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3.4 GHz Strip-Type TS mode Solidly-Mounted BAW Resonator Using X LT

X LT を用いた 3.4 GHz Strip 型厚みすべり音響多層膜共振子

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1. Introduction

Surface and bulk acoustic wave (SAW and BAW) filters are widely used as key RF devices in mobile phone systems. Recently, they are expected to cover a higher frequency range up to 6 GHz. Comparing SAW and BAW devices, it is commonly understood that the BAW devices are suitable for high frequency applications. The most widely used materials for BAW device are polycrystalline AlN and ScAlN. On the other hand, monocrystalline $LiNbO_3$ (LN) and $LiTaO_3$ (LT) thin plates are recently attracting attention for high frequency BAW devices because their thinning technique has become available.

LN has been considered for BAW resonators (BAWRs) with high electromechanical coupling. Before LN thinning technique was established, epitaxially-grown c-axis LN was used for a 3 GHz BAWR. Later, polished 45°Y and 36°Y LN thin plates were used for thickness extension (TE) mode BAWRs[1-4)]. For thickness shear (TS) mode BAWRs, X and 63°Y LN thin plates were used[5)]. LT has moderate electromechanical coupling factors and better temperature characteristics compared with LN. TE mode 2.49 GHz and TS mode 1.64 GHz BAWRs using 42°YX LT and X LT have been reported, respectively[6)].

For GHz range BAWRs, the thickness of LN and LT is submicron. Such thin self-suspended LN and LT are very fragile, which make their practical use challenging. To address this problem, a solidly-mounted type of BAWR using LN and LT has been studied. To date, 0.5 μm thick 43°Y LN and 1 μm thick 20°Y LN were used for 3.18 GHz and 3.31 GHz TE mode resonators, respectively[7-9)]. LT showed better temperature coefficients of frequency (TCF) and higher impedance ratio (Z ratio). A 1 GHz strip-type TS mode solidly-mounted BAWR and 1.19 GHz TS mode one were demonstrated using 2 and 1.5 μm thick X LT, respectively[10, 11)].

In this study, we prototyped a higher frequency strip-type TS mode solidly-mounted BAWR using a thinner LT plate. Resonance frequency higher than 3 GHz was demonstrated using about 0.6 μm thick X LT supported with an Al/Ta Bragg reflector.

2. Fabrication of strip-type BAWR

The fabrication process is shown in Fig. 1. First, a 250 μm thick 4 inch X LT substrate and a 300 μm thick 4 inch Si substrate are directly bonded[12)]. To reduce a thickness variation of LT after polishing, the total thickness variation (TTV) of the Si substrate is less than 1 μm. Then, the LT substrate is polished and thinned to a target thickness of 0.6 μm. As the Bragg reflector, four layers of 140 nm thick Al and Ta are alternately deposited on the polished plane of LT. Another Si substrate (B) for a support is bonded to the Bragg reflector with polymer adhesive, and then the first Si substrate (A) is removed by dry etching. Two 100 nm thick Al electrodes are formed on the LT surface by photolithography. Finally, grooves are formed on both edges of each resonator using a saw dicer.

The thickness of LT after polishing is within 0.55 to 0.63 μm in 70% area of the substrate. In this study, an area of 0.56 μm thick LT was used. The fabricated device is a pair of resonators connected in series. This structure can be fabricated just by patterning double upper electrodes more easily than a single resonator[10, 11)], because the etching of LT for bottom electrode contact is not necessary.

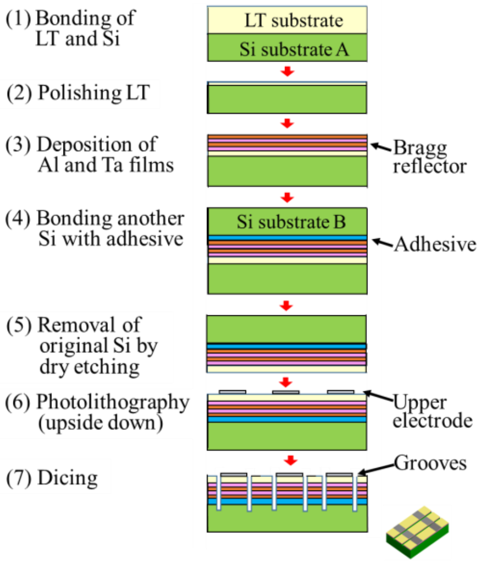

Fig. 1 Fabrication process of solidly-mounted BAWR.

