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Influence on Sol-Gel Composite Properties Caused by Sol-Gel Phase with Different Dielectric Constants

異なる誘電率のゾルゲル相によるゾルゲル複合体全体特性への影響

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1. Introduction

Ultrasonic transducer using a sol-gel composite method has been investigated in the field of non-destructive testing. Sol-gel composite material is made by mixture of piezoelectric powder and sol-gel solution[1], and the combination of piezoelectric powder and sol-gel solution in the sol-gel composite method has been studied for the development of new composite materials with desirable characteristics. It is known that the dielectric constants of the sol-gel phase and the piezoelectric powder phase influence the sol-gel composite performance. $Pb(Zr,Ti)O_3$ (PZT)/Al_2O_3, which is composite of PZT piezoelectric powder and aluminum oxide sol-gel solution, showed about 80pC/N lower piezoelectric constant d_{33} than that of PZT/PZT.[2] From this result, it seems that the high dielectric constant of the sol-gel phase is preferable. In addition, it was suspected that the composite consisting of sol-gel solution with high dielectric constant and piezoelectric powder with low dielectric constant could have superior sensitivity.[3] However, quantitative study about the relationship of sol-gel phase and piezoelectric powder has not been performed.

In this study, 2 sol-gel composite materials, with same piezoelectric powder and different dielectric constant sol-gel solution, were fabricated and their properties were compared quantitatively.

2. Sample Fabrication

$Bi_4Ti_3O_{12}$ (BiT) and PZT sol-gel solution were manufactured and X-ray diffraction (XRD) was performed for BiT sol-gel solution. XRD for PZT sol-gel solution was omitted in this paper because it was performed in the previous study.[4]

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To synthesis the target material, BiT sol-gel solution was heated up for 30 minutes each at 150℃, 450℃ and 650°C. XRD result of BiT sol-gel powder is shown in **Fig. 1**. In Fig. 1, all peak were obtained from ferroelectric BiT. It indicated that BiT was successfully synthesized by BiT sol-gel precursor solution.

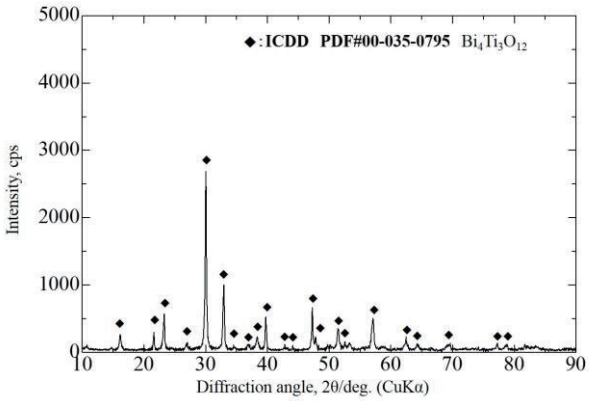


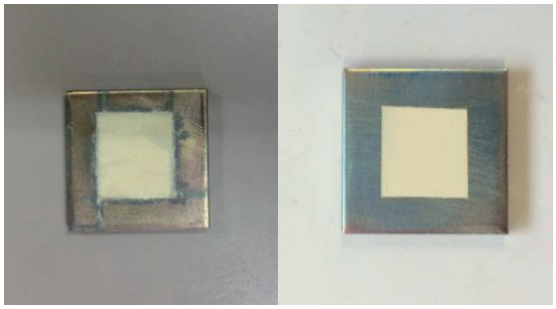
Fig. 1 XRD result of BiT sol-gel powder after heating treatment

After preparing BiT and PZT sol-gel solution, ultrasonic transducer made by $PbTiO_3$ (PT)/BiT and PT/PZT sol-gel composite films were manufactured. PT was chosen because it has relatively low dielectric constant and relatively high piezoelectric constant.[5] The mixtures of PT powder and each sol-gel solution were ball milled for more than a day. Then, the mixtures were sprayed onto titanium substrates. Titanium substrates has dimensions of ~3mm thickness, ~30mm length, ~30mm width. After spray coating, drying process at 150℃, and firing process at 650℃ for 5 minutes each were operated. Those spray coating process and thermal process were repeated until substrates could not be observed by an optical microscope. After this process, poling were operated by corona discharge using a pulse power source at room

temperature. The output voltage of the pulse power supply, pulse width and frequency were 20kV, 5.000μs and 2kHz, respectively. Poling process was operated for 15 seconds.

