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Insertion of Si_3N_4 Layer for Suppression of Hybrid Mode in Low Velocity SAW Resonator

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1. Introduction

SAW velocity (V_{SAW}) reduction is strongly desired for further miniaturization of low-band filters/duplexers.[1)-4)] The authors are interested in SH SAWs propagating in the Al/Pt IDT on the rotated Y-cut $LiTaO_3$ (LT)/SiO_2/Si structure owing to possibility of significant V_{SAW} reduction less than 2,000 m/s.[3)-54)]

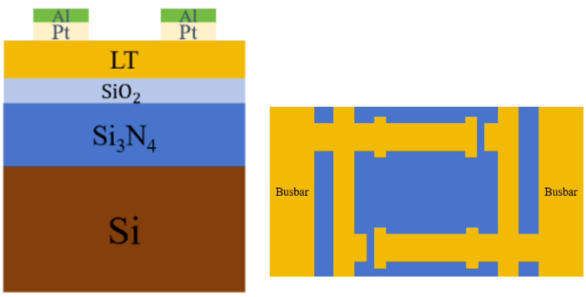
An important difficulty is the hybrid mode caused by acoustic coupling between the Rayleigh and SH SAWs.[4)] Their resonances are relatively strong and remain even when the Rayleigh SAW response is well suppressed by adjusting the LT rotation angle.

Recently, Nakagawa, et al., demonstrated suppression of spurious responses in the I.H.P. SAW resonators by introducing a Si_3N_4 layer between the SiO_2 and Si layers. [6)]

This paper discusses use of the Si_3N_4 layer for the suppression of hybrid modes in the low-velocity SAW configuration.

2. Periodic 2D FEM Analysis

Fig. 1a) shows the device configuration used in the following periodic 2D FEM simulation. Thicknesses of Al, Pt, LT and SiO_2 are set $0.05p_I$, $0.1p_I$, $0.2p_I$, $0.06p_I$, respectively, where p_I is the IDT periodicity, and the metallization ratio MR is set at 0.5. The rotation angle of Y-cut LT is set at 20°. No loss is added in the calculation except tiny viscosity for making the resonance Q finite.



(a) Cross section (b) Top view

Fig. 1 Device configuration used for the analysis

Fig. 2 shows variation of the SH and Rayleigh SAW velocities with the Si_3N_4 thickness t_{Si3N4} normalized by p_I. The Rayleigh SAW velocity increases rapidly with t_{Si3N4} and saturates while the SH one scarcely changes. This reflects the fact that the SH SAW energy is well confined in the LT and SiO_2 layers.

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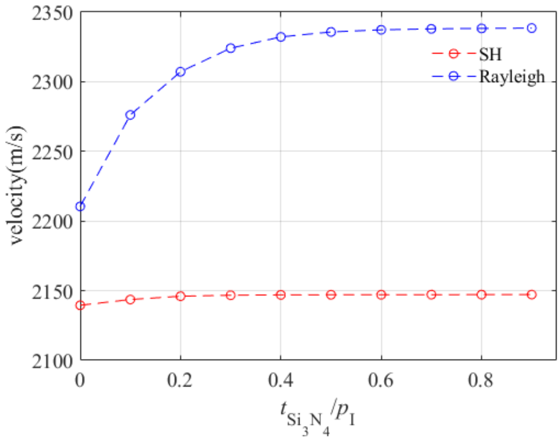


Fig. 2 Variation of SH and Rayleigh SAW velocities with Si_3N_4 thickness.

Fig. 3 shows variation of the electromechanical coupling factor k^2 of these two modes. Although k^2 of the SH SAW decrases gradually with t_{Si3N4}, the decrease is quite small. On the other hand, that of Rayleigh SAW becomes very small even when t_{Si3N4} is small.

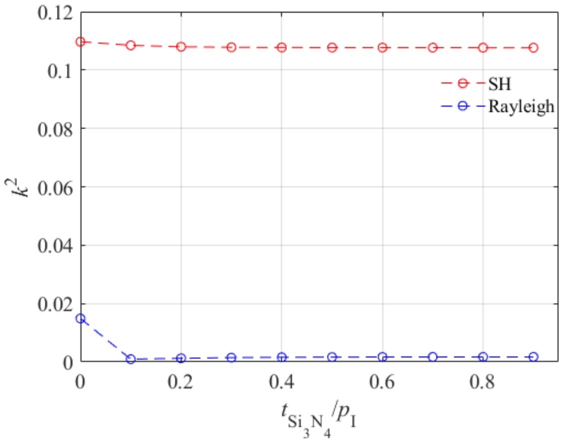


Fig. 3 Variation of electromechcanical coupling factor k^2 of SH and Rayleigh SAWs with Si_3N_4 thickness.

Fig. 4 shows variation of admittance Y and conductance G characteristics calculated by the periodic 2D FEM with t_{Si3N4}. Because of the velocity variation, the Rayleigh SAW resonance is shifted rightward while the main SH SAW resonance is scarcely changed with t_{Si3N4}.

