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Systematic Design of Layered Structures for Wideband and High Frequency SAW Resonators

Qi Liang[1], Zhaohui Wu[1], Keyuan Gong[1], Bin Shi[1], Yawei Li[1], Jingfu Bao[1†], and Ken-ya Hashimoto[1,2]
([1]Univ. Elect. Sci. Technol. China; [2]Chiba Univ.)

1. Introduction

Recently, use of very thin $LiNbO_3$ (LN) and $LiTaO_3$ plates is paid much attention for realization of extremely high performance surface and bulk acoustic wave (SAW/BAW) devices.

For example, the low-cut LN plate bonded with a high velocity substrate such as SiC and sapphire have been stuided extensively for realization of wideband SAW filters in the SHF range[1][2]. However, investigation was carried out for specific structures, and thus it is unclear which kind of structures are preferable for realzation of wideband and high-frequency SAW resonators.

This paper discusses systematic design of layered strructures for wideband and high frequency SAW Resonators.

2. Simulation

Fig. 1 shows the unit cell of a one-port SAW resonator employing the IDT/piezoelectric-plate/base-substrate structure used for the analysis. For the piezoelectric-plate, 15°YX-LN[3] is chosen.

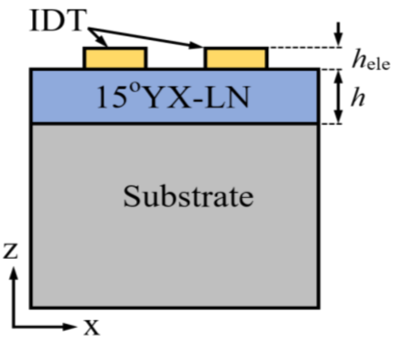

Fig. 1 The model structure used for simulation

Fig. 2 shows variation of the phase velocity V_p and the electromechanical coupling factor K^2 of shear horizontal (SH) SAW with the LN thickness h. In this calculation, Al is chosen as the IDT material and its thickness h_{ele} is set at $0.125p_I$, where p_I is the IDT period. As the base substrate, single crystal diamond, SiC and sapphire are examined.

Large K^2 is achievable only when h is large, and K^2 is small where V_p is large. This trade-off relation between K^2 and V_p seems to be independent of choice of the base substrate material.

Discontinuous change of V_P is seen at h~$0.4p_I$. This is due to coupling of the SH SAW with Rayeligh SAW, and it can be avoided by proper choice of the LN rotation angle.

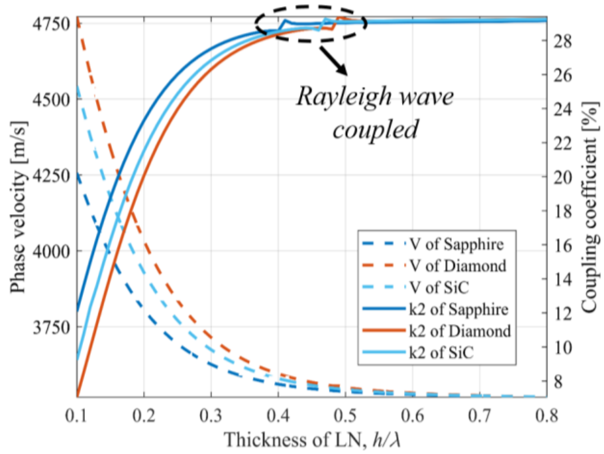

Fig. 2 Variation of phase velocity V_p and electromechanical coupling factor K^2 with LN thickness h.

Fig. 3 shows replot of these data as K^2 variation with V_P. The curve shape is almost independent of the choice of the base-substrate, and the difference becomes significant only in the region when K^2 is small.

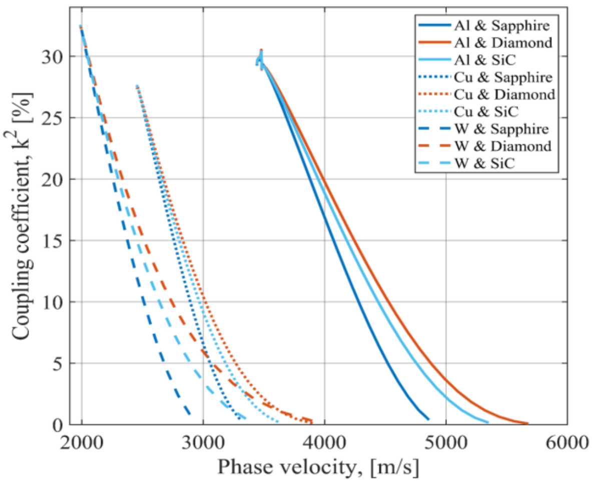

Fig. 3 Variation of the K^2 and V_P relationship with choice of the base IDT materials when the LN thickness h is scanned from $0.01p_I$ to p_I.

Fig. 3 also shows variation of K^2 with V_P when either Cu or W is used for the IDT. In this calculation, h_{ele} is $0.125p_I$. Choice of heavy electrodes only reduces V_p, and achievable K^2

†baojingfu@uestc.edu.cn

seems not to change so much. Thus we can conclude light electrode materials such as Al are preferable for this application.

