3P4-13
Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

Characteristics of large amplitude vibration velocity of hydrothermally deposited $KNbO_3$ films ultrasonic transducers using thickness vibration mode.

水熱合成 KNbO3 膜を用いた超音波トランスデューサの大振幅特性

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1. Introduction

Recently, high-frequency ultrasonic transducer is proposed for medical applications using piezoelectric crystal. For high power application such as ultrasonic cleaner or actuators, it is important to have high piezoelectric constant and higher limitation of vibration velocity. Therefore we measured limitation of vibration velocity of Potassium Niobate ($KNbO_3$) thick films by the hydrothermal method. The limitation of vibration velocity obtained was very high. Actually, the prototype high-frequency ultrasonic transducer was able to radiate high intensity ultrasound at 4MPa or over.

2. Experimental Procedure

$KNbO_3$ piezoelectric films have many advantages for piezoelectric sensor because it has good piezoelectricity and mechanical electrical coupling factor. However the films of $KNbO_3$ materials have not been utilized for the high frequency ultrasonic transducers because it is difficult to fabricate the $KNbO_3$ films for the high frequency ultrasonic transducers by piezoelectric thickness mode vibration. Therefore, we have reported to deposit 150 μm $KNbO_3$ films using hydrothermal method such as Fig.1.

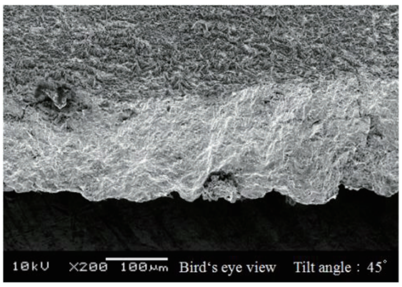
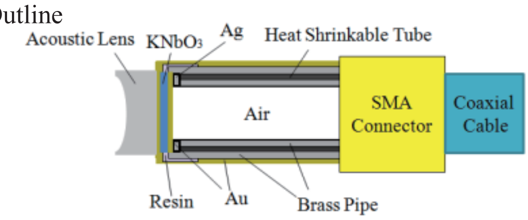


Fig.1 150 μm-$KNbO_3$ thick films by hydrothermal method.

The $KNbO_3$ thick films were grown at 240 ºC on $(100)_c$ Nb-$SrTiO_3$ substrates by the hydrothermal method[1-3]. An autoclave (PARR, 4748) that contained an inner vessel made of Teflon to resist high alkali solutions was utilized for the hydrothermal growth. A 20 m*l* solution of 10 mol/*l* KOH (Kantokagaku) and 1.0 g of niobium oxide powder (Nb_2O_5, purity 99.95%, Kantokagaku) were used as source materials of K and Nb, respectively. The $(100)_c$ Nb-$SrTiO_3$ substrate was kept facing down with a Teflon folder in the inner vessel, and the above-mentioned source materials were mixed and placed in the autoclave. The autoclave was shut tight and placed in a constant-temperature oven (Yamato DS-400) maintained at 240 ºC for a hydrothermal chemical reaction. The epitaxial 150 μm $KNbO_3$ thick films were obtained with repetition of above reaction.

The epitaxial $KNbO_3$ films were peeled from $SrTiO_3$ substrate. And then a prototype transducer was fabricated such as Fig.2.

a) Outline



b) Picture

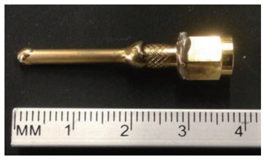


Fig.2 Structure of prototype ultrasonic transducer with $KNbO_3$ thick films

Flat type and a focus type ultrasonic transducer were prepared for measurements of the ultrasonic radiation. Both ultrasonic transducers have air structures and SMA connectors that are used for high frequency driving. The air structure is a backing material for the purpose of ultrasonic reflection to front of apertures. The piezoelectric $KNbO_3$ films are covered by electrode. And the electrode is connected to signal line and grand line respectively. The flat type is able to radiate ultrasound beam in water. And the focus type is able to make focal point for more high intensity ultrasound compared to the flat type.

