Comparative Study of Piston Mode Designs for Temperature-Compensated Surface Acoustic Wave Resonators Using $SiO_2/LiNbO_3$ Structure

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1. Introduction

Temperature compensated SAW (TC-SAW) devices are widely used in recent mobile phones. The most popular technology is deposition of SiO_2 layer on interdigital transducers (IDTs) and reflectors placed on 128°YX-$LiNbO_3$ (LN) substrate [1-3].

In this configuration, one of the most important design goals is suppression of transverse mode resonances. The piston mode design is widely used for the purpose[4-7]. Three structures were used for realization of the piston mode operation, it is unclear which technique is best.

In this paper, three structures were applied to a TC-SAW resonator on 131°YX-LN covered by SiO_2, and achievable performances are compared..

2. Different Piston mode designs

Fig. 1 shows the cross-sectional view of SiO_2/ 131°YX-LN structure used for the analysis. Cu is chosen as the electrode material, and the top surface of covering SiO_2 layer is assumed to be flattened. The perfect matching layer (PML) is given at the bottom surface of LN. No additional loss is included in the simulation. Table I shows its design parameters.

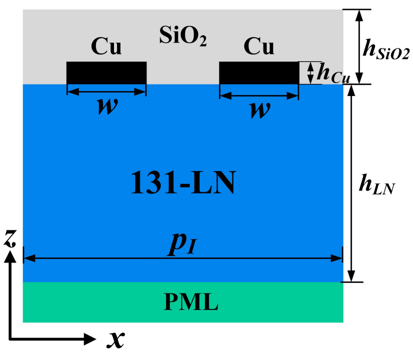

Fig. 1 sectional view of basic resonator design

Fig. 2 shows the top view of four IDT patterns used in this paper. PMLs are given to the left and right boundaries while the periodic boundary conditions are applied to the top and bottom boundaries. Fig. 2(a) shows the basic structure

Table I Used structural parameters

Parameter	Value	Parameter	Value
p_I	1.9 μm	Aperture	$16p_I$
h_{LN}	10 μm	Gap length	p_I
h_{Cu}	$5\%p_I$	Busbar width	$3p_I$
h_{SiO2}	$30\%p_I$	Metallization Ratio (MR)	0.5
w	$0.25p_I$		

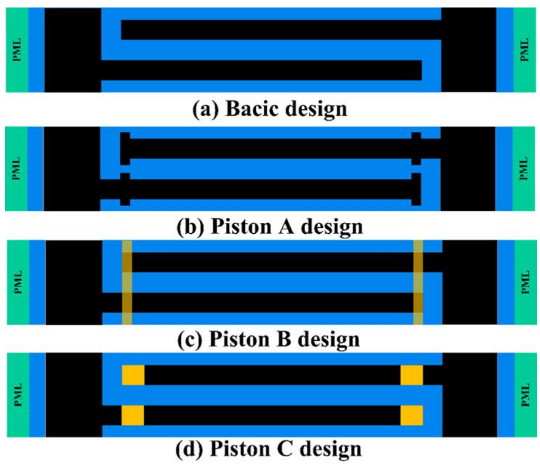

Fig. 2 Top view of four IDT patterns used for the discussion

without the piston design, and Fig. 2(b) shows the Piston A design with widened IDT electrode edges. Fig. 2(c) shows the Piston B design where heavy metal layers are added on the top surface of SiO_2 layer. The metal layers are located at the IDT electrode edges, and Fig. 2(d) shows the Piston C design where heavy metal layers are added to the IDT electrode edges.

Fig. 3(a) shows admittance (Y) and conductance (G) of the basic IDT design calculated by periodic 3D FEM. Transverse mode resonances are clearly seen above the main resonance. Fig. 3(b) shows calculated Y and G of the design A, where the MR of piston region is 0.9 and its length is 1 μm. Transverse modes could not be suppressed well using this design. This may be due to relatively large MR for the IDT region.