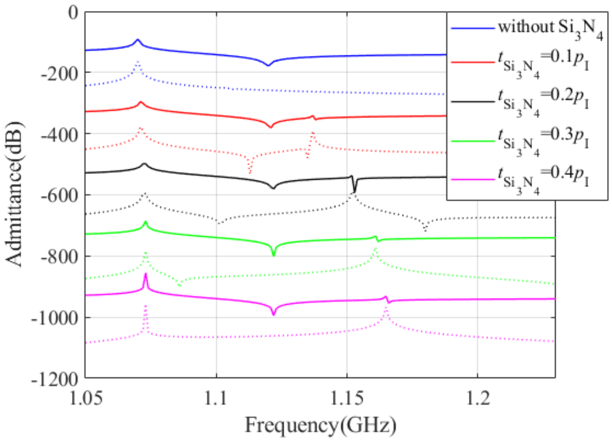


Fig. 4 Variation of admittance characteristics with Si_3N_4 thickness.

3. Periodic 3D FEM Analysis

Fig. 1(b) shows the top view of electrode configuration. The double-busbar configuration is combined with the "hammer-head" design for the conventional transverse mode suppression.[7] In the following calculation, MR for the hammer-head region, its length, aperture width, first gap length, and second gap length are set at 0.7, 0.4p_I, 20p_I and 0.1p_I, and 0.9p_I, respectively.

Red lines in Fig. 5 show the admittance curves and Bode-Q [8] of the resonators when t_{Si3N4}=0. Owing to the piston design, conventional transverse mode resonances are well suppressed. However, series of resonances are seen above 1.12 GHz, which are due to the hybrid mode and its transverse mode resonances.

Blue lines in Fig. 5 show the results when t_{Si3N4}=0.3p_I. Impact of the Si_3N_4 insertion is obvious, and resonance peaks of the hybrid modes are shifted rightward and become weak. On the other hand, the main resonance shifts upward slightly.

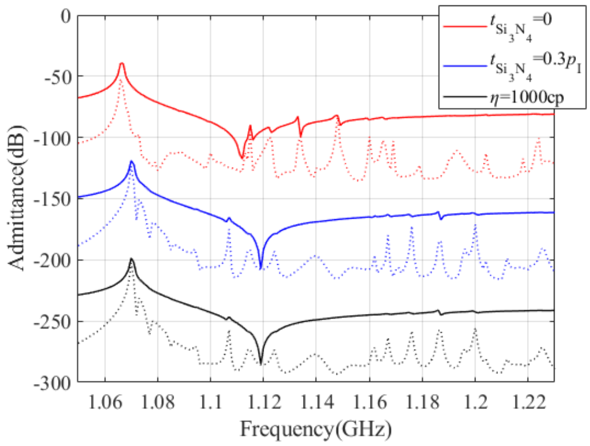
Black lines in Fig. 5 show the results when viscosity η of 1*10^3 cp is included in the Si_3N_4 layer with t_{Si3N4}=0.3p_I. It is seen that η attenuates the hybrid modes resonances in some extent while its impact to the main mode is small.

4. Conclusion

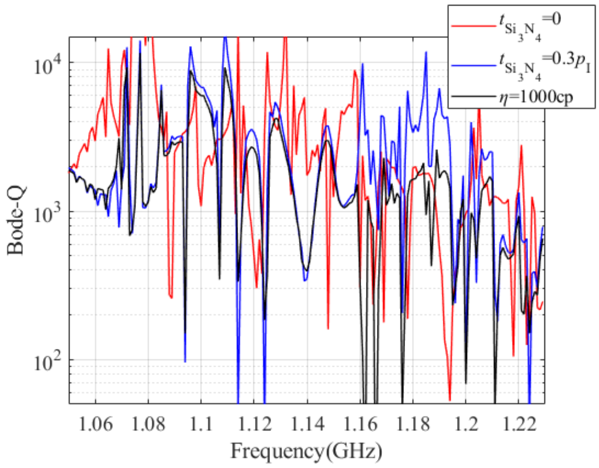
This paper discussed influence of the Si_3N_4 insertion for the hybrid modes in the low velocity SAW resonator structure. The insertion is effective to shift the hybrid mode resonances rightward with scarce influence to the main SH SAW responses. It was also shown that adding acoustic loss in Si_3N_4 is effective to suppress the hybrid mode responses selectively.

Acknowledgment

This work was supported by the Research Project under Grant A1098531023601318 and in part by the National Natural Science Foundation of China and the China Academy of Engineering Physics under Grant U1430102.



(a) Admittance characteristics



(b) Bode Q

Fig. 5 Change of the resonance characteristics with Si_3N_4. Blue lines: without Si_3N_4, red lines: with lossless Si_3N_4, and black lines: lossy Si_3N_4.

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