3P3-3

Suppression of spurious propagation modes on Love wave-type SAWs by divided piezoelectric substrates

Naoto Hara[1‡], Masashi Suzuki[1], Shoji Kakio[1*], and Yasushi Yamamoto[2]
([1]Univ. of Yamanashi; [2]Yamamoto-ADEC LLC.)

1. Introduction

A Love wave-type surface acoustic wave (Love SAW) is a nonleaky propagation mode in which the phase velocity of a shear horizontal (SH)-type leaky SAW (LSAW) is decreased to lower than that of a slow-shear bulk wave using heavy-metal gratings or by loading the substrate with a dielectric thin film.[1)] For instance, a high electromechanical coupling factor K^2 of approximately 30% for a non-leaky Love SAW propagating on a Cu-grating/15°YX-$LiNbO_3$ (LN) structure is advantageous for wideband SAW devices.[2)]

To suppress spurious responses caused by propagation modes other than the main response in S_0 mode Lamb waves, we have proposed a structure in which a piezoelectric thin plate is divided into two layers with different Euler angles and bonded.[3)]

In this study, to suppress the spurious response caused by a Rayleigh-type SAW (R-SAW) in a Love SAW, we developed a structure in which a semi-infinite piezoelectric substrate is divided into a thin plate and support substrate with different Euler angles. The resonance properties of the Love SAW on this structure were analyzed using the finite element method (FEM).

2. Divided substrate structure in Love SAW

By using 10°YX-LN as the piezoelectric substrate, the resonance properties of a Love SAW with a structure in which the LN piezoelectric substrate was divided into a thin plate with Euler angles (0°, 100°, 0°) and a support substrate with Euler angles (0°, 280°, 180°), and then bonded together, were analyzed. **Figure 1** shows the FEM analysis model. The thickness of the support substrate was set to 10 wavelengths, and a perfectly matched layer (PML) was provided at the bottom of the substrate. Two cases were analyzed: an infinite-periodic Al interdigital transducer (IDT) with a wavelength of λ = 10 μm on a piezoelectric thin plate and a high-density infinite-periodic Cu-IDT. The normalized film thickness of the Al-IDT was set to h_{Al}/λ=0.03 and that of the Cu-IDT was set to h_{Cu}/λ=0.08. The material constants of LN were the values reported by Kushibiki et al.[4)] The material Q (Q_m) of LN and these electrodes were not considered.

Table I lists the piezoelectric constant tensor e_{ij} of the LN for the divided piezoelectric thin plate and the support substrate. The influence of the piezoelectric constant tensor e_{ij} of the LN on K^2 of each SAW propagation mode was calculated for the semi-infinite LN (0°, 100°, 0°). The results showed that e_{16} significantly influenced the SH-type LSAW, and e_{15} and e_{31} influenced the R-SAW. Therefore, it is expected that the piezoelectric constants significantly influencing the excitation of the R-SAW, which is a spurious propagation mode, can be canceled out by the piezoelectric thin plate and support substrate to suppress spurious responses without altering the excitation strength of the Love SAW, whose main component is the SH.

Figures 2(a) and **2(b)** show the resonance properties for the Al-IDT and Cu-IDT, respectively. The resonance properties are shown for a normalize thin plate thickness of h/λ=0.02 for the Al-IDT and

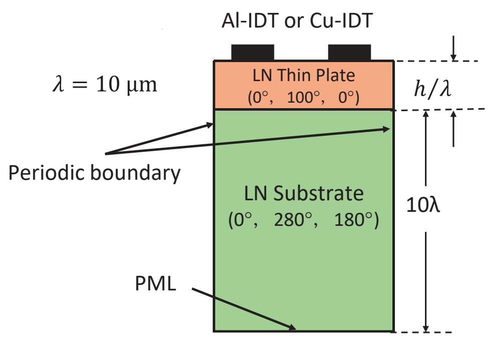


Fig. 1 FEM analysis model of LN substrate divided structure for Love SAW.

Table I Piezoelectric constant tensors of LN (0°, 100°, 0°) and LN (0°, 280°, 180°)

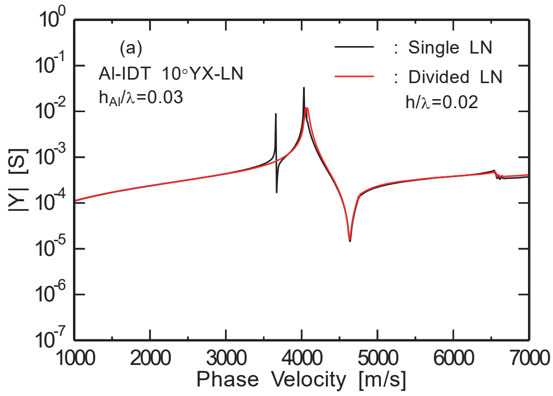
LN(0°, 100°, 0°)

$$e_{ij}\ [\mathrm{C/m^2}] = \begin{bmatrix} 0 & 0 & 0 & 0 & 1.736 & 4.017 \\ 0.741 & 2.023 & -0.253 & 0.261 & 0 & 0 \\ 2.313 & 0.839 & -3.595 & 3.024 & 0 & 0 \end{bmatrix}$$

