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Suppression of Spurious Responses Near Anti-Resonance in Temperature Compensated SAW Devices

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1.Introduction

Temperature compensated SAW (TC SAW) devices using the SiO_2/128°YX-$LiNbO_3$ structure have been widely used in current smartphones[1]-[3]. One of their design challenges is suppression of spurious resonances, and the piston design is known to be effective to suppress transverse mode resonances without sacrificing the *Q* factor of main resonance[2]-[8]. Other types of spurious resonances also exist, and those caused by Love modes are often quite harmful because they appear near the main anti-resonance frequency[3]. Since this mode acoustically couples with the main Rayleigh mode, its transverse mode responses cannot be suppressed completely by simply adjusting the LN cut angle known to effective to suppress the *x*-propagating Love mode[3].

This paper studies spurious resonances near the antiresonance in TC SAW devices.

2. Piston Designs

Fig. 1 shows the cross-section view of unit cell of the TC-SAW used for the periodic 3D FEM. SiO_2 and Cu electrode thicknesses (H_{SiO2} and H_{elt}) are set at $0.25p_I$ and $0.05p_I$, respectively, where the p_I is the IDT period of 1.9 μm, and 131°YX-$LiNbO_3$ is chosen as the substrate for suppression of the *x*-propagating Love mode. The top surface of SiO_2 layer is assumed to be flattened.

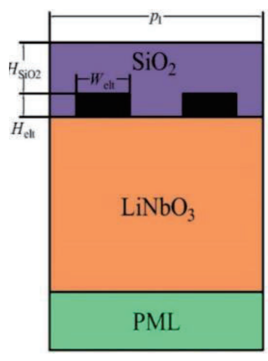

Fig. 1 Cross-section of resonator structure

Fig. 2 shows the top view of two piston mode designs. Design A: Cu stripes are placed on the SiO_2 top surface[5], and their thickness and width are set at $0.037p_I$ and $0.13p_I$, respectively. Design B: Cu dots are placed on the electrode edges directly[4][5], and their thickness and width are set at $0.037p_I$ and $0.35p_I$, respectively. The gap and busbar lengths (L_{gap} and L_{bus}) are set at $2p_I$ and $3p_I$, respectively.

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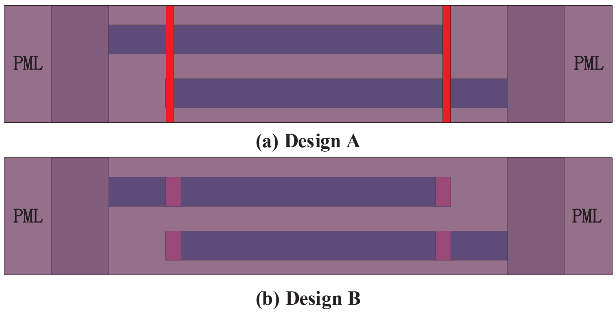

Fig. 2 Top view of two piston mode designs colored in red: (a) Design A: Cu stripes, and (b) Design B: Cu dots.

Fig. 3 shows calculated admittance *Y* and conductance *G* of these two designs. Both of these designs offer good transverse mode suppression. However, strong spurious resonances (S1, S2) are seen near the anti-resonance, and they are due to the Love mode. Note that behaviors of Love modes are influenced by the piston design.

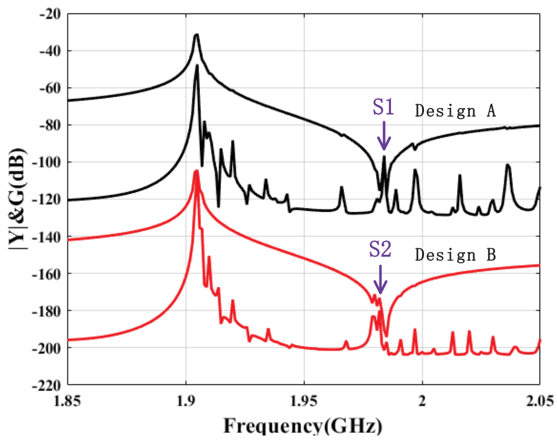

Fig. 3 Calculated admittance and conductance of designed resonators

3. Love mode suppression

The field distribution of S1 and S2 were studied, and it was found that the Love mode mainly concentrates its energy in the gap zones between IDT aperture and busbars. This implies that the Love mode responses may be controlled by adjusting the design of the zones without badly influence to the main response.

