1P3-3

Model Parameter Extraction of Lateral Propagating SAWs with Mode Coupling on TC-SAW Resonators

TC-SAW 共振子における SAW 間結合を含む横モード伝搬のモデル化

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1. Introduction

It is known that in temperature compensated (TC) surface acoustic waves (SAW) resonators on the θ degree rotated Y-cut $LiNbO_3$ substrate, both Rayleigh and shear horizontal (SH) SAWs exist, and their coupling gives significant impacts on their lateral propagation[1].

Recently, the authors proposed the extended thin plate model for the analysis of lateral SAW propagation including two-SAW coupling[1, 2], and pointed out that the piston mode operation (PMO)[3] is possible without phase shifters when two SAW modes are coupled[4].

This paper investigates how parameters defined in the extended thin plate model change with SiO_2 thickness, electrode thickness and rotation angle on SiO_2-overlay/Cu-grating/θ deg. rotated YX-$LiNbO_3$ (θ-LN) substrate structure.

2. Parameter determination

Fig. 1 shows the frequency dependence of the lateral wavenumber β_y on an infinitely long grating on SiO_2/Cu/128-LN structure with grating period p of 2 μm when the longitudinal wavenumber β_x is fixed at π/p. The calculation is performed by the finite element method (FEM). The width l_{Cu} and thickness h_{Cu} of grating electrodes are 0.5p and 0.06p, respectively, and the SiO_2 thickness h_{SiO2} is 0.6p.

There are four branches; two of them are due to the coupled Rayleigh SAW while the others are due to the coupled SH SAW. They exhibit the cutoff nature at the frequencies $f_{R\pm}$ and $f_{S\pm}$ giving the stopband edges, and each mode propagates laterally only above the corresponding cutoff frequency and is evanescent below the frequency. Only one branch is excitable electrically for each SAW mode. In this case, both the lower branches are excitable.

The extended thin plate model[1,3] gives the dispersion relations of these coupled SAW modes as solutions of

$$\begin{vmatrix} a_1\beta_x^2+\beta_y^2-\rho\omega^2/c_{66} & b\beta_x\beta_y \\ b\beta_x\beta_y & \beta_x^2+a_2\beta_y^2-\rho\omega^2/c_{66} \end{vmatrix}=0 \qquad (1)$$

where $a_i=c_{ii}/c_{66}$, $b=1+c_{12}/c_{66}$, c_{ij} are effective elastic constants, ω is the radial frequency, and ρ is the mass density.

Theses parameters are determined from cutoff frequencies f_{R-} and f_{S-} and second-order gradient of the calculated dispersion curves at these frequencies. Only those of excitable branches are considered in the fitting. Fig. 1 also shows the fitted dispersion curves calculated by Eq. (1) with these parameters. It is seen that agreement is excellent with the FEM result. In this cases, a_1=0. 92, a_2=0.48, and b=0.17.

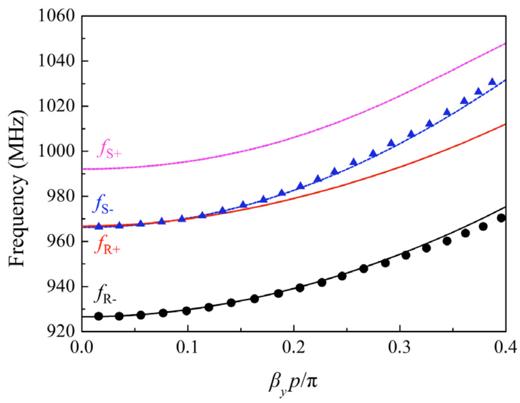

Fig. 1 Frequency dispersion of β_y when $\beta_x=\pi/p$. Solid lines: calculated by FEM, and marks (▲and ●) : calculated by the model given by Eq. (1)

3. Variation of model parameters with structural parameters

The procedure described above was applied to the SiO_2/Cu/θ-LN structure, and we investigate how the model parameters (a_1 a_2, and b) change with SiO_2 and Cu thicknesses h_{SiO2} and h_{cu} and the rotation angle θ.

Fig. 2 shows variation of a_1 a_2 and b with h_{SiO2} and θ for three h_{Cu} settings. It is seen that influence of h_{Cu} and θ is relatively small, and they only affect the amplitude of the parameters. On the other hand, a_1 and b change parabolically with h_{SiO2} while a_2 decreases monotonically with h_{SiO2}.

Parameters in gap region are also extracted. The procedure is the same as that of IDT region but there exists only one electrode per IDT period and the width of electrode is set at l_{Cu} =0.75p. To reduce the SAW velocities, h_{Cu} is set quite large in the case.

