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Longitudinal Leaky SAW with Low Attenuation on $LiTaO_3$ Thin Plate Bonded to Quartz Substrate

$LiTaO_3$薄板と水晶基板の接合による縦型リーキー弾性表面波の低損失化

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1. Introduction

To develop next-generation mobile communication systems, surface acoustic wave (SAW) devices with a high frequency, a large electromechanical coupling factor (K^2), a large Q factor, and a small temperature coefficient of frequency (TCF) are required. Our research group has reported that, when a $LiNbO_3$ (LN) or $LiTaO_3$ (LT) thin plate with a thickness less than the wavelength λ was bonded to an AT-cut 45°X-propagating quartz (AT45°X-Q) substrate, the particle displacement of the longitudinal leaky SAW (LLSAW) was concentrated in the thin plate; thus, a larger K^2 than that on the single LN or LT substrate was obtained.[1,2] However, it was difficult to achieve a high Q factor because the large attenuation of the LLSAW on the bonded structure remained.

In this study, to obtain a bonded structure with low attenuation for an LLSAW, the propagation and resonance properties of an LLSAW on an LT thin plate bonded to an X-cut quartz substrate were investigated theoretically and experimentally.

2. Theoretical Calculation

2.1. Analytical solution

First, the attenuation, K^2, and TCF were calculated for an LLSAW on an X-cut 31°Y-propagating LT (X31°Y-LT) thin plate bonded to a support substrate. X-cut 32°Y-propagating quartz (X32°Y-Q) with a similar phase velocity to AT45°X-Q was chosen as the optimum support substrate. **Figure 1** shows the attenuation on the (a) free and (b) metallized surface as a function of the normalized LT thin-plate thickness (h/λ, λ: wavelength). The attenuation on the free surface of the X31°Y-LT/X32°Y-Q was 0.004 dB/λ at h/λ of 0.06. For the metallized surface, it was 0.0005 dB/λ at h/λ of 0.062. These values of attenuation were lower than that for the previous bonded structure.[1] Moreover, **Fig. 2** shows K^2 and TCF as a function of h/λ. K^2 for the LLSAW on the X31°Y-LT/X32°Y-Q increased with increasing h/λ, and was larger than that on a single LT substrate. At h/λ of 0.062 with the minimum attenuation, K^2 for the LLSAW was 4.8%. In addition, the absolute value of the TCF for the LLSAW on the X31°Y-LT/X32°Y-Q decreased with increasing h/λ, and was -15.2 ppm/°C at h/λ of 0.062. This is approximately half the value for the single LT substrate (-34.9 ppm/°C).

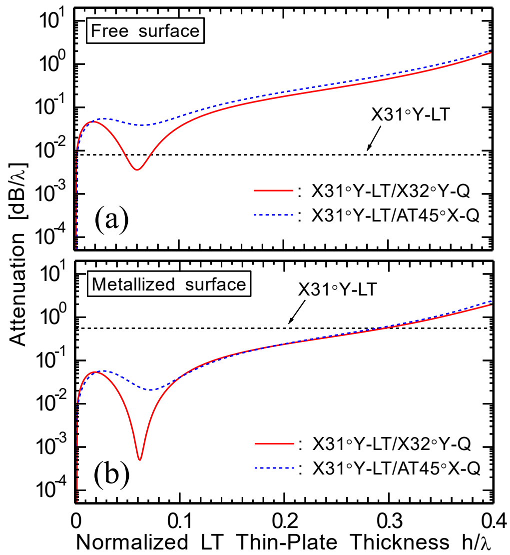

Fig. 1 Attenuation as a function of normalized LT thin-plate thickness for LLSAW for (a) free surface and (b) metallized surface.

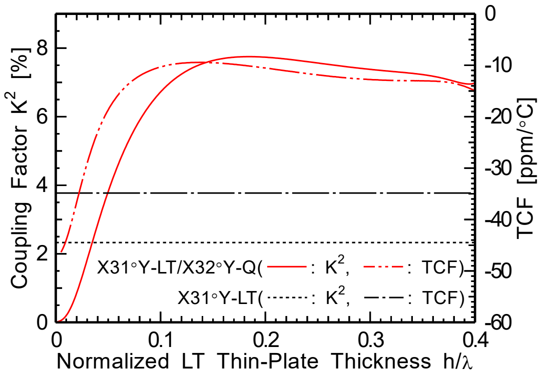

Fig. 2 K^2 and TCF as a function of normalized LT thin-plate thickness for LLSAW.