Here, we investigate thinning of the SiO_2 layer selectively in these zones (see Fig. 4). These “ditches” can be generated by the reactive ion etching[9]. In the following analysis, bottom of the ditches is assumed to be flat.

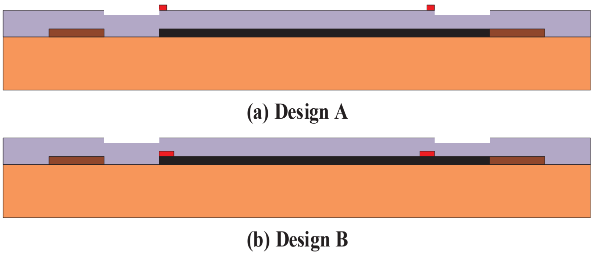

Fig. 4 Ditches in TC-SAW structures.

Fig. 5 shows variation of Y and G of Design A with the ditch depth (H_{ditch}). It is seen that the Love mode response becomes weaker with an increase of H_{ditch} and is well suppressed when H_{ditch} is $0.025p_{\mathrm{I}}$.

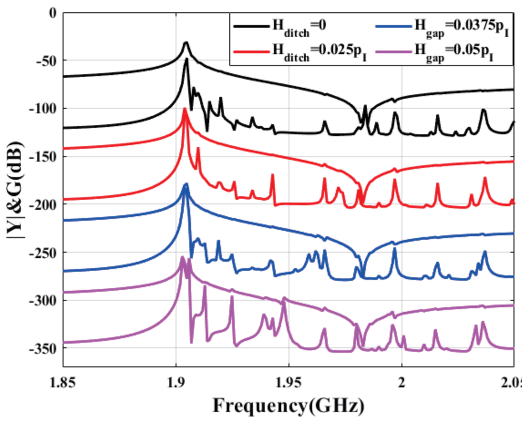

Fig. 5 Variation of G and Y of Design A with H_{ditch}.

Fig. 6 shows variation of Y and G of Design B with H_{ditch}. The H_{ditch} dependence is similar to that of Design A although the Design B seems less sensitive to H_{ditch} than Deign A. It is interesting to note that other spurious resonances are also suppressed well by setting H_{ditch} large although it causes split of the main resonance.

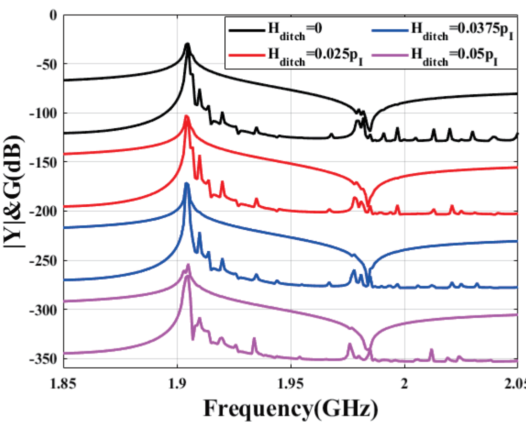

Fig. 6 Variation of G and Y of Design B with H_{ditch}.

It is known that this split can be suppressed by redesigning the piston structure[8]. Fig. 7 shows the calculated Y and G when H_{ditch} is set at $0.05p_{\mathrm{I}}$ for Design B and the Cu dot design is adjusted to $H_{\mathrm{piston}}=0.058p_{\mathrm{I}}$ and $W_{\mathrm{piston}}=0.22p_{\mathrm{I}}$. It is seen that most of all spurious resonances are disappeared without sacrificing the main response.

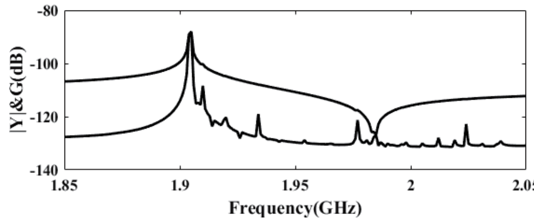

Fig. 7 Calculated Y and G for Design B when $H_{\mathrm{ditch}}=0.05p_{\mathrm{I}}$, $H_{\mathrm{piston}}=0.058p_{\mathrm{I}}$ and $W_{\mathrm{piston}}=0.22p_{\mathrm{I}}$

3. Conclusion

This paper discussed spurious resonances near the anti-resonance in TC-SAW. It was shown the spurious resonances can be suppressed well by thinning of the SiO_2 layer selectively in the gap zones between the IDT aperture and busbars. It was also found that most of spurious resonances can be suppressed under proper piston design in combination with the SiO_2 partial thinning.

Acknowledgment

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