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S_0-like SAW Mode Resonator Based on $LiTaO_3/SiO_2/SiC$ Platform

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1. Introduction

Recently, attention is paid to the S_0-like SAW mode propagating on a $LiNbO_3$ (LN) thin plate bonded with the SiC supporting substrate[1)-4)]. The authors also studied the configuration, and pointed out that insertion of SiO_2 between LN and SiC layers is effective to enhance the electromechanical coupling factor k_{eff}^2 significantly with little reduction of the phase velocity.[5),6)]

This paper discusses application of $LiTaO_3$ (LT) to the S_0-like SAW mode resonator instead of LN for improvement of the temperature stability in trade-off with k_{eff}^2 reduction.

2. Structural Design

Since LT possesses the same crystallographic symmetry, we can use the structural design procedure[5),6)] established for the LN-based S_0-like SAW device.

Fig. 1 shows variation of k_{eff}^2 for the S_0 and SH_0 modes on the LT thin plate as a function of the rotation angle α, i.e., for the Euler angle of [α, -90°, 90°]. In this calculation, the LT thickness h_{LT} is set at 0.1 wavelength. When α is 28°, k_{eff}^2 of the S_0 Lamb mode reaches its maximum value of 11.62% while k_{eff}^2 of the SH_0 mode is small (1.9%). Although α is fixed at 28° in the following calculation, good S_0 mode suppression is possible by setting a close to 45° with certain reduction of k_{eff}^2.

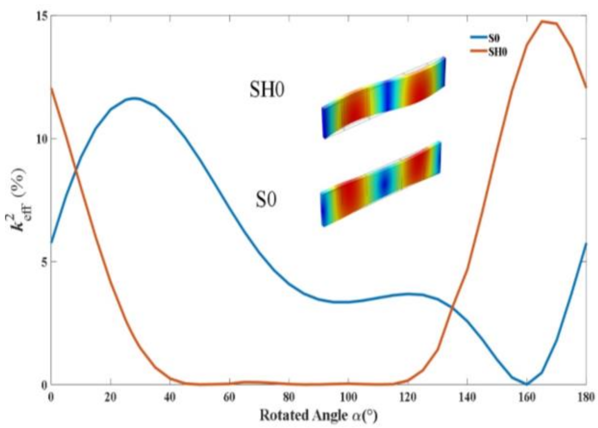

Fig. 1 Variation of k_{eff}^2 of S_0 and SH_0 on LT plate (h_{LT}=0.1 wavelength) with α.

Next, the analysis is extended to the case where this LT plate is bonded on the SiC wafer with SiO_2 interposer. In the following analysis, IDT metallization ratio is fixed at 0.45.

Fig. 2 shows the variation of k_{eff}^2 and the phase velocity V_p with the SiO_2 thickness h_{SiO2} when $h_{LT}=0.16p_I$, where p_I is the IDT period. In this calculation, Al IDT thickness h_{Al} is set at $0.04p_I$. Although k_{eff}^2 is significantly smaller than the value given in Fig. 1, k_{eff}^2 increases rapidly with h_{SiO2} and mostly saturates to 8.3% with small h_{SiO2}. This is because soft and light SiO_2 isolates the LT plate from the stiff SiC substrate. As a tradeoff, decreases with h_{SiO2} in some extent.

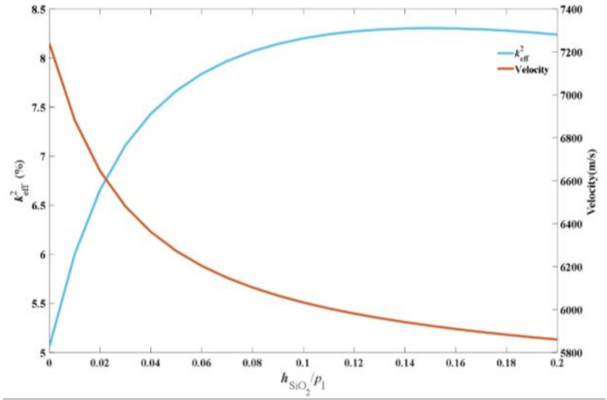

Fig. 2 Variation of k_{eff}^2 and V_p with h_{SiO2}.

Note that k_{eff}^2 is also dependent on h_{LT} in addition to h_{SiO2}. **Fig. 3** shows variation of k_{eff}^2 with h_{LT} and h_{SiO2} when $h_{Al}=0.04p_I$. It is seen that k_{eff}^2 takes a maximum value of 8.3% when $h_{LT}=0.16p_I$ and $h_{SiO2}=0.15p_I$ and does not change rapidly with both h_{LT} and h_{SiO2} near the optimal point.

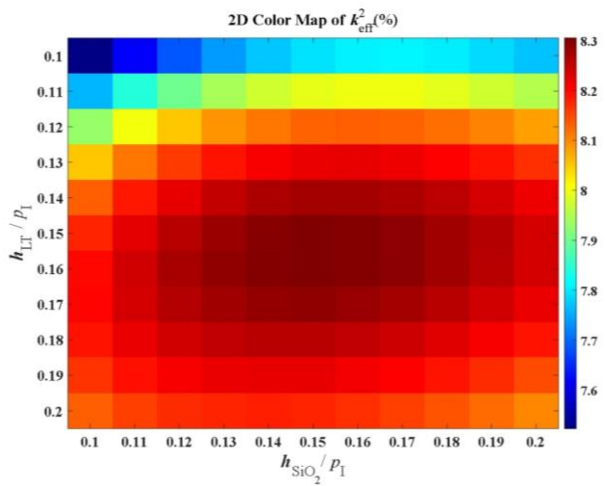

Fig. 3 Variation of k_{eff}^2 with h_{LT} and h_{SiO2}.

