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Resonance Properties of Leaky SAW Harmonics on $LiNbO_3$/Quartz Bonded Structures

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1. Introduction

High-performance surface acoustic wave (SAW) devices with a high frequency, a wide bandwidth, a large *Q* factor, and a small temperature coefficient of frequency (TCF) are required. As an approach to achieving high-frequency operation, the utilization of high-order SAW harmonics has been proposed. The SAW excited by an interdigital transducer (IDT) contains odd-order harmonics components in addition to the fundamental wave. Their excitation intensity depends on the ratio of the electrode width *a* to the pitch *p* (metallization ratio: *a*/*p*) of an IDT[1].

Our research group has experimentally demonstrated the enhancement of the excitation of the leaky SAW (LSAW) third harmonic by utilizing a $LiTaO_3$ (LT)/quartz (Qz) bonded structure.

In this study, we investigated experimentally the resonance properties and TCF of the LSAW fundamental wave, 3rd, and 5th harmonics on a bonded structure consisting of a thin $LiNbO_3$ (LN) plate with a larger piezoelectricity than LT and a Qz support substrate[3].

2. Resonance properties of fundamental wave

A 36°YX-LN wafer with a cut close to the optimal 27°YX-LN for high coupling[2] and a AT90°X-Qz wafer were directly bonded to each other by surface-activated room-temperature bonding, and the LN wafer side was thinned and polished to a plate thickness of h=1.3 μm. A resonator pattern with a period λ of 6.4 or 8 μm, N of 60.5 (number of finger pairs), reflector number N_R of 100, aperture width W of 25λ, and a/p=0.3 was fabricated on the LN surface using a 240-nm-thick Al thin film. For comparison, a single 36°YX-LN sample was also fabricated.

Figure 1 shows the resonance properties of the LSAW fundamental wave on LN/Qz and single LN with λ=6.4 μm measured using a network analyzer. The admittance ratio (*AR*), fractional bandwidth (*FBW*), resonance *Q* factor (Q_r), and antiresonance *Q* factor (Q_a) of the LN/Qz structure were 79 dB, 10.4%, 280, and 1,210, respectively, which were larger than those of the single LN (52 dB, 7.3%, 150, and 170, respectively).

3. Resonance properties of 3rd harmonic

Next, we examined the LSAW 3rd harmonic

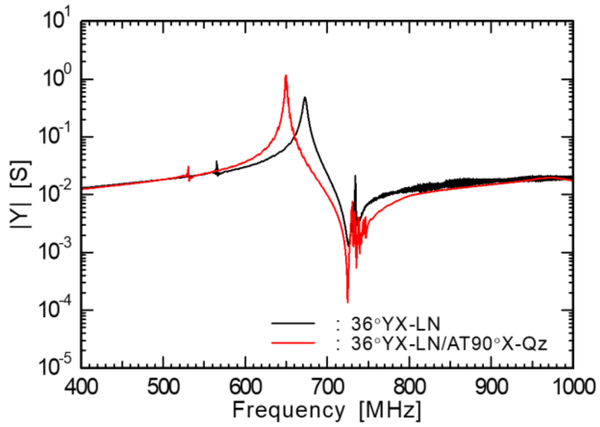

Fig. 1 Measured resonance properties of fundamental wave (λ=6.4 μm).

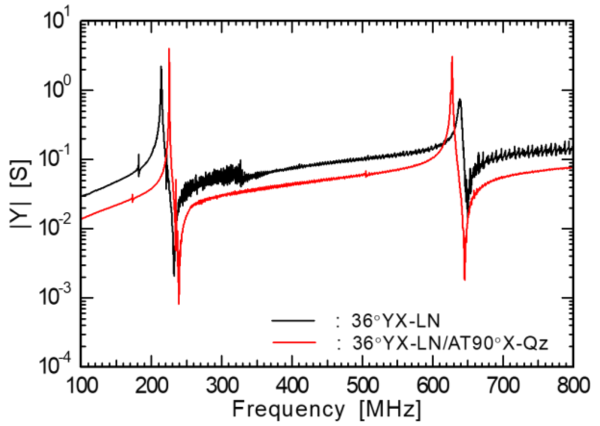

Fig. 2 Measured resonance properties of fundamental wave and 3rd harmonics (λ=20 μm).

on 36°YX-LN/AT90°X-Qz with h=1.3 μm. A resonator pattern with λ=20 or 24 μm, N=100.5, N_R=100, W=25λ, and a/p=0.7 was fabricated on the LN surface using a 420-nm-thick Al thin film.

Figure 2 shows the measured resonance properties of the LSAW fundamental wave and 3rd harmonic with λ=20 μm. The measured *AR*, *FBW*, Q_r, and Q_a values of the 3rd harmonic on LN/Qz at around 620 MHz were 65 dB, 2.8%, 1,030, and 860, respectively, which were larger than those of the single LN (36 dB, 1.6%, 180, and 220, respectively). In addition, this *FBW* was twice the measured *FBW* (1.4%) for the LSAW 3rd harmonic with a similar pattern on the 36°YX-LT(h=1.0 μm)/AT0°X-Qz structure[2].

4. Resonance properties of 5th harmonic

Then, we also examined the 5th harmonic on

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36°YX-LN/AT90°X-Qz with h=1.3 µm. A resonator pattern with λ=32 or 38 µm, N=100.5, N_R=100, W=25λ, and a/p=0.83 was fabricated on the LN surface using a 400-nm-thick Al thin film.

