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SAW velocity reduction on the layer structure

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1. Introduction

Further miniaturization is one of the hottest topics in SAW devices.

For the purpose, Mimura, et al, studied reduction of the Rayleigh SAW velocity using thick Pt electrodes embedded in the SiO_2/128-LN structure known as TC SAW[1,2)]. Nakagawa, et al, demonstrated reduction of SH SAW velocity using the I.H.P.-like structure[3)] composed of Al/Pt/50-LT/SiO_2/Si[4)]. Shi, et al, investigated the electrode configuration preferable for reduction of the SH SAW velocity on the low-cut LN substrate[5)].

This paper investigates use of I.H.P.-like structure for the SAW velocity reduction. It is shown that insertion of SiO_2 is crucial to achieve high electromechanical coupling factor k^2 in addition to the temperature compensation. On the other hand, use of high velocity substrate such as Si is also crucial for bringing spurious resonances much higher than the main resonance. Detailed discussions are also given to their behaviors.

2. SAW properties on the layer structure

Fig.1 shows the unit cell of a one-port resonator for the analysis. It consists of electrodes composed of Al and Pt layers[3)] on the 15°YX-LT/SiO_2/(001)Si structure. Thicknesses of Al and Pt layers are set at 1% and 8% of the IDT period p_I (=2μm), respectively.

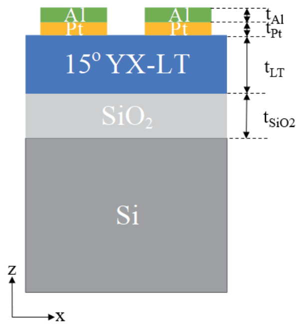

Fig. 1 Unit cell used for simulation.

Variation of the SAW properties with the electrode material and thickness are similar to that of the low-cut LN case given in Ref. [5]. Although use of W instead of Pt is preferable, here we choose Pt due to applicability of the lift-off patterning. Al is given on Pt to reduce the ohmic resistance.

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Fig. 2 shows variation of k^2 and the SAW phase velocity V_p with LT thickness t_{LT} when the SiO_2 thickness t_{SiO2} is set at $0.2p_I$. It is seen that V_p increases monotonically with t_{LT} while k^2 takes a maximum value of 13% at t_{LT}~$0.2p_I$. This k^2 enhancement is owing to SAW energy concentration in the LT layer.

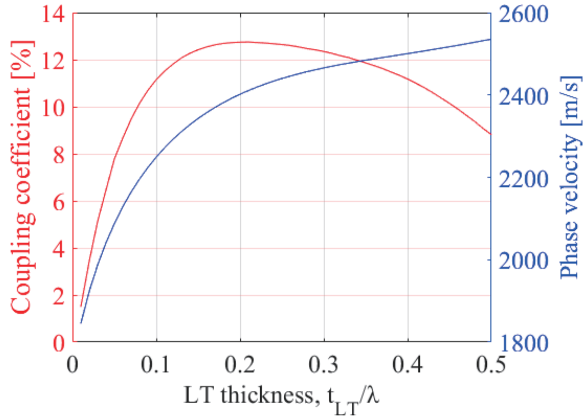

Fig. 2 Variation of k^2 (red curve) and V_p (blue curve) with t_{LT} when $t_{SiO2}=0.2p_I$.

Fig. 3 shows variation of k^2 and V_p with t_{SiO2} when t_{LT} is set at 15%. In this case, V_p decreases and k^2 increases monotonically with t_{SiO2} although SiO_2 does not possess piezoelectricity. This k^2 enhancement is owed to small mechanical impedance of SiO_2 which makes the LT bottom surface close to mechanically free. Note that when $t_{SiO2}=0$ makes the LT bottom surface close to mechanically clumped.

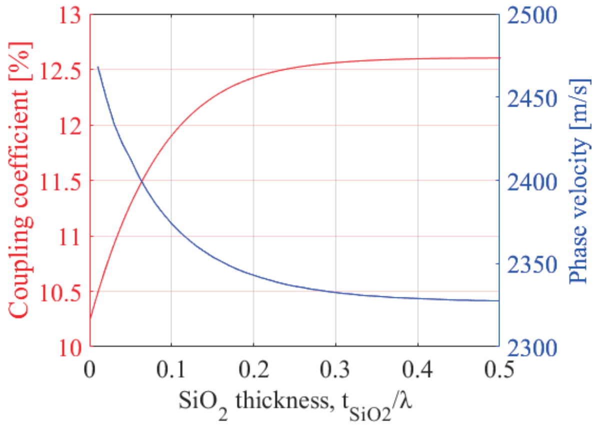

Fig. 3 Variation of k^2 (red curve) and V_p (blue curve) with t_{SiO2} when $t_{LT}=0.15p_I$.

