2P3-7

Fabrication and evaluation of piezoelectric boundary acoustic wave filter for a gate drive circuit

Kazuya Murakami [1†], Masashi Suzuki[1], Shoji Kakio[1*], and Shigeyoshi Goka[2]
([1] Univ. of Yamanashi, [2]Tokyo Metropolitan Univ.)

1. Introduction

Multilevel inverters employing a large number of switching elements to achieve high-efficiency energy conversion have been extensively studied in the field of power electronics. However, the increasing amount of electrical wiring required for each switching element in an inverter control circuit poses challenges in terms of reliability and cost. This research group proposed a gate drive system using a surface acoustic wave (SAW) filter to realize next-generation power conversion circuits with high reliability and high-temperature operation[1,2]. An inverter control circuit requires strong electrical isolation performance from the power supply source and output. In addition, the filter surface has cavities because of the surface wave nature of SAW filters, which limits the improvement in insulation performance.

In this study, a piezoelectric boundary acoustic wave (PBAW) filter, wherein the surface of the filter is sealed by a dielectric material, is used to overcome the issue of SAW filter insulation. For using the PBAW filter in our gate drive system, it must be a transversal-type filter to increase the electrically isolated distance. We aim to improve isolation characteristics by encapsulating the propagation path with a dielectric material, apply PBAW instead of SAW, and fabricate and evaluate a PBAW transversal-type filter[3] for gate drive circuits.

In this report, the $SiO_2/Au/LiNbO_3$ structure, which is an established resonator-type filter[4], is examined. The novel $SiO_2/Ta_2O_5/Au/LiNbO_3$ structure[5] is also examined.

2. PBAW on the SiO_2/Au/YX-LN structure

First, a 60-nm-thick adhesion layer of a Cr film and a 400-nm-thick Au film were deposited on a Y-cut X-propagating LN (YX-LN) substrate (15 × 16 mm^2) by DC sputtering. The input and output interdigital transducers (IDTs) with a wavelength λ of 8 μm, a number of finger pairs N of 10, an overlap length W of 50 λ, and a metallized propagation path length of 10 λ was fabricated by photolithography with wet etching. Then, a 14.4-μm-thick SiO_2 film was deposited on the IDTs and propagation path by RF sputtering to fabricate a SiO_2/Au/YX-LN transversal filter as shown in **Fig. 1**.

E-mail:[†]g23te028@yamanashi.ac.jp,[*]kakio@yamanashi.ac.jp

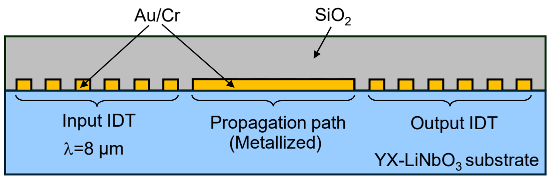

Fig. 1 Configulation of PBAW filter.

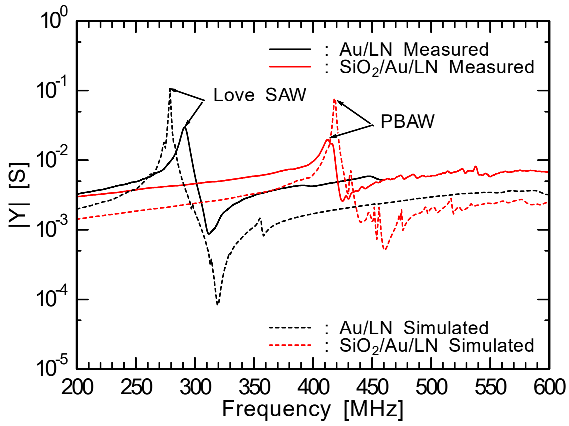

Fig. 2 Measured and simulated IDT admittance properties before and after SiO_2 deposition.

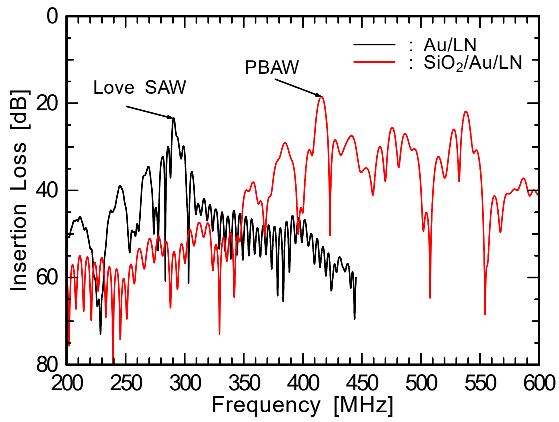

Fig. 3 Measured frequency responses before and after SiO_2 deposition

Figures 2 and **3** show the measured and simulated IDT admittance properties before and after SiO_2 deposition and the measured frequency response between input and output IDTs, respectively. As shown in Fig. 3, responses attributed to electromagnetic waves and a triple transit echo were removed using a time gate option. The response at ~290 MHz before SiO_2 deposition was a Love-wave-type SAW (Love SAW). The response at ~420

MHz after SiO_2 deposition was a PBAW because the insertion loss did not change when an adhesive tape was applied on SiO_2. As shown in Fig. 2, the response frequencies measured before and after SiO_2 deposition are consistent with the simulated values obtained using a finite element method. However, the measured admittance ratio and bandwidth between the resonance and antiresonance frequencies were smaller than the simulated values. This can be attributed to the reflection coefficient in the IDT of the sample being smaller than that in the simulation because of side and over etching. Figure 3 shows that the insertion loss of PBAW is 19 dB, which is smaller than that of the Love SAW (23 dB).