The results are shown in Fig. 3. In this case, all the parameters change smoothly with h_{Cu}, θ and h_{SiO2}. It should be noted that b is more sensitive than other

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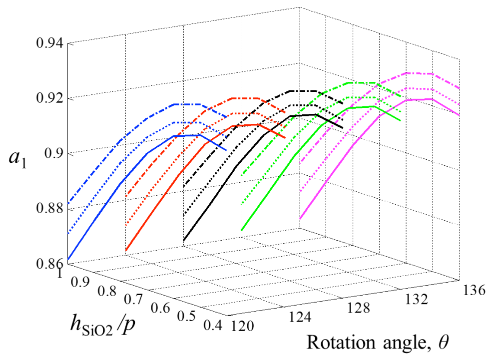
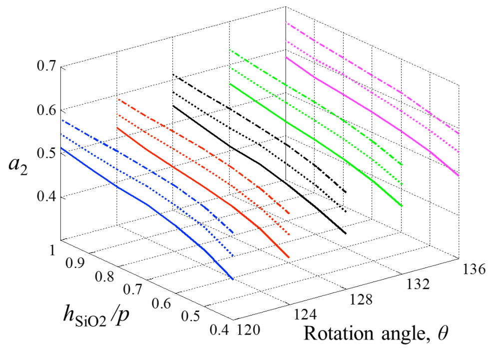
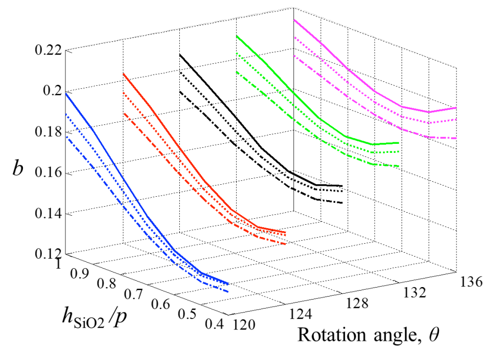
two parameters to h_{SiO2}, θ and h_{Cu}.



(a) a_1



(b) a_2



(c) b

Fig. 2 Change of model parameters in IDT region with h_{SiO2} and θ, Solid lines: h_{Cu}=0.06p, dot lines: h_{Cu}=0.08p, and dash dot lines: h_{Cu}=0.1p

4. Conclusion

This paper discussed how the parameters defined in extended thin plate model change with SiO_2 thickness, electrode thickness and rotation angle on the SiO_2/Cu/θ-LN structure.

We will apply the parameters determined in the paper to find structures to support the PMO by using the technique given in [4]. Details will be discussed at the conference.

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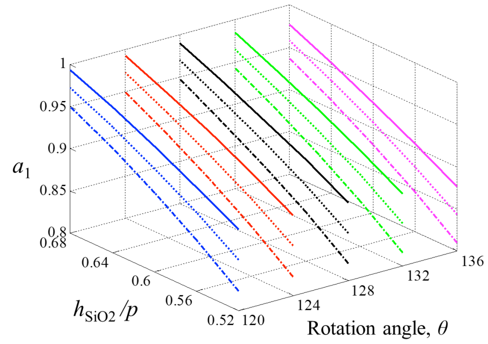
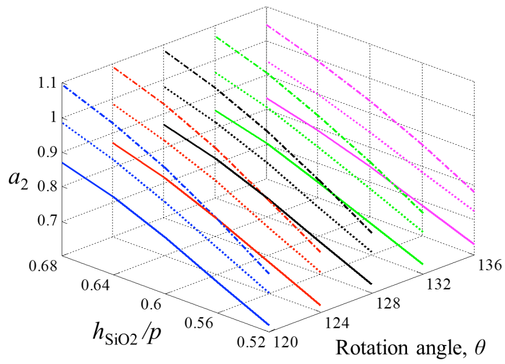
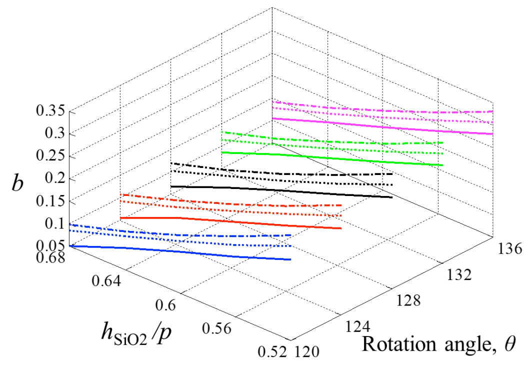


(a) a_1



(b) a_2



(c) b

Fig. 3 Change of model parameters in gap region with h_{SiO2} and θ. Solid lines: h_{Cu}=0.4p, dot lines: h_{Cu}=0.44p, and dash dot lines: h_{Cu}=0.48p

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