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Periodically Slotted SiO_2 Normal to Interdigital Electrodes For k^2 and Transverse Mode Suppression in Layered SAW Structures

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1. Introduction

Extensive studies have been made on SAW resonators using extremely thin 42°YX-$LiTaO_3$ (42-LT) layer bonded with Si wafer with the SiO_2 interlayer owing to high quality factor Q and good temperature stability [1-4]. Recent studies revealed that both high Q and good spurious suppression are achievable by flattening the SAW slowness on the substrate surface [2-4].

Use of low-cut LT such as 20-LT is also paid attention for its intrinsic larger electro-mechanical coupling factor k^2. Due to large convex curvature of the slowness of low-cut LT, its combination with SiO_2/Si cannot flatten the slowness without significant reduction of k^2. The authors' group proposed to replace SiO_2/Si with 69°Y-90°X quartz or ZX-$Li_2B_4O_7$ for the slowness manipulation [5].

Recently, the authors proposed use of the periodically slotted SiO_2 for both the k^2 enhancement and slowness manipulation [6]. Although excellent performances are expected theoretically when the slots are placed parallel to IDT fingers, the configuration seems difficult to fabricate due to required alignment accuracy between slots and fingers.

This paper discusses applicability of the periodically slotted SiO_2 placed normal to IDT fingers. In the case, stringent alignment is not necessary because the slotted SiO_2 behaves like a uniform layer for waves with the lateral wavelength much larger than the slot period p_s. It is shown that both the k^2 enhancement and slowness manipulation can be achievable also for this case under proper design.

2. Periodically slotted SiO_2 design

Fig. 1 shows the unit cell of Al-electrode/20-LT/periodically-slotted-SiO_2/Si-substrate structure under concern. Al and LT thicknesses and IDT period (p_I) are set at 0.18 μm, 0.736 μm and 2 μm, respectively. The perfectly matched layer (PML) is given to the bottom for the FEM analysis. The gaps are vacuum.

Fig. 2 shows how k^2 and phase velocity V_p change with the slot width r normalized by p_s of 2 μm. In this case, the SiO_2 thickness (=t_{SiO2}) is set at 0.4 μm. It is seen that k^2 increases and V_p decreases monotonically width. This is because the SAW behaves like a SH0 mode in the 42-LT thin plate when r approaches to unity.

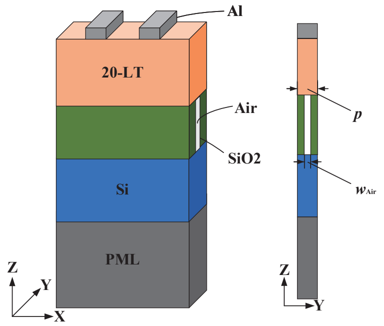

Fig.1. Layered SAW structure with slotted SiO_2

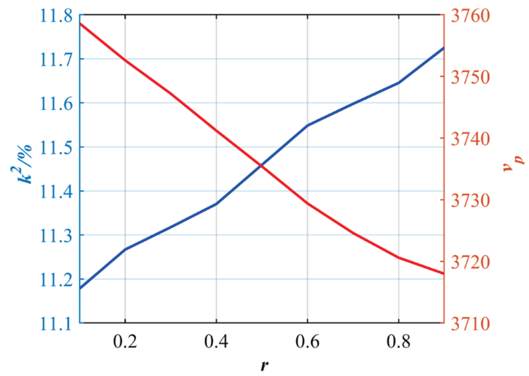

Fig.2. Variation of k_{eff}^2 and V_p with r.

Fig. 3 shows how the slowness curve change with r, h (=t_{SiO2}/p_I), and p_s. Although the slowness can be manipulated in some extent by r, h, and p_s, adjustability is limited in comparison with the case where the slot is given parallel to IDT fingers [6].

