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A Study of Ultrasonic Transducer using Lithium Niobate at High Temperature

ニオブ酸リチウムを使用した高温環境用超音波振動子に関する研究

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1. Introduction

Ultrasonic technologies are used in mixing process for producing materials, and lead zirconate titanate is utilized in a number of ultrasonic mixers.[1, 2] However, the curie temperature of lead zirconate titanate is approximately 300 degrees, and the electromechanical coupling factor rapidly drops to zero at approximately 280 degrees. Therefore, ultrasonic application of lead zirconate titanate cannot be used in environment above 280 degrees.[3]

The curie temperature of lithium niobate is 1210 degrees, and material property of lithium niobate is suitable for actuator.[4] Some research have been reported about the ultrasonic actuators using lithium niobate.[5, 6, 7]

In this study, we aim to design an ultrasonic transducer using lithium niobate which can drive in environment above 280 degrees. Additionally, we have evaluated the transducer in the environment from room temperature to around 300 degrees.

2. Design and fabrication

In this research, we designed bolt-clamped Langevin-type ultrasonic transducer using lithium niobate which orientation is 36 degrees y-cut. This transducer generates longitudinal vibration.

We designed the transducer using finited element method analysis results. The dimensions of a transducer were decided by this analysis. The transducer generates primary mode of longitudinal vibration at 45.2 kHz from result of analysis. The photograph of fabricated transducer and the structure of transducer are shown in **Figs. 1** and **2**, respectively. The length and diameter of transducer are 56 and 14 mm. This transducer consist of a stainless steel body of transducer, a stainless steel bolt, a stainless steel nut, four lithium niobate rings and five phosphor bronze electrodes. The thickness of one lithium niobate ring is 3.8 mm. Gold thin film was deposited on both surfaces of the ring. This thin film has on effect of applying even voltage and even pressure to lithum niobate rings.

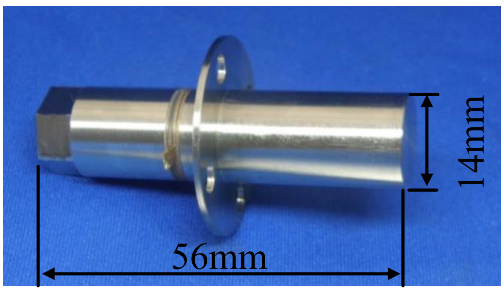

Fig. 1 Photograph of fabricated transducer

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3. Evaluation at room temperature

First, we decided the pre-stress of the transducer. The relationship between the applied pre-stress and the admittance of transducer is shown in **Fig. 3**. When the applied pre-stress increases, the admittance also increase. However we cannot apply pre-stress more than 18 Nm because the diameter of bolt is 7 mm. Therefore following results of experiment, applied pre-stress was 18 Nm, and resonance frequency is 42.1 kHz under this pre-stress.

Secondly, we measured the vibration velocity and the relationship between the appiled voltage and the vibration velocity at resonance frequency is

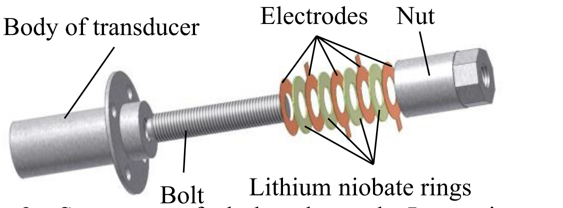

Fig. 2 Structure of bolt clamped Langevin-type ultrasonic transducer

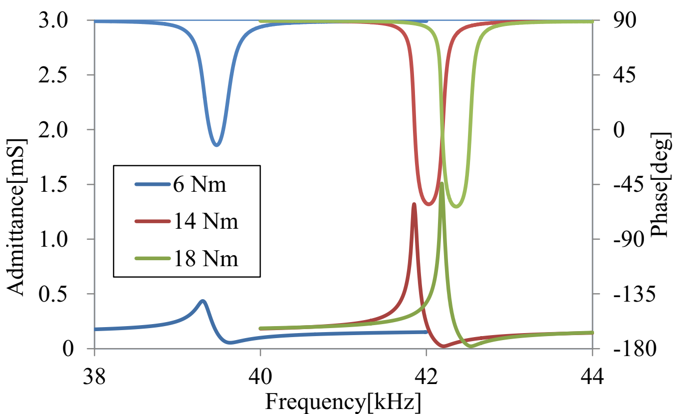

Fig. 3 Relationship between admittance and pre-stress

show in **Fig. 4**. The transducer generated longitudinal vibration at around 42 kHz. The applied voltage, up to 150 $V_{p\text{-}p}$, had linear relation with vibration velocity. The vibration velocity was 400 mm/s when applied voltage was 150 $V_{p\text{-}p}$, and the mechanical Q factor was 719.