Fig. 4 shows variation of K^2 with V_P when h is fixed at $0.2p_I$, and h_{ele} is scanned from $0.001p_I$ to $0.5p_I$. Giving small h_{ele} gives slight increase in K^2 and slight decrease in V_p. This dependence can be explained by energy concentration to the top surface by the mass loading[4].

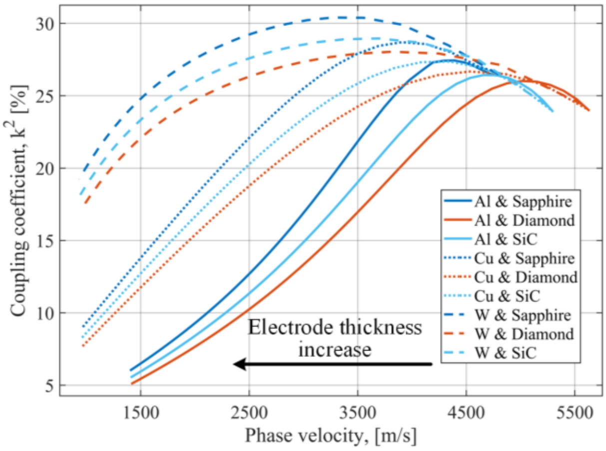

Fig. 4 Influence of the electrode thickness to the K^2 and V_P relationship when h_{ele} is scanned from $0.001p_I$ to $0.5\ p_I$.

Fig. 5 shows input admittance of infinitely long IDT on Al-IDT/15°YX -LN/sapphire structure when h and h_{ele} are chosen $0.2p_I$ and $0.13p_I$, respectively. Relative frequency is determined by f*p_I*1e-3, Large k^2 of 24.0% is achieved but V_p is dropped to 3,669 m/s.

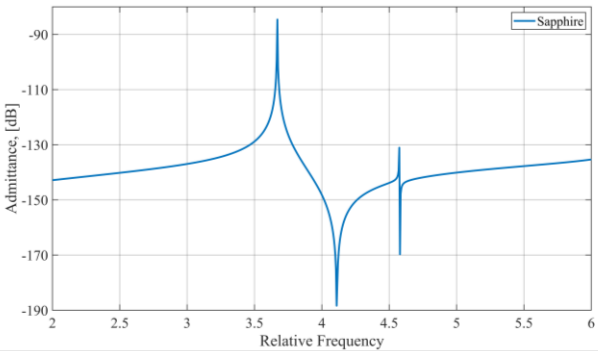

Fig. 5 Input admittance of infinitely long IDT on 15 °YX -LN/sapphire structure.

Fig. 6 shows input admittance of infinitely long IDT on Al-IDT/15°YX-LN/SiC structure when h and h_{ele} are chosen $0.2p_I$ and $0.1p_I$, respectively. Relative frequency is determined by f*p_I*1e-3, Large K^2 of 25.3% and large V_p of 4,185 m/s are attained simultaneously.

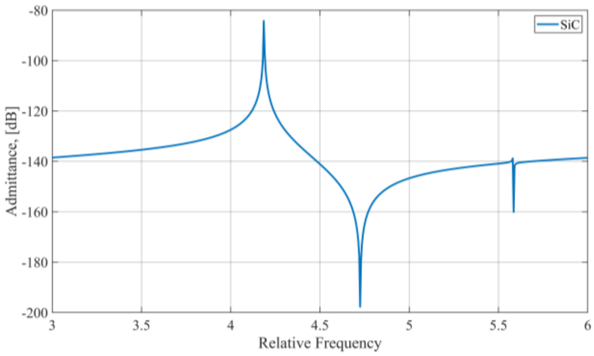

Fig. 6 Input admittance of infinitely long IDT on 15°YX-LN/SiC structure.

Spurious resonances can be seen both in Fig. 5 and Fig. 6. They are due to the secondary Rayleigh SAW mode called the Sezawa mode.

3. Conclusion

This paper discussed systematic design of layered strructures for wideband and high frequency SAW Resonators.

It was shown that k^2 of 24.0% and V_p of 3,669 m/s are achievable simultaneously. However, these values are inferior so much to those achievable by the SH0 mode plate mode devices.[5] It may be due to the fact that high velocity substrates behave like the fix boundary for 15°YX-LN plate.

As the next step, the authors are attempting to extend the present discussion to the case when the Bragg reflector is used instead of the high velocity substrates. Sometimes the SiO_2 layer is inserted between the 15°YX-LN plate and the high-velocity substrate[1],[2]. This configuration can be regarded as a simplified Bragg reflector.

Acknowledgment

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4. References

[1] R. Su, et al., IEEE Electron Device Lett., **42**, 3 (2021) pp. 438–441

[2] J. Shen, et al, IEEE Microwave Theory and Tech. (2021) 10.1109/TMTT.2021.3077261

[3] K. Hashimoto, et al, Jpn. J. Appl. Phys. **4**3 (2004) pp. 3063–3066

[4] G. Tang, et al, Jpn. J. Appl. Phys. **55** (2016) 852.

[5] M. Kadota, et al, Jpn. J. Appl. Phys., **52** (2013) 07HD04