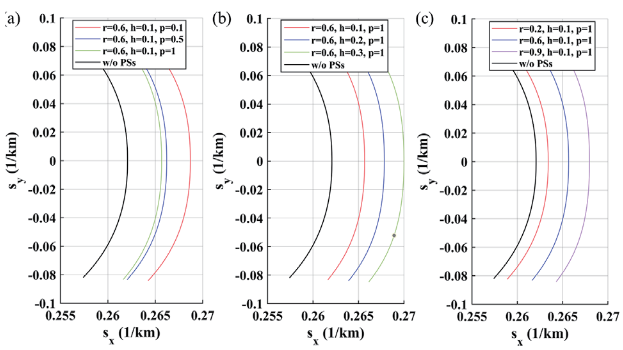

Fig.3. Variation of SAW slowness on the surface with (a) r (=w_{Air}/p_s), (b) h (=t_{SiO2}/p_I), and (c) p_s

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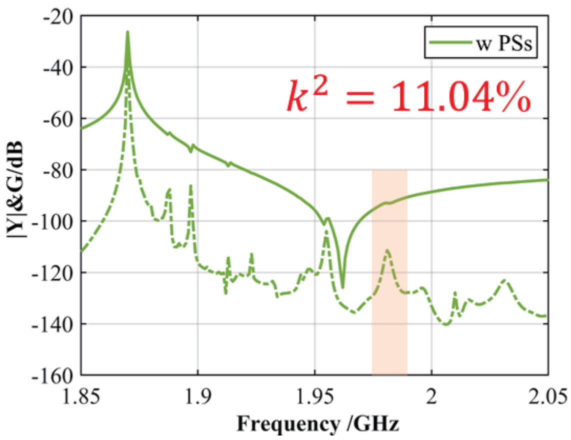
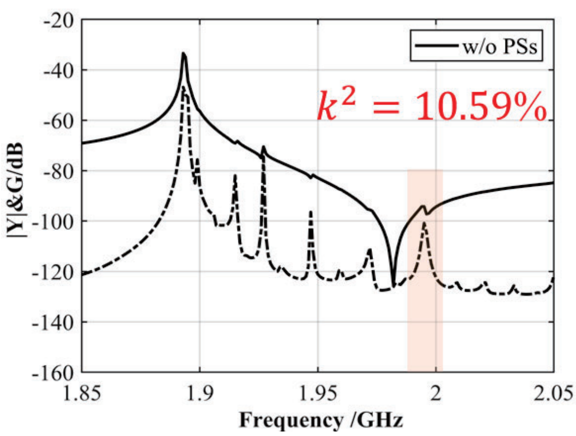
3. SAW Resonator Performances

SAW resonator performances are analyzed by the periodic 3D FEM for the configuration shown in Fig. 1. The double busbar configuration[4] is applied to the Al electrodes and the “hammer-head” design is applied for the piston mode operation. The IDT and structural parameters are taken from [4], and r, h and p_s are set at 0.6, 0.4, and 1 μm, respectively.

Fig. 4(a) shows the simulated admittance Y and conductance G of the resonator structure shown in Fig. 1. For comparison, Fig. 4(b) shows Y and G when the SiO_2 layer is not slotted. It is seen that owing to the curvature manipulation, transverse mode resonances can be suppressed in some extent and k^2 can be enhanced by the use of periodically slotted SiO_2. Due to remaining slowness curvature, the transverse mode suppression is inferior to the results shown in [5] and [6]. Note that a spurious resonance at 1.96 GHz is caused by the “gap mode” resonance in the double busbar structure[4] and its mitigation techniques are described in [7] and [8].



(a) with periodical slots



(b) without periodical slot

Fig.4 Calculated Y and G

The field distribution ($|u|$) of gap mode which is higher than anti-resonance frequency fa is shown in Fig.5 (a) and (b). Spurious modes vibration in the secondary gap region have been eliminated, which means PSs structure can suppress the SAW scattering in gap2 region in higher frequency region.

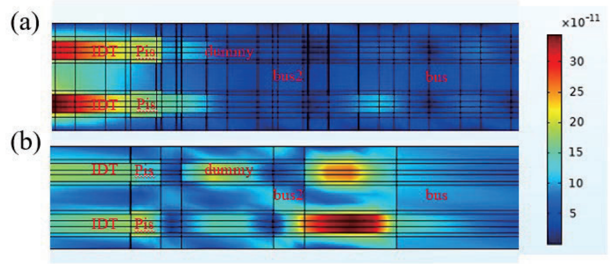


Fig.5. Field distribution ($|u|$) in gap2 region (a) With PSs, and (b) Without PSs

4. Conclusion

This paper describes the Periodically slotted SiO_2 structure in layered SAW construction employing low-cut LT. The k^2 enhancement and gap mode suppression are revealed without spurious modes addition, which is promising for wider bandwidth and steeper skirts of filters.

The authors are investigating the suppression of spurious resonances in passband by designing Al electrodes on resonators with PSs structure. The next target is trying to implement the fabrication of the device design.

Acknowledgment

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