Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Influence of Coupling with SH SAW on Lateral Propagation of Rayleigh SAW on 128°YX-$LiNbO_3$

128ºYX-$LiNbO_3$ 上のレーリーSAW 斜め伝搬に及ぼす SH SAW との結合の影響

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1. Introduction

Recently, the Rayleigh surface acoustic wave (SAW) on 128°YX-$LiNbO_3$ (128-LN) is paid much attention for realization of high performance temperature compensated (TC) SAW devices[1)].

It is known that the shear horizontal (SH) SAW also exists on the substrate, and proper adjustment of the rotation angle θ enables to make its electromechanical coupling factor K^2 zero[2)]. However, in grating structures, the mechanical coupling between the SH and Rayleigh SAWs occurs and causes undesirable impacts on device performances[3,4)].

This paper discusses impact of the mechanical coupling with the SH SAW on the propagation of the Rayleigh SAW on 128-LN. The thin plate model proposed by the authors' group[5),6)] is applied for the analysis of lateral propagation and resonance characteristics. It is shown that the model can describe lateral propagation of Rayleigh SAW well.

2. Mode Coupling in 128-LN

Fig. 1 shows the input admittance of an infinitely long Cu IDT on the 128-LN substrate. In the calculation, the Cu thickness h is set at $0.06p$ where p is the grating period and is set at 2 μm. Series and parallel resonances of the SH SAW are seen at f=971 MHz and 973.8 MHz in addition to those of the Rayleigh SAW at f=932.4 MHz and 964.2 MHz. The figure also shows the input admittance when θ

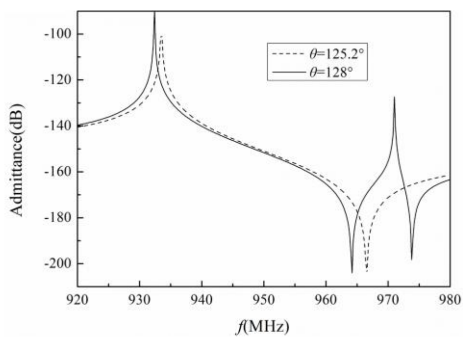

Fig.1 Admittance of infinitely long IDTs (Cu, h=0.06p) on rotated Y-cut $LiNbO_3$.

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is changed to 125.2°. In this case, the resonances of the SH SAW are not observable. This means that the electromechanical coupling factor K^2 of SH SAW can be made zero by setting θ=125.2º when h=0.06p. It should be noted that K^2 of the SH SAW takes a minimum at θ~128° when h=0[2)].

Fig. 2 shows the frequency dependence of the longitudinal wavenumber β_x of SH and Rayleigh SAWs in the Cu grating (h=0.06p) on 125.2-LN. There exists a stopband at β_x=π/p, which is caused by the Bragg condition between forward and backward propagating Rayleigh SAWs. Another stopband is seen at β_x~0.975π/p, which is caused by the Bragg condition between forward propagating Rayleigh SAW and backward propagating SH SAW and vice versa[3)]. Since K^2 for the SH SAW is zero, this coupling is caused mechanically.

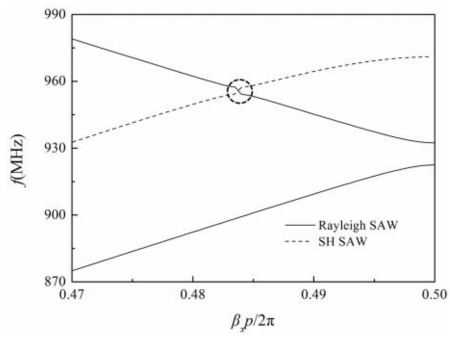
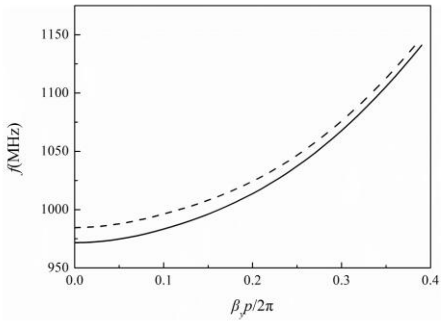