3. Experimental results

First, optical images of PT/BiT and PT/PZT films onto titanium substrate were shown in **Fig.2**. Films thickness of PT/BiT and PT/PZT were measured by a micrometer and the values were ~10μm and ~9μm, respectively. d_{33} of PT/BiT and PT/PZT films were measured by ZJ-3B piezo d33 meter and the values were 0.3pC/N and 1.6pC/N, respectively. Capacitance of PT/BiT and PT/PZT films were measured by a LCZ meter and the values were ~179pF and ~142pF, respectively. Despite substantially the same film thickness and poling conditions, value of d_{33} was higher PT/PZT than PT/BiT. It could be explained that electric field used during poling process was applied more efficiently to the PT powder of PT/PZT than that of BiT/PZT since PZT sol-gel solution has higher dielectric constant than BiT sol-gel solution.



(a) (b)

Fig. 2 Optical images of films made by (a) PT/BiT and (b) PT/PZT onto titanium substrate.

Ultrasonic responses of the PT/BiT and PT/PZT films were monitored in pulse-echo mode and reflected echoes from the bottom surface of titanium substrate were observed as shown in **Figs. 3** and **4**. Center frequency of PT/BiT and PT/PZT were ~29MHz and ~34MHz, respectively. Fig. 4 shows clear multiple echoes of PT/PZT from surface of titanium substrate could be obtained. However, Fig. 3 shows echoes of PT/BiT showed lower signal strength than PT/PZT, in addition, signal-to-noise ratio (SNR) was also poor. This result was reasonably agreed with d_{33} measurement result difference, caused by dielectric constant difference of sol-gel phase.

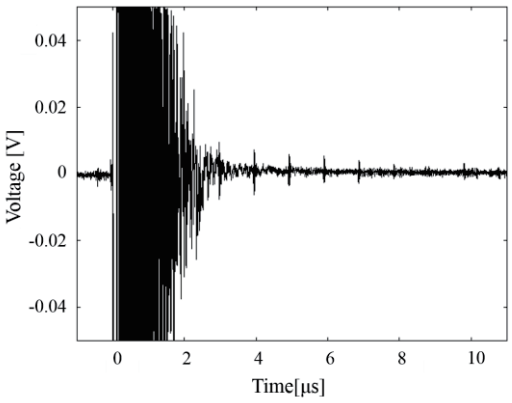


Fig. 3 Ultrasonic response of PT/BiT ultrasonic transducer on ~3mm thick titanium substrate.

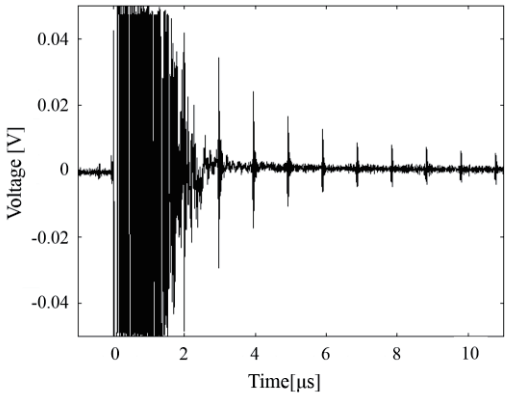


Fig. 4 Ultrasonic response of PT/PZT ultrasonic transducer on ~3mm thick titanium substrate.

4. Conclusions

PT/BiT and PT/PZT sol-gel composite films were fabricated onto titanium substrates. PT/PZT demonstrated higher d_{33} value, signal strength and SNR than those of PT/BiT. These results show whole performance of the sol-gel composite could be improved by using sol-gel solution with high dielectric constant.

References

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