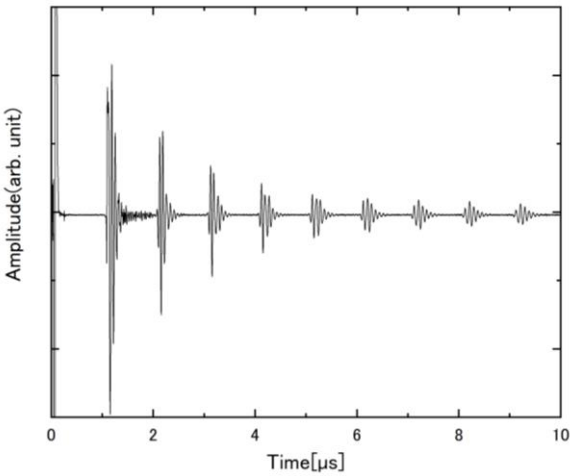

Fig. 4 Ultrasonic response of LN/Al_2O_3 with negative poling process

4. Conclusions

In this study, LN/Al_2O_3 sol-gel composite ultrasonic transducers were fabricated at the first time by automated spray method. The samples were able to be poled negatively and positively at 400℃ by corona discharge.

The difference between positive and negative poling did not give a significant effect on the SNR of the ultrasonic response at room temperature. However, the positively poled sample tended to have a higher amplitude than the negatively poled sample.

In the future, ultrasonic measurements at high temperatures will be performed to investigate the high temperature durability of LN/Al_2O_3

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