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GHz reflectometry fingerprint imaging using epitaxial $PbTiO_3$ ultrasonic transducers

GHz 帯 $PbTiO_3$ エピ薄膜を用いた基板裏面での
反射率測定によるイメージング

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1. Introduction

Fingerprint reader based on PZT and ScAlN pMUT in the MHz range are extensively studied. In contrast, fingerprint imaging using thickness extensional mode AlN transducers in the GHz range were reported to improve spatial resolution [1]. However, the capacitive impedance of the AlN transducer become much higher than 50 Ω when size of the acoustic source is reduced, because of low dielectric constant of AlN.

In this study, to obtain small acoustic source with 50 Ω impedance matching, we reports epitaxial $PbTiO_3$ (PTO) transducer which possess high dielectric constant and electromechanical coupling coefficient k_t^2 . Moreover, we propose insertion loss imaging using time domain analysis of network analyzer.

Here, fingeprint imaging with 9 $PbTiO_3$ transducer array are demonstrated.

2. Fabrication of $PbTiO_3$ transducer array

$PbTiO_3$ epitaxial films were grown on a conductive La-$SrTiO_3$ substrate by RF magnetron sputtering. The crystalline orientation of the $PbTiO_3$ film was examined by X-ray diffraction (PANalytical, X'pert pro). $PbTiO_3$(002) peaks were observed in 2θ-ω XRD patterns as shown Fig.1.

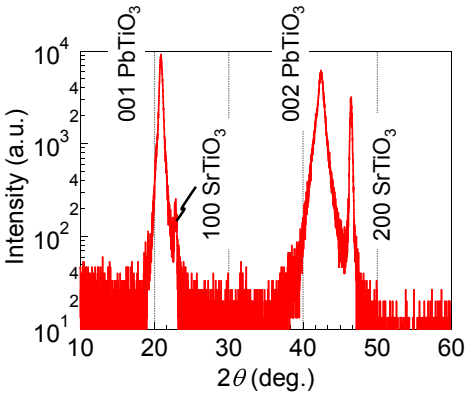

Fig. 1 XRD patterns of $PbTiO_3$ epitaxial film

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3. Conversion loss of $PbTiO_3$ transducer

Electromechanical coupling coefficient k_t^2 of $PbTiO_3$ epitaxial transducers was estimated from longitudinal wave conversion loss curves which was measured by a network analyzer (Keysight Technologies, E9031C) [3,4]. Fig. 2 shows experimental conversion loss curves of $PbTiO_3$ epitaxial transducers. Minimum conversion loss was 2.2 dB at 0.8 GHz. Also, described are the theoretical curves simulated by Mason's equivalent circuit model. The theoretical curves agreed well with the experimental curves. k_t^2 of $PbTiO_3$ was demonstrated to be 28.9%.

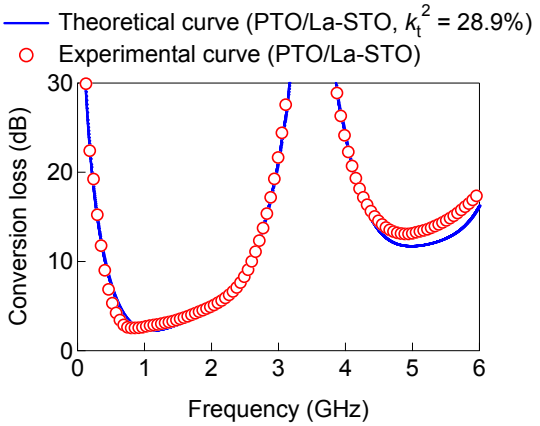

Fig. 2 Conversion loss of $PbTiO_3$ transducer

4. Insertion loss with and without elastomer

The thermoplastic elastomer was used as a substitute for the fingerprint. The difference of acoustic impedance between the substrate and the elastomer was smaller than that between the substrate and air. Insertion loss of piezoelectric film/substrate structure was degraded by contacting the elastomer due to the change of reflection coefficient of the substrate bottom/elastomer interface. Transducer insertion loss with and without elastomer were measured by a network analyzer. The maximum insertion loss with elastomer was 60%. On the other hand, maximum insertion loss without elastomer was 55%. The difference of reflection coefficient between with and without elastomer are confirmed.