Figure 3 shows the resonance properties of 36°YX-LN/AT90°X-Qz with λ=32 µm measured over a wide frequency band. In addition to the resonances of the LSAW fundamental wave and 3rd harmonic, the resonances of the 5th and 7th harmonics were clearly observed. **Figure 4** shows an enlarged view of the resonance properties of the 5th harmonic and the simulated result obtained by the finite element method using the model with the above parameters. The mechanical loss of LN was assumed to be 1,000. The measured AR, FBW, Q_r, and Q_a values of the 5th harmonic on LN/Qz were 50 dB, 1.8 %, 380, and 470, respectively, which were equivalent to the simulated results of 52 dB, 1.7 %, 370, and 540, and also were larger than those of the single LN (28 dB, 1.1%, 80, and 450, respectively).

5. TCF

The TCF was determined by measuring the rates of changes in the resonance frequency f_r values of the LSAW fundamental wave and 3rd and 5th harmonics when the temperature of the hot plate on which the sample was placed was changed from 30°C to 80°C.

Figure 5 shows the measured TCF together with the calculated TCF as functions of $h/λ$ for the metallized surface. The TCF of the fundamental wave ($h/λ$=0.203) of the bonded sample for λ=6.4 µm was –59.3 ppm/°C, which was better than that of the single LN (–71.9 ppm/°C). The TCF of the 3rd harmonic for λ=20 µm was –80.7 ppm/°C ($h/λ$=0.195), which was almost equal to the measured TCF of the 5th harmonic at λ=32 µm of –79.6 ppm/°C ($h/λ$=0.203). However, in spite of $h/λ$ being the same, the absolute TCF values of the 3rd and 5th harmonics were observed to be larger than that of the fundamental wave.

6. Conclusion

In this study, the resonance properties and TCF of the LSAW fundamental wave and 3rd and 5th harmonics on the LN/Qz bonded structure were investigated experimentally. The experimental results showed that the bonded structure excites the harmonics more strongly than in the case of the single LN. For the 3rd harmonic, the FBW of 2.8%, twice the FBW of LT/Qz[2], was obtained. The bonded structure exhibited a better TCF than did the single LN; however, the absolute TCF values of the harmonics were larger than that of the fundamental wave. In the future, we will examine the factors that cause the TCF difference between the fundamental wave and the harmonics, and investigate methods of improving the TCF.

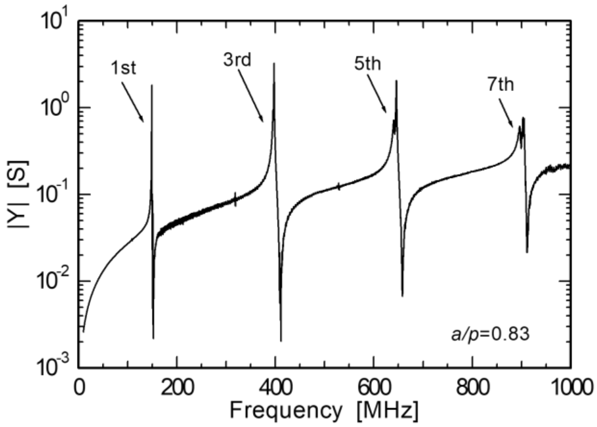

Fig. 3 Measured resonance properties of 36°YX-LN/AT90°X-Qz (λ=32 µm).

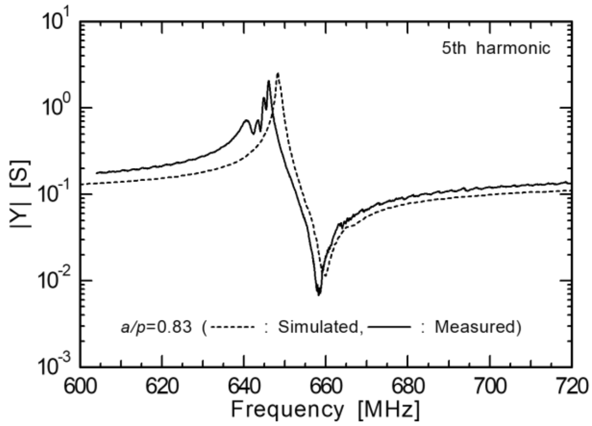

Fig. 4 Measured and simulated resonance properties of 5th harmonic (λ=32 µm).

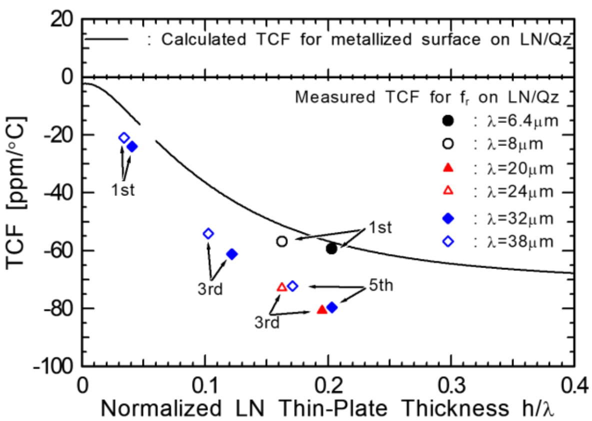

Fig. 5 Measured and calculated TCF values.

Acknowledgments

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References

1. H. Engan, IEEE Trans. Electron Devices, **ED-16** (1969) 1014.
2. S. Asakawa, *et al.*, JJAP **60** (2021) SDDC07.
3. M. Gomi, *et al.*, JJAP **56** (2017) 07JD13.