4. Evaluation at high temperature

To evaluate thermal property of the transducer, we used a thermostatic oven to controll temperature. A photograph of experimental setup for evaluating thermal property is shown in **Fig. 5**. We measured the vibration velocity and the admittance at resonance frequency from room temperature to 300 degrees when the applied voltage was 100 $V_{p\text{-}p}$. The relationship between the vibration velocity and the adimittance with each temperatures is shown in **Fig. 6**. The relationship between the vibration velocity and the driving frequency is shown in **Fig. 7**. As shown in the graph, the resonance frequency is decreased with temperature increase. This is because, Young's modulus of the transducer materials decreases with increasing temperature. The vibration velocity at 300 degrees was 414 mm/s, and the mechanical Q factor was 918. That the vibration velocity increase with increasing temperature.

5. Conclusion

We have designed the transducer using lithium niobate for driving above 280 degrees, and we have evaluated the thermal property of the transducer. In this driving experiment, the transducer could generate longitudinal vibration from room temperature to 300 degrees. We confirmed that the vibration velocity increased with increasing temperature.

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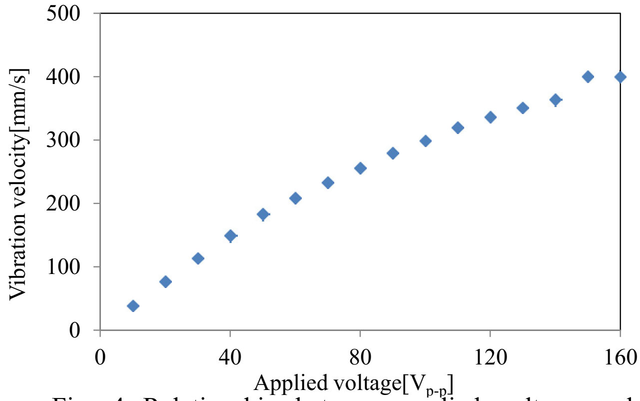

Fig. 4 Relationship between applied voltage and vibration velocity at 25 degrees

Fig. 5 Photograph of experimental setup for evaluating performance about thermal temperature condition

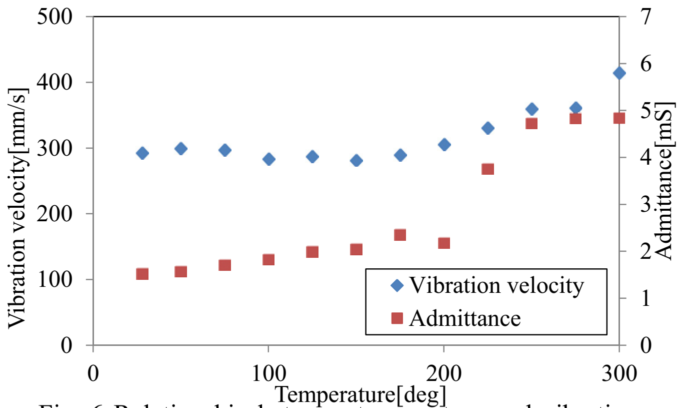

Fig. 6 Relationship between temperature and vibration velocity

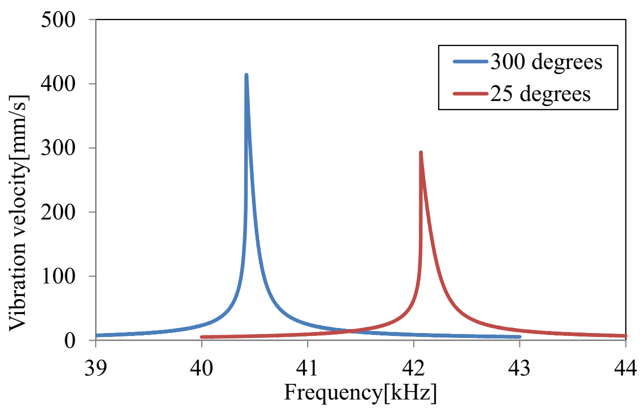

Fig. 7 Relationship between vibration velocity and temperature