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Acoustic Wave Devices composed of Periodical Poled Z-cut $LiTaO_3$ Plate

周期的分極反転 $LiTaO_3$ 基板からなる弾性波デバイス

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1. Introduction

Currently, high frequency SAW devices are required. When the high frequency devices are realized by shortening lines (fingers' width) and spaces (gaps' width) (L&S) of an interdigital transducer (IDT), its device is weak to an input electrical power. Authors consider that an acoustic device composed of a top-electrode/periodical poled (PP) substrate/bottom-electrode[1)] would be strong to the input electrical power compared with the conventioal SAW devices using the IDT.

It was reported that acoustic devices composed of a PP $Pb(Zr_x,Ti_{1-x})O_3$ (PZT) plate on Si substrate, a PP $Pb(Zr_{0.2},Ti_{0.8})O_3$ thin film on (001)$SrTiO_3$ substrate, and a PP Z-$LiNbO_3$ had only weak responsed of 0.1 to 3 dB such as impedance, conductance, or susceptance.[2-4)] Conventional surface acoustic wave (SAW) resonator type devices such as a resonator, a multi-mode resonator filter, and a ladder type filter realize a good frequency characteristics by applying a reflection of electrode fingers of the IDT and grating reflectors at the both sides of the IDT. So, this reason is considered that their PP devices have neither the IDTs nor the grating reflector electrodes for the reflection of the acoustic wave.

This time, authors have proposed an effective reflectors for the PP device by using edge reflections.

2. Principle and Calculation

By applying a high frequency electric field to the periodically poled plate in the vertical direction of the plate using the top and bottom parallel electrodes, the acoustic waves can be excitated. In this excitation method, the direction of pole inverses periodically. On the other hand, in conventional SAW devices, the direction of electric field inverses periodically.

Fig. 1 shows the calculated velocity and electro-mechanical coupling factor of a fundamental symmetrical (S_0) mode of lamb wave in the PP $LiTaO_3$ (PPLT) plate. When the normalized thickness is 0.5λ to 0.7λ, a largest coupling factor is obtained. However, its value is not so large compared with other Lamb waves and conventional SAWs.[5-7)]

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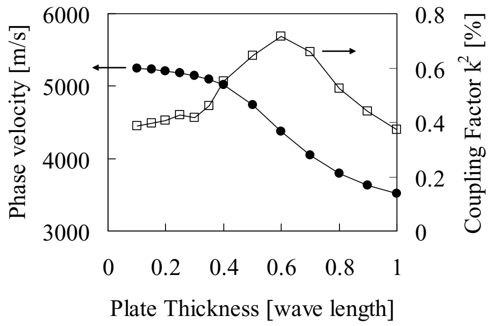

Fig. 1 Calculated velocity and electro-mechanical coupling factor.

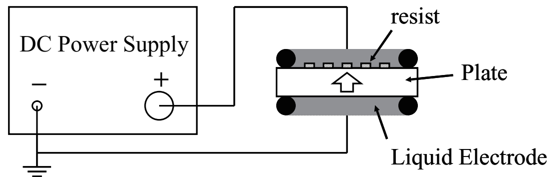

Fig. 2 Polarization system.

3. Fabrication of PPLT

Authors attempted to fabricate the PP devices using the $LiTaO_3$ single crystal plate of thickness of 0.7λ, which λ is 500μm. **Fig. 2** shows a polarizaing system. After forming periodical chemical resist lines on the top surface of the $LiTaO_3$ plate, the substrate was polarized by applying a DC voltage to liquid electrodes on both sides of the plate. The lines without the resist were polarized in the opposite direction. After polarizing, the substrate was washed and the resist lines were removed. After that, by depositing electrodes on both side of the substrate and dicing it, the PP devices were fabricated.

4. Frequency Characteristics

A. Resonator composed of PPLT

It is known that the ultra small resonator or resonator filter are realized by using the edge reflection.[8)] Authors propose to apply the edge reflection to the PPLT devices. The shear horizontal (SH) wave reflects completely at the free edges of the substrate. Though the PPLT device does not have the SH conponent and has only the longitudinal wave, authors attempted to use the reflection of a longitudinal wave in the PPLT at the substrate edges. **Figs. 3(a) and (b)** show schematic views of fabricated resonator and resonator filter using the PPLT. A length of the resonator in the propagating direction of the acoustic wave of the PPLT and a vertical width to its direction were decided by dicing the PPLT. The PPLT resonators has the aperture of 18 λ and 20 domain pairs. **Fig. 4** shows the frequency characteristic of the PPLT resonator. The resonator with the impedance ratio of 33 dB have been realized. This characteristic is epoch-making as the PP device. It is considered that a larger impedance ratio could be obtained by improving a supporting method of the resonator and optimizing the aperture and domain pairs.