3. Higher-order modes and their suppression

Fig. 4 shows variation of admittance Y of the resonator with the Pt thickness when t_{LT} and t_{SiO2} are set at $0.15p_I$ and $0.2p_I$, respectively. Although thick Pt reduces the main resonance frequency, it also decreases that of the higher-order one. The spurious responses are due to the Sezawa mode trapped in the LT layer[6].

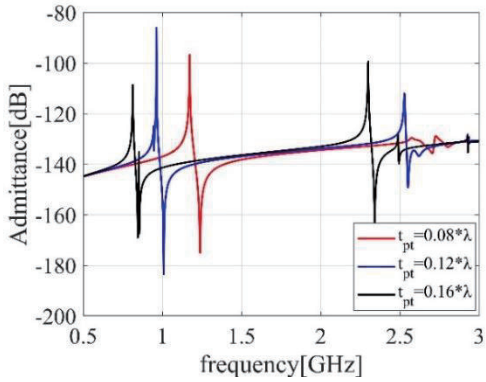

Fig. 4 Variation of input admittance with t_{Pt}.

SAW resonances above 2.5 GHz will be leaky and attenuated. This is due to cutoff of (slow-shear) bulk wave radiation to Si. Note that Y is pure capacitive below this cutoff except near these resonances. This feature is important for application to multiplexers.

It is known that these resonance frequencies can be separated by reducing t_{LT}. Fig. 5 shows variation of admittance characteristics with t_{LT} when t_{pt} and t_{SiO2} are $0.16p_I$ and $0.2p_I$, respectively. As expected, the separation can be increased. However, thinner t_{LT} makes its fabrication and control harder. In addition, too thin t_{LT} reduces achievable k^2 (see Fig. 2).

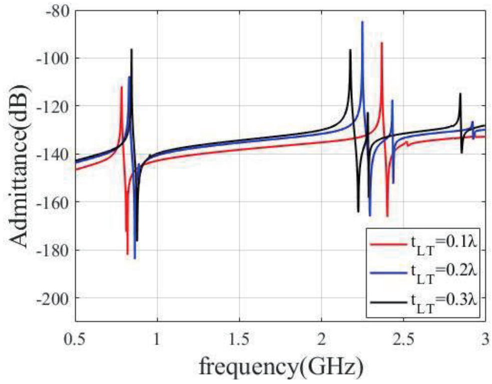

Fig. 5 Variation of input admittance with t_{LT}.

This spurious resonance can be attenuated by replacing Si with a low velocity material such as SiO_2. However, this countermeasure degrades usefulness of this device structure because Re(Y) will be not negligible above the cutoff.

Until now, all the calculations were performed for the case when the Si <100>-axis is chosen to coincide with the SAW propagation (x) direction. It is known that the slow-shear velocity changes with the orientation, and it takes a minimum at the Si <110> direction in the (001) plane.

Fig. 6 shows impact of the Si orientation to Y when t_{Al}, t_{Pt}, t_{LT} and t_{SiO2} are set at $0.01p_I$, $0.1465p_I$, $0.135\ p_I$, and $0.05\ p_I$, respectively. The spurious resonance is well suppressed when the propagation direction is set to the <110> direction. In the case, Y is pure capacitive below 2.3 GHz, and k^2 of 9% and V_p of 1,728 m/s are attained simultaneously.

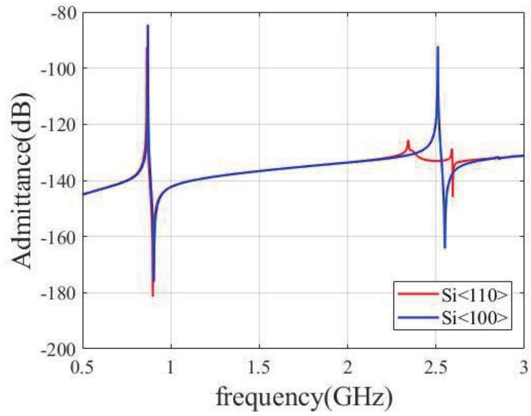

Fig. 6 Impact of Si orientation to the admittance characteristics.

4. Conclusion

This paper discusses the velocity reduction and the generation of spurious modes on the high frequency on the layer structure.

As the next step, the authors will suppress the high-order spurious modes and the transverse modes to further improve the performance of the resonator.

Acknowledgment

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References

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