SAW excitation by solid flat electrode on periodically polarization inverted structure

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1. Background

SAW filters using IDT electrodes have only been implemented up to 3.5 GHz[1)], because IDT electrodes have the problem of high-power durability when the line width of IDT electrodes become narrow. We have proposed a structure that enables SAW excitation using solid flat electrodes instead of IDT electrodes. In 2009, longitudinal BAW excitation by solid flat electrode using periodically polarization inverted Z-cut $LiTaO_3$ plate was reported[2)]. In this study, epitaxial $PbTiO_3$ piezoelectric thin films are used for periodically polarization inverted structure, as shown in **Fig. 1**.

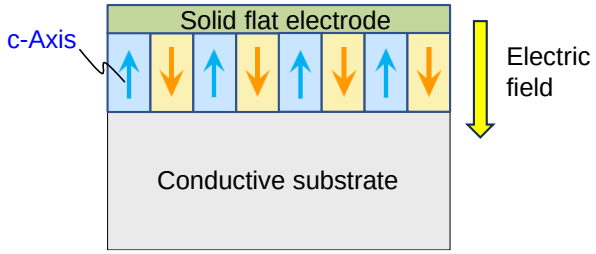

Fig. 1 Proposed structure using periodically polarization inverted piezoelectric thin films

2. FEM simulation

FEM simulations were performed to examine whether the proposed structure can excite SAW or not. **Fig. 2** shows the impedance response of the proposed flat electrode PTO SAW device obtained by FEM simulation. As a result, SAW excitation at 2.6 GHz was confirmed. We also compared conventional IDT structure with newly proposed flat electrode structure in the simulation. The same resonant frequencies were observed in both structures with the same PTO thickness, indicating that the proposed structure can excite SAW.

Fig. 3 shows h/λ-dependence of K^2 of the periodically polarization inverted c-axis perpendicular PTO SAW. This structure has the maximum K^2 of 19.2% at h/λ=0.23. Also, the proposed structure using 35º tilted PTO thin film as the maximum K^2 of 11.5% at h/λ=0.44.

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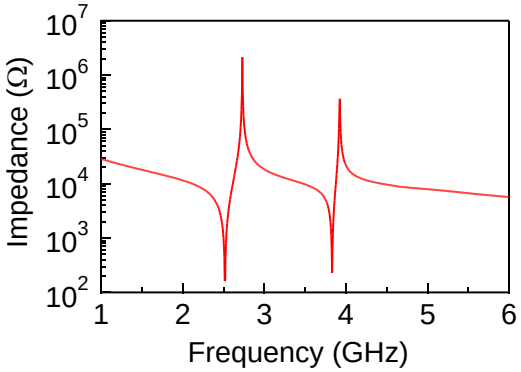

Fig. 2 Impedance response of the proposed flat electrode PTO SAW device obtained by FEM simulation

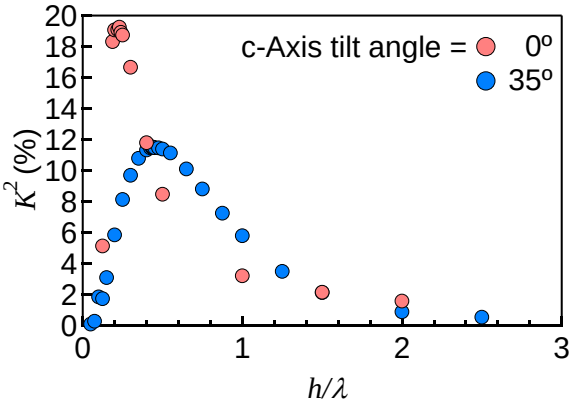

Fig. 3 h/λ-dependence of K^2 of the periodically polarization inverted PTO SAW obtained by FEM simulation (c-Axis tilt angle = 0º or 35º)

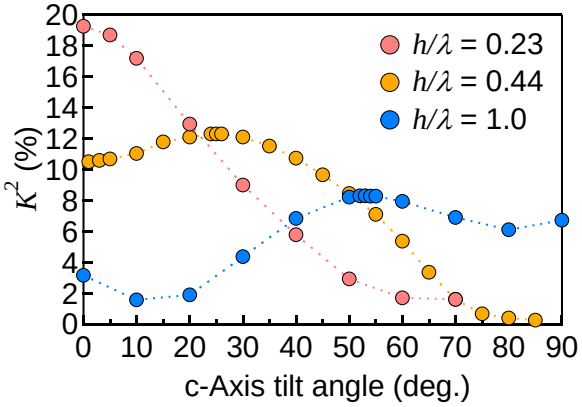

Fig. 4 c-Axis tilt angle-dependence of K^2 of the proposed flat electrode PTO SAW device obtained by FEM simulation (h/λ = 0.23 or 0.44 or 1.0)

