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Polarity inverted PZT/PbTiO$_3$ epitaxial stack resonators for frequency switchable filters

周波数スイッチャブルフィルタを目指した
分極反転 PZT/PbTiO$_3$ エピタキシャル薄膜共振子

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1. Introduction

In recent years, increasing number of frequency filters due to global roaming is a problem to reduce the size of a mobile communication device. Frequency switchable filters are a promising solution to the problem. The switchable FBAR based on cubic BaSrTiO$_3$ (BST) stacks whose polarization and piezoelectricity can be induced by DC field are previously reported[1-2]. However, it is required to insert conductive layer between the two BST layers for the resonance mode switching.

On the other hand, coercive field of PbTiO$_3$ (PTO) is higer than that of PZT. In this study, we experimentally demonstrated frequency switching in PZT/PTO epitaxial stack resonators using different in coercive field of PZT and PTO, as shown in Fig. 1.

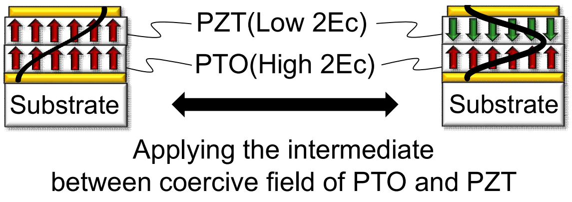

Fig. 1 Polarity inverted PZT/PTO epitaxial stack resonators for frequency switchable filters.

2. Growth of PZT/PTO epitaxial stacks

Single-layered PZT and PTO films and multi-layered PZT/PTO stacks were grown on conductive La-SrTiO$_3$ (STO) substrate by RF magnetron sputtering with powder target. The RF power, the total gas pressure and Ar/O$_2$ gas ratio were set to be 100 W, 0.5 Pa and 20, respectively. Next, top electrode Au were evaporated on PZT or PTO layer. We obtained High-overtone bulk acoustic resonator (HBAR) structure with Au/single-layered films or multi-layered stacks/La-STO.

3. Single-layered PZT and PTO films

Electromechanical coupling coefficient k_t^2 of single-layered PZT and PTO films were investigated from longitudinal wave conversion losses (*CL*) of the HBAR, which were measured by network analyzer (E5071C, Agilent Technologies). Fig. 2 shows experimental *CL* curves of the PZT and the PTO film resonators in as grown. Also described are theoretical one simulated by Mason's model. k_t^2 of the PZT and the PTO were estimated to be 14.4% and 17.6%, respectively.

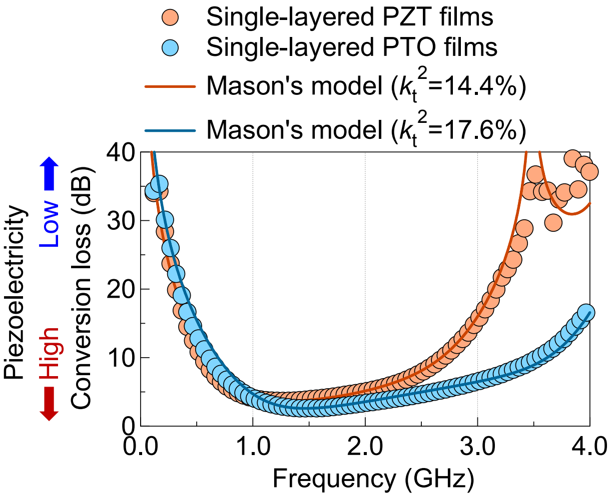

Fig. 2 Conversion loss curves of as grown single-layered PZT and PTO film resonators.

Next, coercive field (2Ec), which is enough high DC field for polarity inversion, of the PZT and the PTO films were investigated from minimum *CL* during the application of (1) 0 V to 24 V, (2) 24 V to 0 V, (3) 0 V to -24 V, (4) -24 V to 0 V, and (5) 0 V to 24 V, as shown in Fig. 3. In these cases, 2Ec of the PZT and the PTO films were estimated to be 220 kV/cm (-100 kV/cm, +120 kV/cm) and 470 kV/cm (-160 kV/cm, +310 kV/cm) from peaks of minimum *CL* where ultrasonic excitations are suppressed, respectively.

