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Thick PZT epitaxial film for ultrasonic transducer in the 80 MHz range

PZT エピタキシャル厚膜を用いた 80 MHz 帯の超音波トランスデューサ

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1. Introduction

The frequency range of 20−100 MHz ultrasonics are promising for photoacoustic imaging [1], which is useful to observe blood *in vivo* at high resolution. PVDF (Polyvinylidene Difluoride) is a common material[2] for ulrasonic transducers for photoacoustic imaging as shown in **Fig. 1**. However, electromechanical coupling of PVDF (k_t^2=4%[2]) is too low for practical application. On the other hand, PZT is an attractive material for applications such as medical imaging, resonator and so on due to its high k_t^2. We previously reported high k_t^2 of 28.1%[3] of PTO (the PZT family) epitaxial thin films.

In order to achieve lower frequency operation, thicker film is one of the approaches. However, internal stress control becomes more difficult as the film gets thicker. Many studies of PZT thick film transducers, therefore, were centered on the use of polycrystalline films.

In this study, we reports sputter PZT epitaxial thick film (16.0 μm) high efficient transducer operating in the 20−100 MHz.

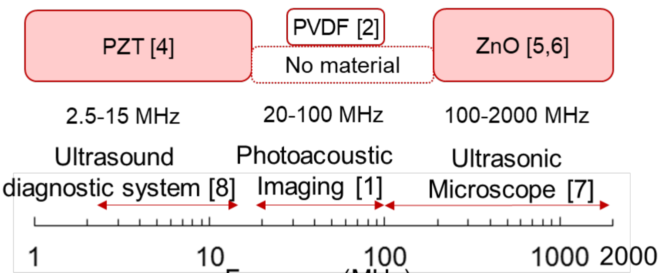

Fig. 1 Relationship between the operating frequency and ultrasonic measurement system.

2. Growth of PZT thick film

PZT thick films were grown on conductive single crystalline La−$SrTiO_3$ (La−STO) substrate by RF magnetron sputtering [9,10], as illustrated in **Fig. 2**. Growth conditions are summarized in **Table I**. The substrate is at the floating potential to reduce the effects of ion−irradiation−induced stress during the deposition.

Next, we measured crystalline quality of the PZT thick film. As shown in **Fig. 3**, strong PZT (002) peak was observed at around 2θ=43º. (002) peak rocking curve FWHM of the PZT were measured to be 0.4º which shows high crystalline quality.

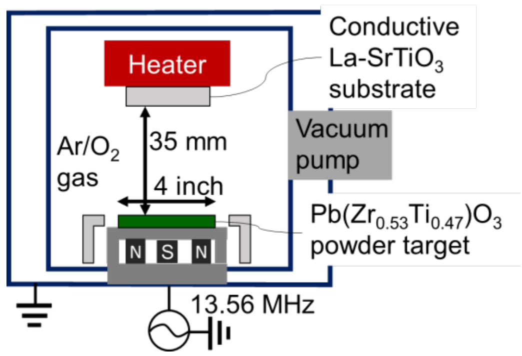

Fig. 2 The RF magnetron sputtering system.

Table I Growth conditions

Ar/O_2	20
Deposition time	100 hours
RF power	100 W
Deposition pressure	0.5 Pa
Deposition temperature	500 °C

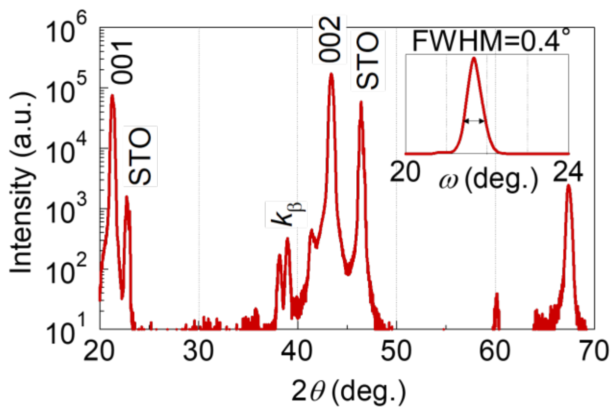

Fig. 3 XRD pattern and rocking curve of the PZT thick film.

