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High Temperature Performance at 700℃ of $LiNbO_3/Bi_4Ti_3O_{12}$ Ultrasonic Transducer Composite

$LiNbO_3/Bi_4Ti_3O_{12}$超音波トランスデューサの 700°Cでの超音波特性に関する研究

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1. Introduction

In recent years, on-line ultrasonic nondestructive testing (NDT) in the industrial fields has been demanded. One of the main nondestructive inspection methods is ultrasound using an ultrasonic transducer. Compared with conventional ultrasonic sensors, no coupling agent nor backing material is required, so ultrasonic NDT can be performed at high temperature during operation. Non-destructive inspection during high-temperature operation has been desired to assure safety and reduce economical loss during shut-down. In addition, new thermal power plants require operating temperatures up to 700°C, so high temperature durable ultrasonic transducers are required to monitor new system during test operation.

In previous research, sol-gel composite ultrasonic transducers by $LiNbO_3$(LN)/$Bi_4Ti_3O_{12}$ (BiT) demostrated high temperature ultrasonic performance up to 1000°C.[1)] It indicated that LN/BiT sol-gel composite ultrasonic transducers were able to operate at 700°C, though no long-term durality test was operated yet. In this study, thermal cycle test at 700°C and ultrasonic measurements at 700°C for 48 hours were executed to confirm the high temperature durability of LN/BiT ultrasonic transducers at 700°C.

2. Fabrication of $LiNbO_3$/BiT sol-gel composite samples

LN/BiT samples were manufactured by sol-gel spray technique.[2-5)] LN piezoelectric powders and BiT sol gel solution were mixed in a ball mill machine. The thoroughly mixed solution was coated onto a 3 mm thick titanium substrate by spray method. The spray-coated sample was dried at 150 °C and calcined at 650°C for 5 minutes each. These processes were repeated to produce a LN/BiT sample having a film thickness of 50μm. Thereafter, an electrode having a diameter of 1 cm was formed on the sample by using platinum paste, and the electrode was subjected to poling treatment. Poling was performed by applying a corona discharge to a sample from 900°C to room temperature conditions. The optical image of LN/BiT sample is shown in **Fig. 1**.

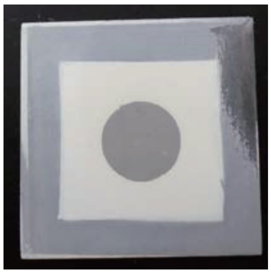

Fig.1 Optical image of LN/BiT film fabricated on 3mm thick titanium substrate.

3. Experimental results

First, three thermal cycles of LN/BiT were performed. The ultrasonic response was measured at each temperature while increasing the temperature from room temperature by 100°C. After 5min holding time at each temperature, ultrasonic response was recorded by a digital oscilloscope up to 700°C. The ultrasonic response of LN/BiT at 700°C in the third cycle is shown in **Fig. 2**. From Fig.2, reflected echoes from the bottom of the titanium substrate were clearly confirmed in the third thermal cycle.

Thermal cycle test results of LN/BiT are shown in **Fig.3**. The sensitivity was calculated as following;

$$\text{Sensitivity} = -(20\log_{10}V_1/V_2 + \text{gain of P/R})\ (\text{dB}) \quad (1)$$

where V_1 is the ideal amplitude, 0.1 (V) in this experiment, V_2 is the amplitude (V) of the second reflected echo from the bottom surface of the substrate. From Fig.3, the sensitivity slightly dropped after 1st thermal cycle due to permanent depoling component. Even though the temperature stability is high, the sensitivity is lower than previous study. It was caused by sample individual variability due to manual spray coating..

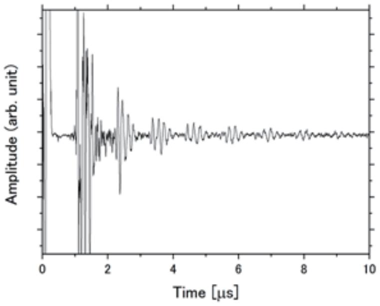

Fig.2 Ultrasonic response of LN/BiT at 700°C in the third cycle

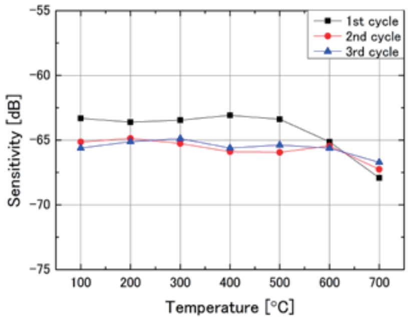

Fig.3 Thermal cycle test results of LN/BiT.

Next, a long-term of LN/BiT test was performed at 700 °C for 48 hours. The ultrasonic response that heating starts at 700 °C is shown in **Fig. 4**. Ultrasonic response continued heating for 48 hours is shown in **Fig. 5**. From Figs. 4 and 5, there is no significance difference. The FFT result of the second wave in Fig.5 is shown in **Fig.6**. The center frequency and 6 dB bandwidth of LN/BiT sample were 5.72 MHz and 4.19 MHz. Center frequency was relatively low even though film thickness was just 50μm. It also indicates low film quality.

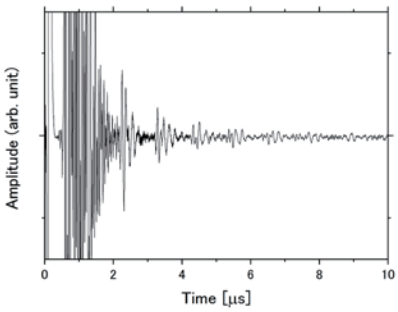

Fig.4 Ultrasonic response of LN/BiT at 700°C after 0h.

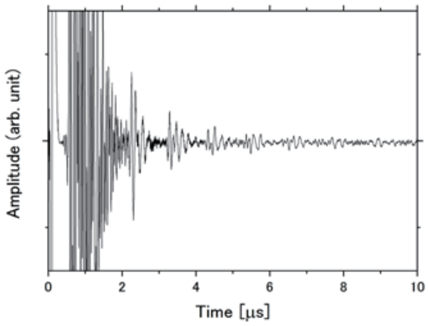

Fig.5 Ultrasonic response of LN/BiT continued heating at 700°C after 48 hours.

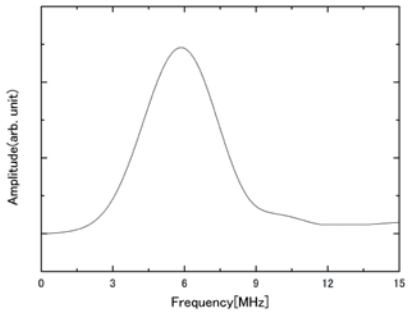

Fig.6 Ultrasonic response in frequency domain of the second reflected in Fig.5

4. Conclusions

LN/BiT sol-gel composites were fabricated on 3mm thick titanium. Throughout the thermal cycle test up to 700°C, sensitivity was very stable. In addition, long-term test was conducted and no significant difference was confirmed after 48hour heating. However, sensitivity was lower than precious study probably due to low film quality and it is necessary to fabricate LN/BiT films by automatic spray system for further evaluation.

References

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