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2.2. FEM analysis

Using a finite element method (FEM) system, the ideal resonance properties of an LLSAW on X31°Y-LT and X31°Y-LT(h/λ=0.072)/AT45°X-Q and X31°Y-LT(h/λ=0.062)/X32°Y-Q models consisting of an infinite periodic interdigital transducer (IDT) with a period λ of 8.0 μm and an aperture width (W) of 25λ (1,000-Å-thick Al) were simulated. **Figure 3** shows the simulation results for these structures. For the X31°Y-LT/X32°Y-Q model, the admittance ratio and Q factor were improved to 120 dB and 53,400 from 62 dB and 1,000 for the X31°Y-LT/AT45°X-Q model, respectively. Therefore, the bonded structure with the X32°Y-Q support substrate is considered to be effective for improving the attenuation of the LLSAW.

3. Experiment

Several samples with an X31°Y-LT thin plate bonded to a quartz support substrate (AT-cut or X-cut) were fabricated. The propagation directions of the AT-cut and X-cut quartz were set to 45°X and 32°Y, respectively. These wafers were bonded by surface-activated room-temperature bonding (SAB).

First, the surface on the LT wafer side was thinned to a plate thickness h of 9.0 μm for X31°Y-LT/AT45°X-Q and 6.0 μm for X31°Y-LT/X32°Y-Q for measurement of K^2. IDT-type resonator patterns with λ=96 μm, 30 finger pairs (N), the reflector number (N_R) of 0, and W=3 mm were fabricated on the LT surface using a 5,500-Å-thick Al thin film. A similar sample was also fabricated using the single LT substrate. The values of K^2 were determined from the admittance properties. For the X31°Y-LT/AT45°X-Q and X31°Y-LT/X32°Y-Q, the values of K^2 increased to 6.4% and 5.6% from 1.8% for the single LT substrate, respectively. Good agreement between the measured and calculated values of K^2 were obtained for both bonded samples.

Next, the surface on the LT wafer side was thinned to a plate thickness h of 3.0 μm for X31°Y-LT/X32°Y-Q for measurement of resonance properties. IDT-type resonator patterns with λ=32 μm (h/λ=0.094), N=50.5, N_R=50, and W=25λ was fabricated on the bonded sample and a single LT surface using a 3,000-Å-thick Al thin film. **Figure 4** shows the measured and simulated resonance properties of an LLSAW on each sample. In the measured result, the ripple responses due to bulk waves reflected from the back polished surface of the quartz substrate were removed by a time gate option. For the X31°Y-LT/X32°Y-Q sample, the admittance ratio, Q factor, and anti-Q factor increased to 45.0 dB, 282, and 404 from 9.4 dB, 32, and 32 for the single LT, respectively. The measured Q factor was smaller than the simulated value. It is expected that a larger Q factor can be obtained by controlling the normalized LT thin-plate thickness.

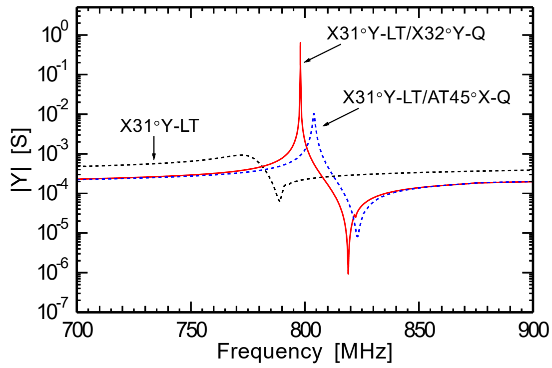

Fig. 3 Simulated resonance properties for LLSAW.

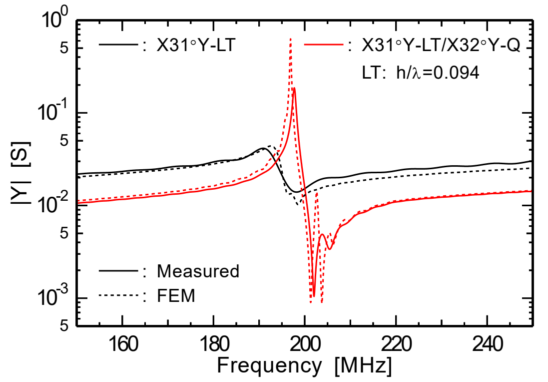

Fig. 4 Measured and simulated resonance properties for LLSAW.

4. Conclusions

In this study, to obtain a low attenuation, the propagation and resonance properties of an LLSAW on an X31°Y-LT/X32°Y-Q structure were investigated. The attenuation on the metallized surface of the structure was calculated to be 0.0005 dB/λ at h/λ=0.062 and was lower than that on an X31°Y-LT/AT45°X-Q structure. In addition, for the X31°Y-LT/X32°Y-Q, the measured values of K^2 and Q factor increased to 5.6% and 282 from 1.8% and 32 for the single LT, respectively. The value of K^2 is 3.1 times the value of the single LT. A larger Q factor will be obtained by controlling the normalized LT thin-plate thickness.

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References

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