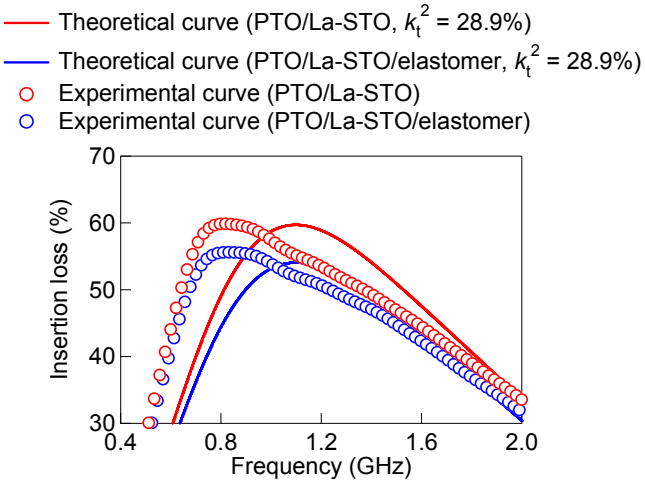

Fig. 3 Insertion loss curves of $PbTiO_3$ transducer with and without elastomer

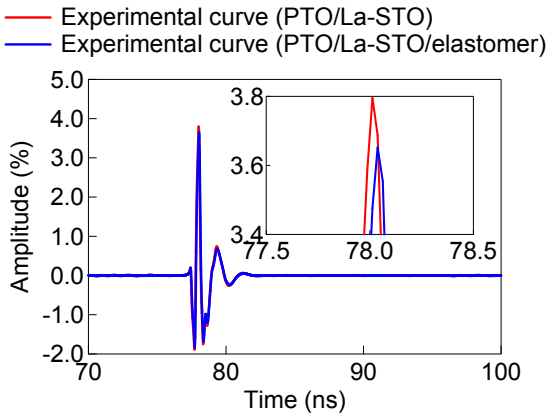

Fig. 4 Time domain impulse response of $PbTiO_3$ transducer with and without elastomer

4. Fingerprint imaging

The fingerprint elastomer phantom was contacted on the bottom of $PbTiO_3$ transducers. The maximum insertion loss images were obtained by mechanically scanning 9 $PbTiO_3$ transducer array. Fig. 6 shows the optical microscope image. Fig. 7 shows the acoustic maximum insertion loss image. Fig.8 shows the maximum first echo amplitude image.

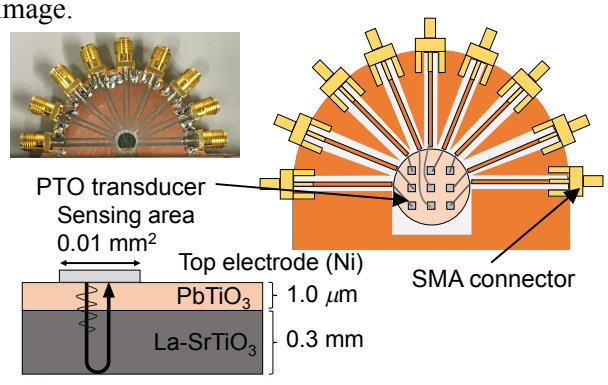

Fig.5 9 $PbTiO_3$ transducer array bonded the SMA connector and top electrode

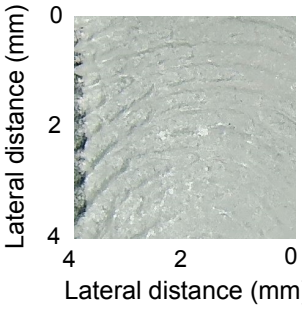

Fig. 6 Fingerprint phantom based on elastomer

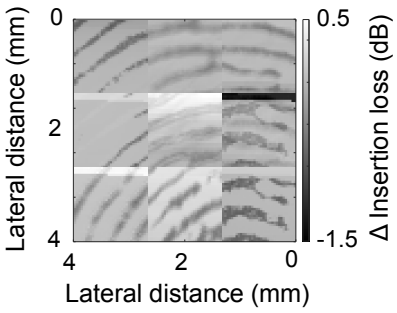

Fig.7 Maximum insertion loss image

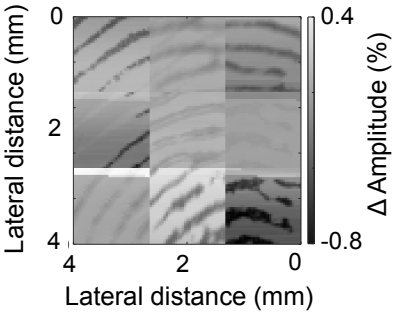

Fig.8 Maximum first echo amplitude image

5. Conclusion

$PbTiO_3$ epitaxial films were grown on conductive La-$SrTiO_3$ substrate. Electromechanical coupling coefficient k_t^2 of $PbTiO_3$ epitaxial transducers was 28.9%. We demonstrated phantom fingerprint imaging using 9 $PbTiO_3$ transducer array.

Acknowledgment

This work was supported by the JST CREST (N0. JPMJCR20Q1) and KAKENHI (Grant-in-Aid for Scientific Research No. 19H02202, and No. 21K18734).

References

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