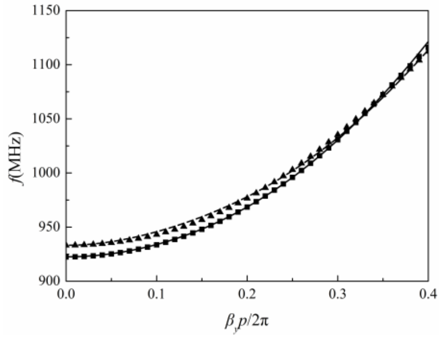
Fig. 2 Freuency f dispersion of the longitudinal wavenumber β_x when h=0.06p

Fig. 3(a) shows the frequency dispersion of lateral wavenumber β_y of the Rayleigh SAW in the grating with h=0 on 128-LN when the "longitudinal resonance condition" [4)] of $\beta_x p$=π is satisfied. Two branches exist, and one exhibits a cutoff at f~971 MHz, which corresponds to the lower stopband edge of the short-circuited (SC) grating and also to the main resonance frequency (see Fig. 1). As will be discussed later, behavior of transverse mode resonances is governed by this branch. On the other hand, another branch has a cutoff at f~984 MHz, which corresponds to the higher stopband edge of the SC grating. It coincides with the lower stopband edge of the open-circuited (OC) grating, and this branch is not excitable electrically. Note that below the cutoff frequency, corresponding mode is evanescent laterally.

Fig. 3(b) shows the case when h=0.06p and θ=125.2°. It seems similar to Fig. 3(a). However, two branches intersects only in this case. This is due to the mechanical coupling mentioned above, and this phenomenon cannot be explained when the coupling is ignored. Furthermore, this coupling causes rapid variation of β_y with f near the cutoff as the authors pointed out in Ref.4.



(a) θ=128° and h=0



(b) θ=125.2° and h=0.06p. ■ and ▲: thin plate model

Fig. 3 Variation of β_y with f under the longitudinal resonance condition

3. Analysis by thin plate model

The extended version[6)] of the thin plate model[5)], which can take coupling between two SAWs into account, is applied to this case, and influence of the coupling on the device performance is investigated.

Fig. 3(b) also shows β_y calculated by the extended thin plate model using parameters obtained by the fitting. The agreement is excellent. This fact indicates that the intersection is caused by the mechanical coupling of the Rayleigh SAW with the SH SAW.

Then, the extended thin plate model is applied to an infinitely long Cu IDT (h=0.06p)/125.2-LN substrate structure, which consists of busbar, gap and aperture regions. Gap and aperture lengths are 0.5p and 40p, respectively.

Fig. 4 shows the calculated admittance curve. In addition to the largest peak and dip due to the main resonance, a number of satellite resonances are seen. They are identified as transverse ones. The figure also shows the result obtained by the three

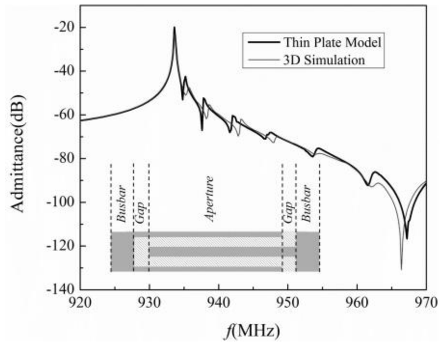


Fig. 4 Comparison of admittance of infinitely long IDT calculated by the thin plate model and 3D FEM

dimensional (3D) finite element method (FEM). It is seen that the two admittance curves agree very well. Remaining discrepancies may be due to inaccuracy of parameters used for busbar and gap regions and/or improper setting of the perfect matched layer.

4 Conclusion

The propagation characteristics of Rayleigh SAW and SH SAW on Cu grating/128 -LN structure were investigated. It was shown that mechanical coupling of SH SAW gives significant impact on propagation characteristics of Rayleigh SAW. The thin plate model was applied to analyze the influence of the mechanical coupling on the lateral propagation. The result indicates that the model can describe the dispersion behavior well. The model was also applied to analyze resonance characteristics of an infinitely long Cu IDT on 125.2-LN substrate structure. The result agreed well with that of 3D FEM simulation.

Acknowledgment

The work was partially supported by the Natural Science Foundation of China (No.11174205, No.11474203) and the Ministry of Education of China (NCET-12-0357 and RFDP-20120073110021). Tang also acknowledges the support of the Japanese Government (MEXT) for the scholarship through the Super Global University Project.

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