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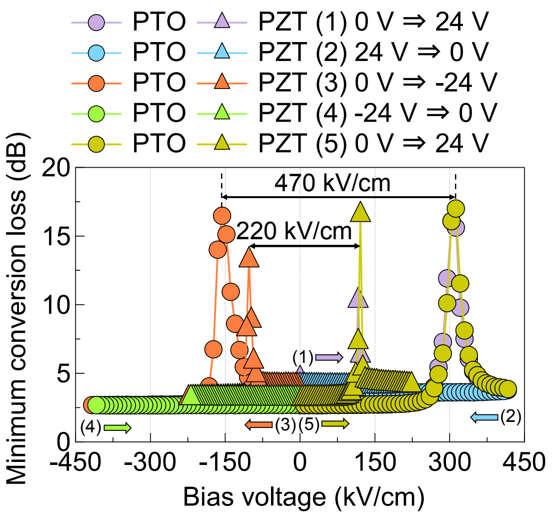

Fig. 3 Minimum conversion loss hysteresis curves of the PZT and the PTO films.

4. Multi-layered PZT/PTO stacks

Fig. 4 shows *CL* curves of the PZT/PTO stack resonators after applying ±34 V (±205 kV/cm). Second mode resonance at 1.58 GHz was observed, whereas fundamental mode resonance was suppressed when +34 V (+205 kV/cm) was applied. Experimental curve shows good agreement with theoretical one taking account of polarity inversion. In contrast, fundamental mode resonance at 0.56 GHz was observed, whereas second mode resonance were suppressed when -34 V (-205 kV/cm) was applied. From these results, the PZT/PTO stack resonators are able to switch between fundamental and second mode resonance by applying ±34 V (±205 kV/cm).

Next, minimum *CL* of the fundamental and the second mode during the application of (1) 0 V to 36 V, (2) 36 V to 0 V, (3) 0 V to -36 V, (4) -36 V to 0 V, and (5) 0 V to 36 V were measured. Fig. 5 shows minimum *CL* hysteresis curves. In the process (1), the minimum *CL* of the second mode increases with increasing the bias voltage, whereas that of the fundamental mode decreases. The minimum *CL* of the fundamental mode and the second mode are reversed at +100 kV/cm, which is almost the same as coercive field of the PZT. This shows polarity inversion of the PZT layer. In the processes (2) and (3), the minimum *CL* of the second mode decreases with decreasing the bias voltage, whereas that of fundamental mode increases. The minimum *CL* of the fundamental mode and the second mode are reversed again at -85 kV/cm, which is almost the same as coercive field of the PZT. This shows polarity inversion again of the PZT layer. In the processes (4) and (5), the resonance mode is switched from the fundamental to the second mode again, as expected.

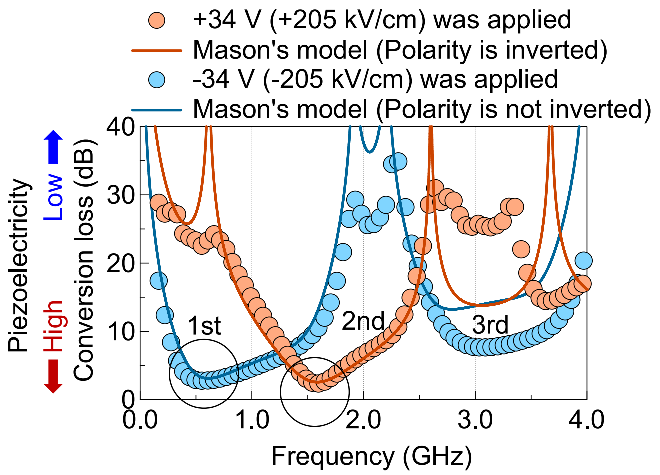

Fig. 4 Conversion loss curves of multi-layered PZT/PTO stack resonators after applying ±34 V (±205 kV/cm).

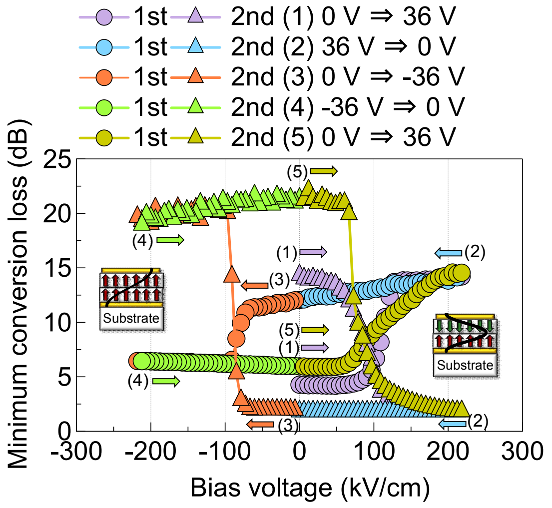

Fig. 5 Minimum conversion loss hysteresis curves of the PZT/PTO stacks.

5. Conclusion

The PZT/PTO epitaxial stacks were fabricated by an RF magnetron sputtering technique. Switching between fundamental and second mode resonance was observed by applying the DC field which is intermediate between coercive field of the PZT and the PTO. The resonators were attractive for frequency switchable filters in GHz range.

Acknowledgment

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References

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