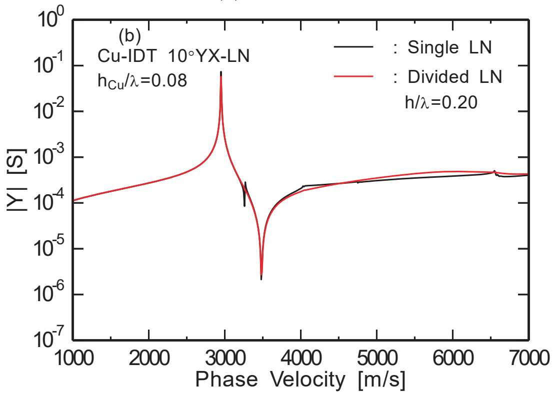
LN(0°, 280°, 180°)

$$e_{ij}\ [\mathrm{C/m^2}] = \begin{bmatrix} 0 & 0 & 0 & 0 & -1.736 & 4.017 \\ 0.741 & 2.023 & -0.253 & -0.261 & 0 & 0 \\ -2.313 & -0.839 & 3.595 & 3.024 & 0 & 0 \end{bmatrix}$$

E-mail: †g22te020@yamanashi.ac.jp, *kakio@yamanashi.ac.jp



(a) Al-IDT



(b) Cu-IDT

Fig. 2 Simulated resonance properties of Love SAW on single and divided LN structures.

h/λ=0.20 for the Cu-IDT, where the spurious response attributed to R-SAW is the most suppressed. As shown in Fig. 2(a), for the Al-IDT, the divided structure suppressed the spurious response owing to the R-SAW at a frequency lower than the resonance frequency at h/λ=0.02. However, as shown in Fig. 2(b), for the Cu-IDT, the divided structure suppressed the spurious response owing to the R-SAW between the resonance and antiresonance frequencies at h/λ=0.20.

These results indicate that in a Love SAW propagating on a semi-infinite piezoelectric substrate, the spurious response can be suppressed by selecting the Euler angle at which the piezoelectric constants significantly influence the excitation of the propagation mode that induces a spurious response, canceling out between the thin plate and the support substrate.

3. Dependence on film thickness and Euler angle

The dependence of resonance properties on the normalized film thickness of Cu-IDT and the second Euler angle of LN for the case of infinite period Cu-IDT with wavelength λ=10 μm in the divided piezoelectric substrate structure using LN in the Love SAW were analyzed. LN thin plates with Euler angles (0°, θ, 0°) and LN support substrates with Euler angles of (0°, 180°+θ, 180°) were used.

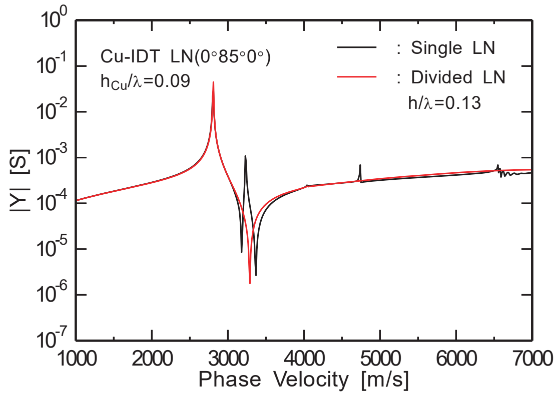


Fig. 3 Simulated resonance properties of Love SAW on single and divided LN structures at h_{Cu}/λ=0.09 and θ=85°.

Figure 3 shows the resonance properties of the Cu-IDT before and after divided the LN substrate for a normalized film thickness of h_{Cu}/λ=0.09 and θ=85°. The normalized thickness of the LN piezoelectric thin plate in the divided structure was set to h/λ=0.13. As shown in Fig. 3, the spurious response owing to R-SAW was significantly suppressed when h/λ=0.13. The results show that the R-SAW spurious response can be suppressed in the divided LN piezoelectric substrate structure by selecting an appropriate thin-plate thickness, even when the electrode film thickness and second Euler angle vary.

4. Conclusions

In this study, we propose a divided LN piezoelectric substrate structure consisting of a thin plate and support substrate with different Euler angles to suppress the spurious response caused by R-SAWs in a Love SAW propagating on a semi-infinite piezoelectric substrate. By selecting an Euler angle at which the piezoelectric constants that significantly influence the excitation of spurious propagation modes cancel each other between the thin plate and the support substrate, it was found that a thickness of the thin plate existed at which the R-SAW spurious response was significantly suppressed, while the main response was maintained. In a future study, we will experimentally examine the divided piezoelectric substrate structure.

References

1) H. Shimizu, Y. Suzuki, and T. Kanda, IEEE Ultrason. Symp., 1990, p. 103.
2) K. Hashimoto, H. Asano, K. Matsuda, N. Yokoyama, T. Omori, and M. Yamaguchi, IEEE Ultrason. Symp., 2004, p. 1330.
3) N. Hara, M. Suzuki, S. Kakio, and Y. Yamamoto, Jpn. J. Appl. Phys. **62**, SJ1056 (2023).
4) J. Kushibiki, I. Takanaga, M. Arakawa, and T. Sannomiya, IEEE Trans. Ultrason. Ferroelectr. Freq. Control, **46**, 1315 (1999).