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Analysis of resonance properties of longitudinal leaky SAW on $LiNbO_3/Ca_3TaGa_3Si_2O_{14}$ bonded structure

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1. Introduction

With the recent developments in mobile communication systems, there is a need for high-performance surface acoustic wave (SAW) devices. Langasite-type crystals, such as La_3GaSiO_{14} (LGS) and $La_3Ga_{5.5}Ta_{0.5}O_{14}$, have approximately three times larger electromechanical coupling factor (K^2) than quartz. However, controlling their uniform composition during crystal growth is difficult. Naumenko analyzed a longitudinal leaky SAW (LLSAW) excited by a Cu interdigital transducer (IDT) on a bonded structure of an LGS support substrate and a $LiNbO_3$ (LN) thin plate; accordingly, the conditions for low attenuation (high Q), a phase velocity of 6,200 m/s, and a K^2 value of 14.5% were reported[1)].

In our previous study, we focused on a new class of langasite-type crystal with ordered structure, $Ca_3TaGa_3Si_2O_{14}$ (CTGS), that can be grown as homogeneous crystal. The propagation and resonance properties of a shear-horizontal SAW on CTGS(0°, θ, 90°) with Au- or Al-IDTs were theoretically and experimentally investigated; a K^2 of approximately 1.2% and zero temperature coefficient of frequency (TCF) were thus reported[2)].

In this study, we analyzed the resonance properties of LLSAW excited by an Al-IDT on a bonded structure of a CTGS support substrate and an LN (0°, θ, 90°) thin plate; this is expected to demonstrate a higher Q because the LLSAW is not coupled with a fast shear wave component.

2. Simulation

Figure 1 shows the analytical model of the finite element method (FEM). The resonance properties of LLSAW on a bonded structure of LN(0° θ, 90°)/CTGS(0°, 90°, 90°) with an infinite period of Al-IDTs with a wavelength λ = 10 μm and normalized thickness of h_{Al}/λ were analyzed. A material with Q (Q_m) = 600 was set on an LN thin plate with a normalized thickness of h/λ. The Euler angles of the CTGS were set such that the LLSAW phase velocity was the fastest for a single CTGS substrate. A perfectly matched layer was placed at the bottom of the support substrate with a thickness of 10λ.

Figure 2 shows the simulated LLSAW resonance property for LN(0°, 80°, 90°)/CTGS(0°, 90°, 90°) with h_{LN}/λ = 0.57 and h_{Al}/λ = 0.076, exhibiting the largest admittance ratio (*AR*). The horizontal axis in Fig. 2 is converted to phase velocity by multiplying the frequency by λ. The properties of LLSAW on LN(90°, 90° ψ)/CTGS(0°, 90°, 90°) are also shown in Fig. 2.

For the conditions of θ = 80°, h_{LN}/λ = 0.57, and h_{Al}/λ = 0.076, an effective K^2 (K^2_{eff}) of 12.3%, *AR* of 75.7 dB, a resonance Q (Q_r) of 844, and an antiresonance Q (Q_a) of 662 were obtained for the phase velocities of 6,160 and 6,500 m/s at the resonance and antiresonance frequencies, respectively.

Figures 3(a)–3(d) show the simulated resonance properties of LLSAW on LN(0°, θ, 90°)/CTGS(0°, 90°, 90°) for (a) K^2_{eff}, (b) *AR*, (c) Q_r, and (d) Q_a as a function of θ for h_{LN}/λ = 0.57. The parameters of h_{Al}/λ considered are 0.04, 0.06, 0.076, and 0.1.

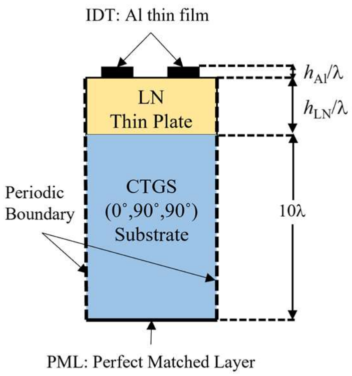

Fig. 1 Analytical model.

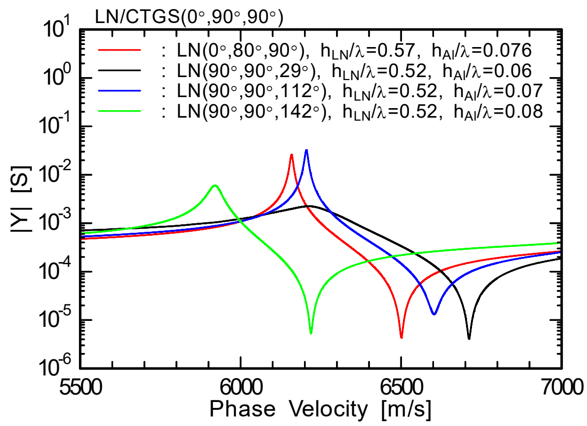

Fig. 2 Simulated LLSAW resonance properties on LN(0°, 80°, 90°)/CTGS(0°, 90°, 90°) and LN(90°, 90°, ψ)/CTGS(0°, 90°, 90°).