Furthermore, **Fig. 4** shows c-axis tilt angle-dependence of K^2, indicating that the proposed structure with h/λ=0.23 has the maximum K^2 of 19.2% at c-axis tilt angle of 0º (c-axis perpendicular). In contrast, the proposed structure with h/λ=0.44 has the maximum K^2 of 12.3% at c-axis tilt angle of 25º, and that with h/λ=1.0 has the maximum K^2 of 8.3% at c-axis tilt angle of 53º. The above results indicate that the proposed structure using c-axis tilted piezoelectric thin film has higher K^2 at higher h/λ, i.e., using thicker piezoelectric film.

4. Experimental results

4.1 Fabrication

To fabricate periodically polarization inverted structure, epitaxial $PbTiO_3$ films (1.8 μm) were grown on conductive La-doped $SrTiO_3$ substrate (0.2 mm) by RF magnetron sputtering. 4 μm IDTs (Au) for polarization inversion were fabricated on the PTO films. Then, from 0 to 25 V DC electric field was applied only under the IDT. After the polarization inversion, the IDT was removed, and the solid flat top electrode (Au) was fabricated. In the same way, we also fabricated 25º tilted epitaxial PTO SAW device on 25º off-angle conductive La-doped STO.

4.2 Characterization

Fig. 5 shows experimental impedance characteristics of flat electrode PTO SAW device. The impedance characteristics was measured using a network analyzer. The SAW excitation at 430 MHz was observed. The h/λ of the fabricated device was 0.225.

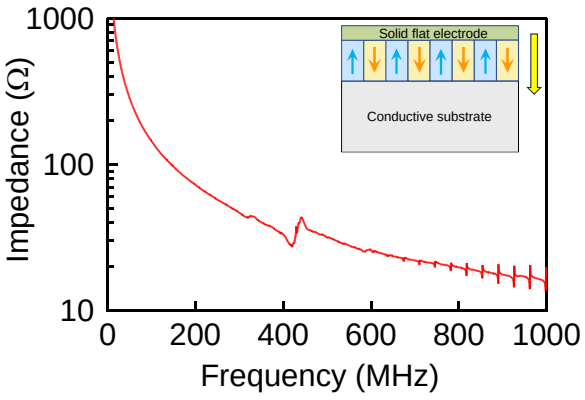

Fig. 5 Impedance response of the proposed flat electrode PTO SAW device

On the other hand, **Fig. 6** shows impedance characteristics of flat electrode SAW device using 25º tilted epitaxial PTO. The weak SAW excitation at 300 MHz was observed. The h/λ of the fabricated device was 0.1.

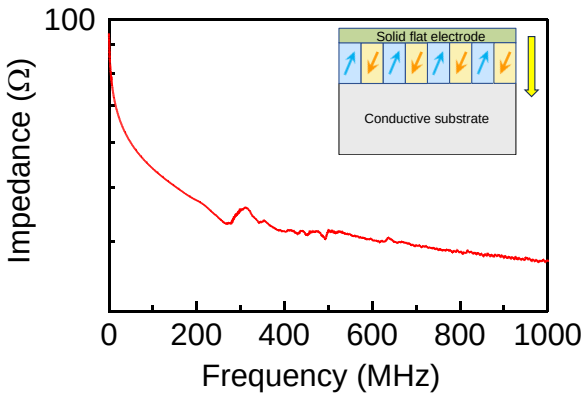

Fig. 6 Impedance response of the proposed flat electrode PTO SAW device using 25 º tilted PTO

5. Conclusion

We proposed periodically polarization inverted structure with a solid flat electrode that can excite SAW without the use of IDT electrode. FEM simulations confirmed that SAW excitation is possible with this structure. The fabricated flat electrode PTO SAW device (h/λ=0.225) showed SAW excitation at 430 MHz.

Acknowledgment

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References

1) Yan Liu, Yao Cai, Yi Zhang, Alexander Tovstopyat, Sheng Liu and Chengliang Sun, *Micromachines*, 11, 630 (2020).
2) M. Kadota, T. Ogami, K. Yamamoto, and Y. Cho, *IEEE IFCS*, 919 (2009).