First, the vibration velocity and frequency characteristics of the prototype transducer were measured by LDV(Polytec OFV-3001). The vibration velocity was measured at surface of the prototype transducer. A peak of vibration velocity of thickness mode was around 10MHz at flat type ultrasonic transducer. The mechanical factor was approximately 5 in this case. Next, the radiated ultrasound at resonance frequency was measured by kept hydrophone (EASTEK, TNU001A) in water.

3. Experimental Results

Figure 3 shows the vibration velocity at resonance frequency of ultrasonic transducer with $KNbO_3$ 150 μm films. The vibration velocity has a linearity relationship between the applied voltages until 1 kV. The ultrasonic transducer didn't break down till 1.5kVp-p or over. When the applied voltage was 250 Vp-p, the vibration velocity was 0.8m/s or over. And maximum value of vibration velocity was 2.5m/s or over. This value indicates that the $KNbO_3$ ultrasonic transducer has the potential for high power ultrasonic radiation without high mechanical factor. This is the superiority value compared to the PZT ceramics which is the major piezoelectric material.

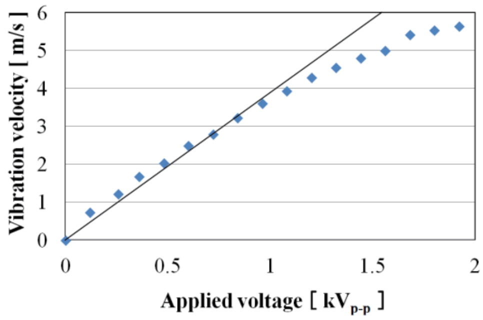


Fig.3 Relationship between applied voltage and vibration velocity of prototype ultrasonic transducer.

Figure 4 shows the resonance frequency of the flat and focus prototype $KNbO_3$ ultrasonic transducers that measured by hydrophone. Broad peaks of thickness mode appeared at approximately 11 MHz respectively. Also, the quality factor of the resonance frequency was approximately 3. The driving voltage was arbitrarily value that was utilized for measurement of resonance frequency.

Figure 5 shows result of measurement of the radiated sound pressure. Also, the radiated sound pressure has a linearity relationship between the applied voltages until 3 MPa respectively. And the maximum pressure was approximately 4MPa or over. This value is very high ultrasound and enough value for several high intensity ultrasonic applications. Additionally, the 4MPa was limit due to our set up.

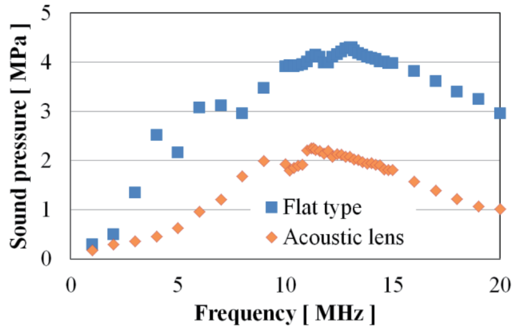


Fig.4 Relationship between driving frequency and radiated sound pressure using prototype ultrasonic transducer.

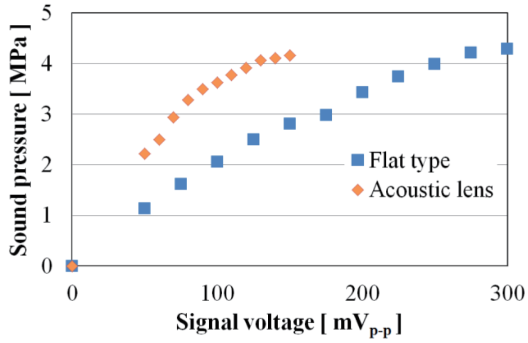


Fig.5 Relationship between signal voltages and radiated sound pressure with prototype ultrasonic transducer.

4. Conclusions

We measured the limitation of the vibration velocity and radiated sound pressure at resonance frequency of thickness mode of the 150 μm $KNbO_3$ films ultrasonic transducers. The maximum vibration velocity was 2.5m/s or over. And the proto type ultrasonic transducer is able to radiate at 4 MPa. A simulation value of radiation sound pressure from vibration velocity was almost same. The reason of the

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