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Fig. 4 shows the variation of k_{eff}^2 and V_p with h_{Al} when h_{LT}=0.16p_I and h_{SiO2}=0.15p_I. Like the S_0-like SAW mode resonators on LN, electrode mass-loading gives negative impacts. With an increase in h_{Al}, k_{eff}^2 increases a little and then decreases rapidly. In contrast, V_p decreases monotonically with h_{Al}. When another heavy material like Cu is chosen for the IDT, k_{eff}^2 decreases more rapidly with h_{Al}. Since certain electrode thickness is necessary to make the electrode resistance small, use of Al is the best for this application.

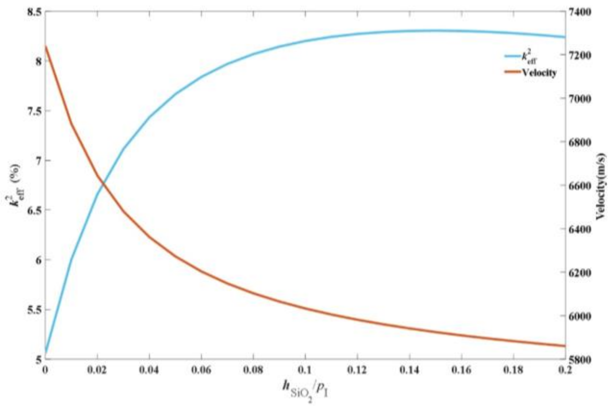

Fig. 4 Variation of variation of k_{eff}^2 and V_p with h_{Al}.

Fig. 5 shows variation of temperature coefficient of velocity (TCV) with h_{SiO2} when h_{LT}=0.16p_I and h_{Al}=0.04p_I. TCV increases rapidly with h_{SiO2} and almost saturates when h_{SiO2}=0.04p_I. temperature coefficient of frequency (TCF) seems quite possible when the thermal expansion coefficient toward the propagation direction of this composite structure.

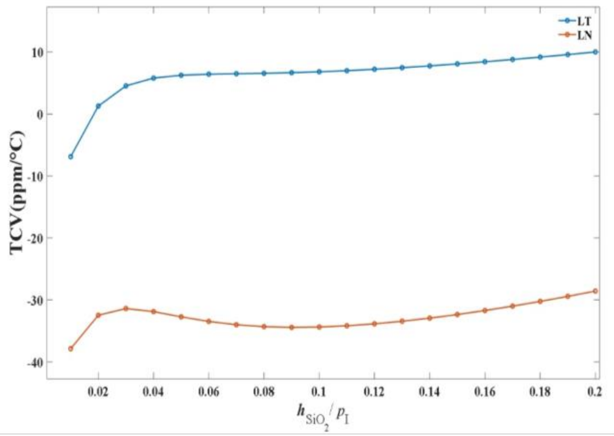

Fig. 5 Variation of TCV of S_0-like mode SAW resonator using LT with h_{SiO2} when h_{LT}=0.16p_I. For comparison, that of the S_0-like SAW resonator using LN is also shown.

This means zero TCF, relatively large k_{eff}^2, and high V_p are achievable simultaneously in this configuration.

In the figure, TCV of S_0-like mode SAW resonator on LN[5] is also shown. Although use of LT gives smaller k_{eff}^2 than that of LN, good TCV makes use of LT attractive.

3. Admittance characteristics

Fig. 6 shows the admittance Y and conductance G when p_I=6 μm obtained by the periodic 2D FEM analysis. The main response is seen at around 1 GHz. The cutoff of bulk radiation is circa 1.4 GHz, which is determined by the slow-shear wave velocity in SiC.

Two spurious resonances are seen below the main resonances, and those at 0.5 GHz and 0.6 GHz are due to Rayleigh and SH_0-like SAW modes respectively. These resonances may be suppressed by finely adjusting θ and/or h_{LT}.

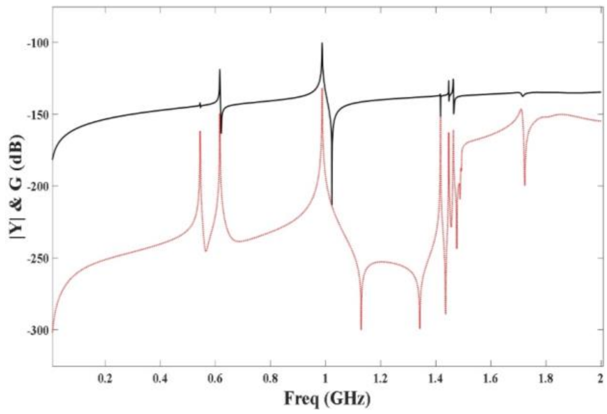

Fig. 6 Calculated $|Y|$ and G of designed S_0-like SAW resonator.

6. Conclusion

This paper described the S_0-like SAW mode resonator using the Al-eletrode/LT/SiO_2/SiC structure. It was shown that zero TCF, relatively large k_{eff}^2, and high V_p are achievable simultaneously in this configuration.

As the next step, the authors will apply the piston mode design to suppression transverse mode resonances.

Acknowledgment

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