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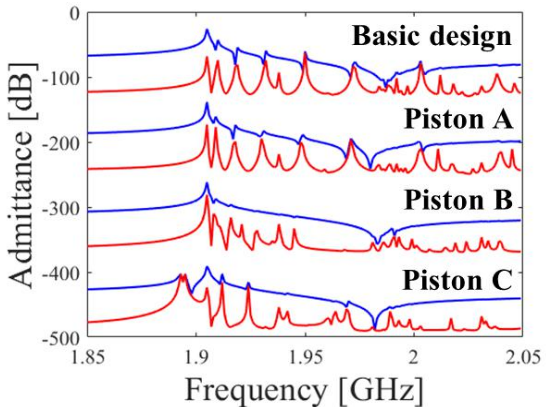

Fig. 3 Calculated admittance (Y) and conductance (G) of the basic TC-SAW resonator design and three Piston designs

Fig. 3(c) shows calculated Y and G of the design B, where the thickness and width of Cu line are 70 nm and 0.21 µm, respectively. It is seen that the transverse mode resonances are well suppressed.

Fig. 3(d) shows calculated Y and G of the design C, where Cu was chosen as the metal layer, and its thickness and length are 110 nm and 2.1 µm, respectively. MR of the piston region is 0.9 and its length is 1 µm. Although transverse modes are well suppressed at frequencies above 1.97 GHz, series of resonances remain below 1.97 GHz, and another spurious response appear below the main resonance.

Fig. 4 shows variation of Y and G of the design C with the Cu length. It is seen that the frequency of this spurious peak decreases with an increase in the Cu length. This indicates that this spurious peak is due to the guided mode mainly trapped in the heavy Cu region.

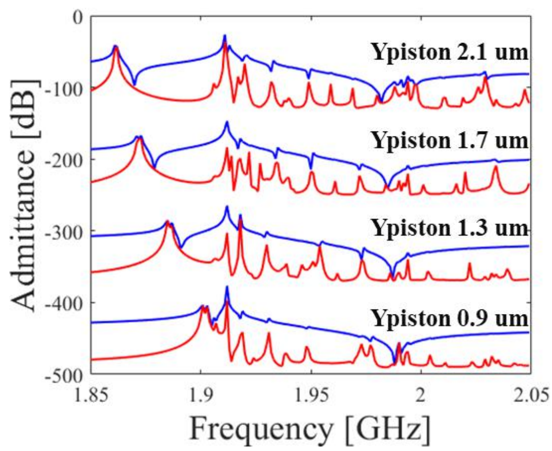

Fig. 4 Variation of calculated Y and G with the Cu length.

Among these three designs, Piston B offers the highest effective electromechanical coupling factor k^2 defined by separation between the resonance and anti-resonance. This may be due to lack of regions with large MR existing in Piston A and lack of the lowest spurious response appearing in Piston C.

Fig. 5 shows how the Bode Q [8] changes with the location. In the figure, the Q value at the anti-resonance is also shown for each design. It is seen that the Piston B design gives relatively high Bode Q values below 1.98 GHz, and thus offers the highest Q value at the anti-resonance.

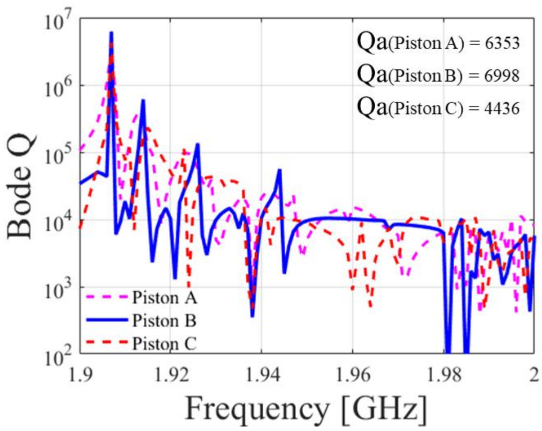

Fig. 5 Bode Q comparison of three PM designs

3. Conclusion

This paper discussed three different piston mode designs for the TC-SAW resonator. The piston B design showed better performance than other two designs. Since this conclusion may change with the SiO_2 and/or Cu thicknesses, we will check how these two parameters affect the device performance when these piston mode designs are applied.

Acknowledgment

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