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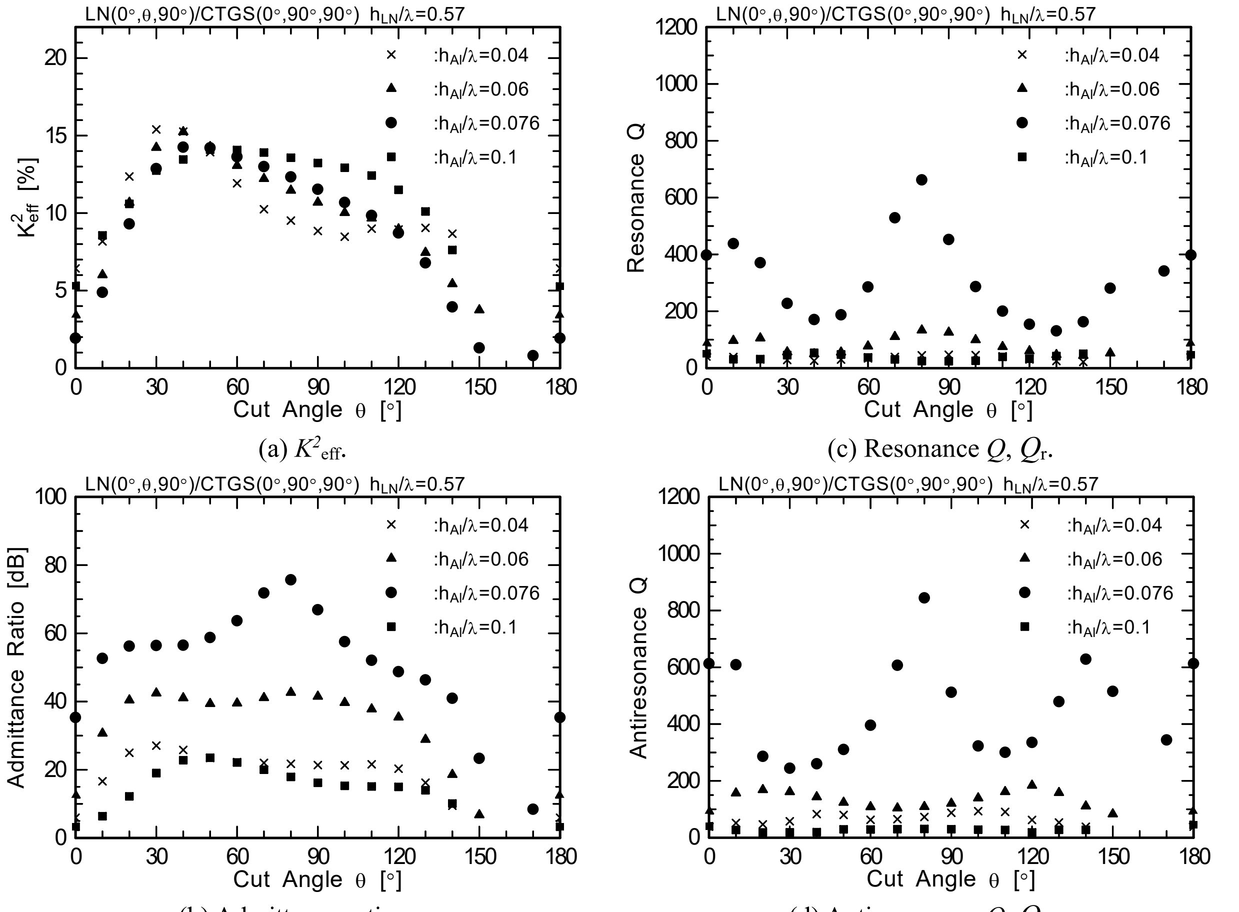

(a) K^2_{eff}.

(c) Resonance Q, Q_{r}.

(b) Admittance ratio.

(d) Antiresonance Q, Q_{a}.

Fig. 3 Simulated LLSAW properties on LN(0°, θ, 90°)/CTGS(0°, 90°, 90°).

As shown in Fig. 3(a), K^2_{eff} showed a maximum value of 15.4% at θ = 30° for $h_{\mathrm{Al}}/\lambda = 0.04$, and it decreased with increasing θ, regardless of the Al thin-film thickness. With increasing Al thickness, the angle θ with the maximum K^2_{eff} increased, and the maximum value decreased. However, as shown in Fig. 3(b), *AR* shows a maximum value of 75.7 dB at θ = 80° for $h_{\mathrm{Al}}/\lambda = 0.076$, and it changes more significantly with θ than with Al thicknesses. Q_{r} shows a maximum value of 662 at θ = 80° for $h_{\mathrm{Al}}/\lambda = 0.076$ and varies from 130 to 662 depending on θ, which is a large variation compared to that with other Al thicknesses, as shown in Fig. 3(c). Q_{a} also exhibits a maximum value of 844 at θ = 80° and varies widely from 244 to 844 depending on θ, as shown in Fig. 3(d).

The resonance properties of LLSAW on the bonded structure of CTGS(0°, 90°, 90°) and an X-cut LN thin plate, that is, the LN(90°, 90°, ψ) thin plate, which is expected to exhibit a larger K^2_{eff}, were also analyzed, as shown in Fig. 2. In this combination, the propagation angles ψ with a high *AR* were obtained for $h/\lambda = 0.52$ and $h_{\mathrm{Al}}/\lambda = 0.06$–$0.08$.

For ψ = 29°, K^2_{eff} of 17.1%, *AR* of 54.8 dB, and Q_{a} of 799 were obtained, Q_{r} had a low value of 29.4. For ψ = 142°, although Q_{a} was 829, Q_{r} had a low value of 150, with K^2_{eff} of 11.3% and *AR* of 61.1 dB. On the contrary, for ψ = 112°, while Q_{r} was 646, Q_{a} was 272, with K^2_{eff} of 13.9% and *AR* of 67.8 dB.

3. Conclusion

The resonance properties of LLSAW on the bonded LN(0°, θ, 90°)/CTGS(0°, 90°, 90°) and LN(90°, 90°, ψ)/CTGS(0°, 90°, 90°) structures were analyzed. The results showed that several combinations of the Euler angle, LN thin-plate thickness, and Al film thickness achieved K^2_{eff} values larger than 11% and high values of Q_{r} and/or Q_{a}. In the future, we plan to investigate on TCF through experimental studies.

Acknowledgment

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References

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