3. PBAW on the $SiO_2/Ta_2O_5/Au$/YX-LN structure

Boundary wave propagation requires a large IDT electrode mass that reduces the PBAW velocity, thereby increasing the acoustic impedance difference between the electrode and no electrode. Further, it increases the reflection coefficient at each electrode end and impedes PBAW propagation. The acoustic impedance in the propagation direction of PBAW is affected by mass loading, and therefore, we attempted to increase the acoustic impedance in a no electrode area by substituting a Ta_2O_5 thin film with a higher mass density than that of SiO_2 with part of the SiO_2 layer[5].

We fabricated a simpler structure because the device fabrication process becomes extremely complicated, as shown in **Fig. 4**. In this structure, a Ta_2O_5 film with a thickness of 0.88 µm was deposited on the entire surface of the Au-IDT/LN with λ = 9.6 µm, N = 6, and W = 28 λ, and then, a SiO_2 film with a thickness of 15.7 µm was deposited. The propagation path length of 5 λ consisted of a Au open grating with the same period as that of the IDT.

Figure 5 shows the measured IDT admittance properties for the Au/LN, Ta_2O_5/Au/LN, and SiO_2/Ta_2O_5/Au/LN structures. The response frequency of the Love SAW on the Ta_2O_5/Au/LN shifted from 350 on the Au/LN to 300 MHz because of the high acoustic impedance of Ta_2O_5. **Figure 6** shows the corresponding frequency responses. The response appeared around 330 MHz on the SiO_2/Ta_2O_5/Au/LN was confirmed to be PBAW because insertion loss did not change after applying an adhesive tape on SiO_2. However, as shown in Fig. 6, the insertion loss of PBAW was large, at ~15 dB.

4. Conclusion

In this report, transversal-type PBAW filters were fabricated and evaluated for application in inverter gate-drive circuits. To this end, a SiO_2/Au/YX-LN sample was fabricated and a better insertion loss was obtained for PBAW than that for Love SAW. Finally, the $SiO_2/Ta_2O_5/Au$/YX-LN

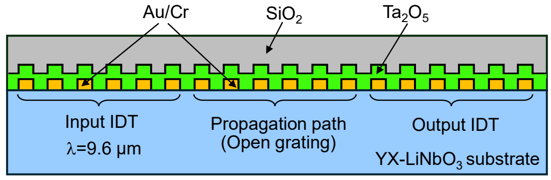

Fig. 4 Configulation of PBAW filter with Ta_2O_5.

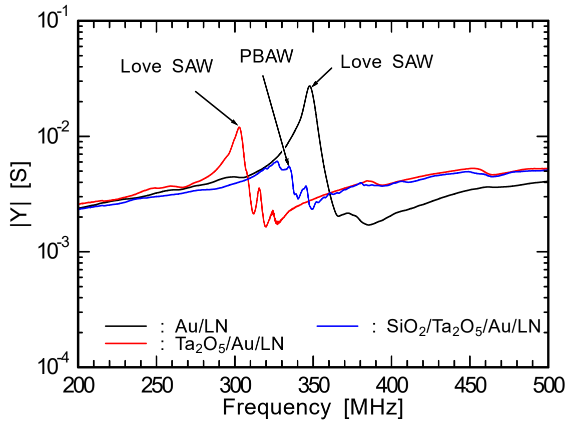

Fig. 5 Measured IDT admittance properties.

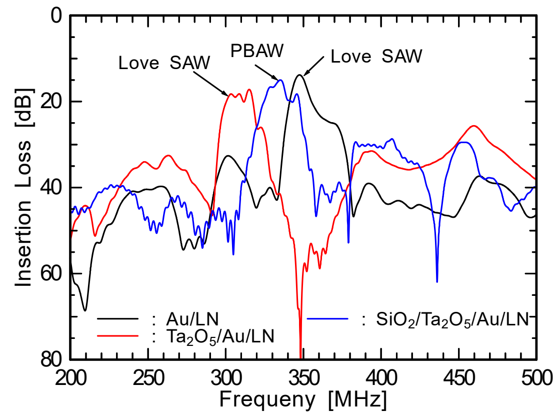

Fig. 6 Measured frequency responses.

structure was fabricated to reduce the reflection coefficient at the electrode edge; however, the measured insertion loss was still large (~15 dB). We will consider improving this insertion loss in future.

Acknowledgment

This work was supported by a Grant-in-Aid for Scientific Research (B) (No. 22H01476) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

1) A. Suzuki, *et al.*, Jpn. J. Appl. Phys. **55,** 07KD01 (2016).
2) K. Kubo, *et al.*, Jpn. J. Appl. Phys. **56,** 07JD03 (2017).
3) Y. Mitsui, *et al.*, Proc. USE, 1P3-7 (2023).
4) H. Kando, *et al.*, Jpn. J. Appl. Phys. **45**, 4651 (2006).
5) K. Imamura, *et al.*, Proc. 50th EM Symp., EM50-1-05 (2021). [in Japanese].