3. Evaluation of the electromechanical coupling k_t^2

We fabricated the high-overtone bulk acoustic resonator (HBAR) structure (Au/PZT/La-STO substrate).

Next, We obtained the impulse response by an inverse Fourier transform of the reflection coefficient S_{11} measured using a network analyzer (E5071C, Agilent Technology), as illustrated in **Fig. 4**. As shown in **Fig. 5**, ultrasonic echoes reflected from the bottom of the substrate were observed at 89 nsec. intervals. From longitudinal velocity and thickness of PZT and La-STO substrate, these echoes were determined to be longitudinal wave. Longitudinal wave conversion loss (CL) was calculated by a Fourier transform of the fist echo.

Fig. 6 shows experimental CL and theoretical one simulated by Mason's equivalent circuit model. The minimum CL of 2.8 dB was found at 89 MHz. k_t^2 estimated by comparison of experimental and theoretical CLs was 26.0%, which is much higher than that of PVDF (4%).

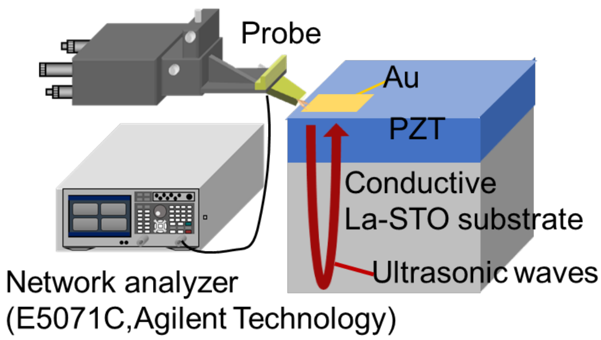

Fig. 4 Measurement system for longitudinal CL.

4. Conclusion

In recent years, ultrasonic applications are receiving attention in medical imaging for its safety and versatility to investigate various properties. Particularly, most photoacoustic microscopy uses transducers operating in the 20-100 MHz. However, PVDF commonly used for transducers in the 20-100 MHz exhibits low piezoelectricity.

In this study, we achieved PZT thick epitaxial growth (16 μm) by using RF magnetron sputtering. k_t^2 of the PZT is estimated to be 26.0%. This k_t^2 are much higher than that of PVDF (4%). Therefore, PZT thick film transducer is well suited for photoacoustic imaging and medical ultrasonic applications.

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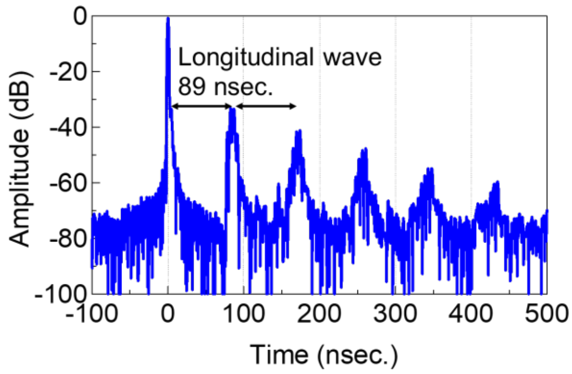

Fig. 5 The impulse response obtained by an inverse Fourier transform of the S_{11}.

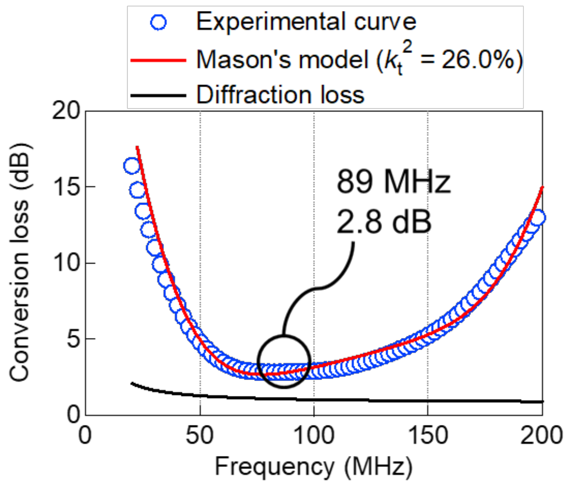

Fig. 6 Longitudinal CL curve of the PZT thick film transducer.

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