B. Resonator filter composed of PPLT

Authors have also attempted to fablicate a multi-mode longitudinal resonator filter composed of the PPLT as shown in Fig. 3(b). The filter is composed of the aperture of 18 λ, the input and output electrodes of each 10 domain pairs, and a gap length of 2 λ between input and output electrode. **Fig. 5** shows the frequency characteristic of the filter, which has an insertion loss of 2.6 dB, a relative bandwidth of 2.2%, and a good attenuation.

5. Conclusion

The previously reported PP structure devices did not have excellent characteristics so far. Authors have considered that the reason was because the previous PP structure devices did not have any effective reflectors to obtain excellent characteristics. Authors considered that the reflection of the longitudinal bulk wave of the PPLT at the substrate edges might be applied to realize PP device with a good characterictic as well as edge reflection devices using SH wave. Authors have fabricated the PPLT devices utilizing the edge reflections of the longitudinal bulk wave. As the result, a resonator having the impedance ratio of 33 dB and the resonator filter having an insertion loss of 2.6 dB and a relative 3dB bandwidth of 2.2 % are realized for the first time. High frequency PPLT devices higher than 1 GHz could be realized, if the plate thickness thinner than 2.6 μm and the PP width narrower than 2.2 μm are fabricated.

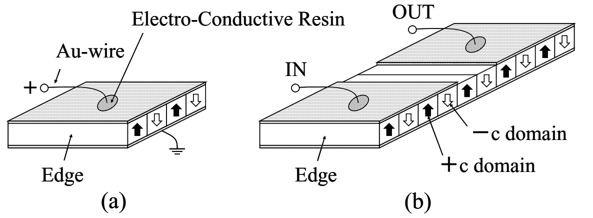

Fig. 3 Schematic views of (a) PPLT resonator and (b) resonator filter using edge reflection.

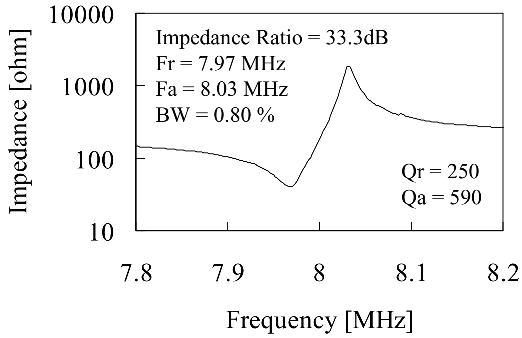

Fig. 4 Frequency characteristic of PPLT resonator using edge reflection.

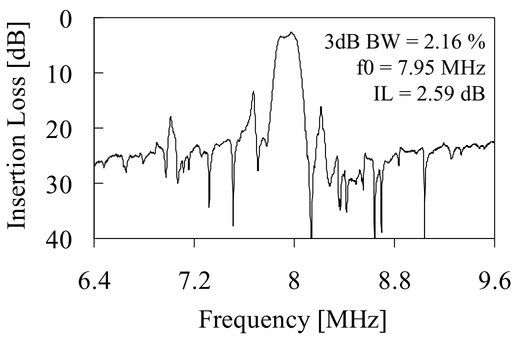

Fig. 5 Frequency characteristic of PPLT longitudinal resonator filter using edge reflection.

References

1. Y. Shimizu and T. Shimizu: Trans. IECE Japan **J68-C** (1985) 532. [in Japanese]
2. S. Ballandras : Proc. IEEE Freq. Cont. Symp. (2003) 893.
3. A. K. Sarin Kumar, P. Paruch, J. -M. Triscone, W. Dainau, S. Ballandras, L. Pellegrino, D. Marre, and T. Tybell : Appl. Phys. Lett. **85** (2004) 1757.
4. E. Courjon, N. Courjal, W. Daniau, G. Lengaigne, L. Gauthier-Manuel, S. Ballandras. and J. Hauden : Joul. Appl. Phys. **102** (2007) 114107.
5. K. Kadota, T. Ogami, K. Yamamoto, Y. negoro, H. Tochishita : Proc. 37-th Elect. Mech. Symp. (2008) 69. [in Japanese]
6. K. Yamanouchi and K. Shibayama : Jpn. J. Appl. Phys. **43** (1972) 856.
7. K. Nakamura, M. Kazumi, and H. Shimizu : Tech. Rep. of IEICE Japan **US77-42** (1977) 31. [in Japanese]
8. Y. Suzuki, H. Shimizu, M. Takeuchi, K. Nakamura, and A. Yamada : Proc. IEEE Ultrason. Symp. (1976) 297.