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3. Measured frequency characteristics

Two types of solidly-mounted BAWRs were fabricated using (90°, 90°, 37°) (X37°Y) and (90°, 90°, 127°) (X127°Y) LT as shown in Fig. 2. The dimensions of the fabricated resonators range 60-500 μm in width (*W*), 80-470 μm in length (*L*) and 150-340 μm in gap (*G*). The best performance was obtained when *G* was 150 μm, which was the minimum in this study, for both types. A shorter gap should be investigated in the future.

Figure 3 shows the measured frequency characteristics. The X37°Y LT BAWR (*W* = 150 μm, *L* = 90 μm and *G* = 150 μm) exhibited a resonance frequency (f_r) of 3.250 GHz, an antiresonance frequency (f_a) of 3.463 GHz, a bandwidth (BW) of 6.6% and an *Z* ratio of 48 dB. The X127°Y LT BAWR (*W* = 150 μm, *L* = 140 μm and *G* = 150 μm) has a similar characteristic with f_r of 3.153 GHz, f_a of 3.367 GHz, a BW of 6.8% and an *Z* ratio of 46 dB. Finite element method (FEM) simulation suggested that the X37°Y LT BAWR with one upper electrode had about 17 dB higher *Z* ratio than the X127°Y LT BAWR[10, 13], but the measure results of the BAWRs with double upper electrodes showed an advantage of only 2 dB.

The resistivity of the double upper Al electrodes deposited in our laboratory is as high as 44 nΩm, which is 1.7 times higher than the theoretical value of 26.5 nΩm, which cause major degradation in *Z* ratio, especially in SAW resonators[14]. Another concern is a plasma damage of LT by the dry etching removal of the first Si substrate, which will be investigated in the future.

4. Conclusion

We fabricated strip-type TS mode solidly-mounted BAWRs working above 3 GHz using 0.56 μm thick X37°Y and X127°Y LT. The X37°Y LT device exhibited a BW of 6.6% and an *Z* ratio of 48 dB at 3.4 GHz. This performance is better than that of the X127°Y LT device, but the advantage is not so prominent as predicted by FEM simulation. The optimization of the electrode design and the fabrication process is necessary for better perforomace.

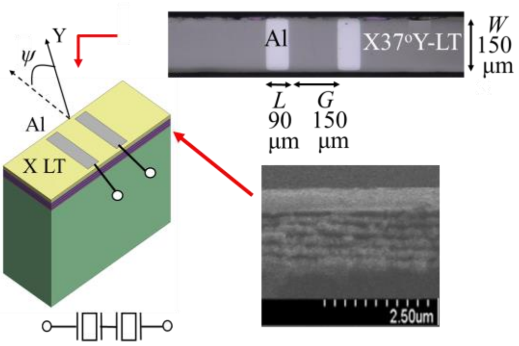

Fig. 2 Top view and cross section of X37°Y LT solidly-mounted BAWR.

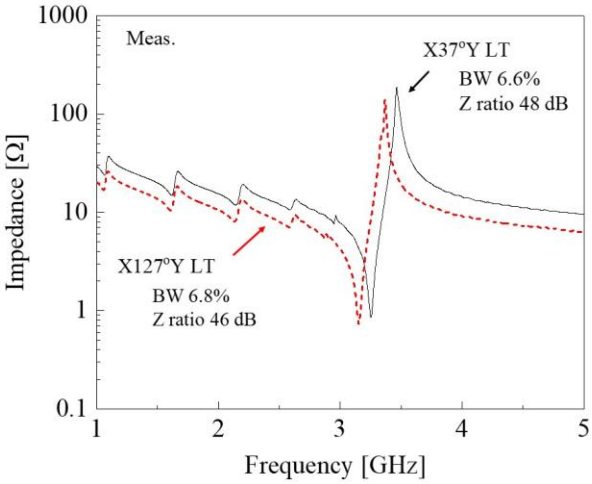

Fig. 3 Frequency characteristics of strip-type TS mode solidly-mounted BAWRs using X37°Y LT (solid line) and X127°Y LT (broken line).

Acknowledgment

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