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Low Velocity I.H.P. SAW using Heavy Electrodes for Downsizing
重い電極を用いた低音速 I.H.P. SAW デバイス

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1. Introduction

After the disclosure of Incredible High-Performance (I.H.P.) SAW in 2016[1], significant improvements of main important characteristics of SAW devices for RF front-end portions of cellurer phone handsets, such as quality factor (Q), temparature stability, and electromechanical coupling, have been achieved in recent few years by employing multilayered structures with a very thin singl-crystal piezoelectric layer. In addition to these improvements, another large concern for SAW devices is its downsizing.

The technique for the velocity redcution of Rayleigh SAW on $LiNbO_3$ substrate using heavy metal for electrodes, that is for device miniualization, has been proposed in [2]. On the basis of the same aproach, in this work, we attempt to reduce the velocity of I.H.P. SAW using hevy metal electrode while keeping other important main characteristics.

2. FEM Simulation

Fig. 1 shows the simulation model of 2D-FEM in this work. This model is constructed by a couple of Al/Pt electrodes and layered 50°YX-$LiTaO_3$ (50LT)/SiO_2/Si substrate. In addition, applying periodic boundary conditions to the each side boundary, this model is assumed to be a part of the infinitely long interdigital transducer (IDT) structure. Thicknesses of Al, LT, and SiO_2 layer in wavelength ratio are 7.3%, 30.0%, and 33.7%, respectively, and they are identical with the conventional I.H.P. SAW structure. Using this model, variations of SAW velocity and fractional bandwidth of a resonator with respect to the Pt thickness is estimated.

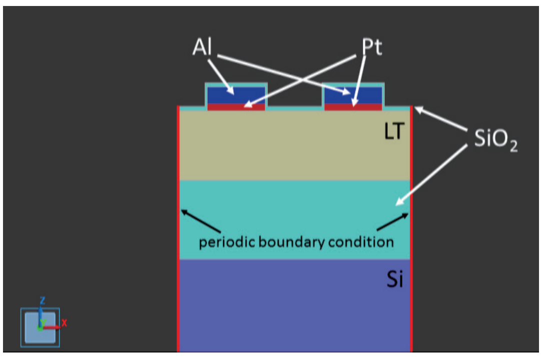

Fig. 1 Simulation model for 2D-FEM.

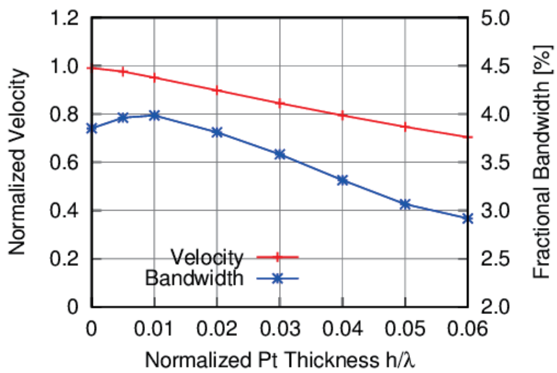

Fig. 2 Simulated variation of velocity and fractional band width with Pt thickness.

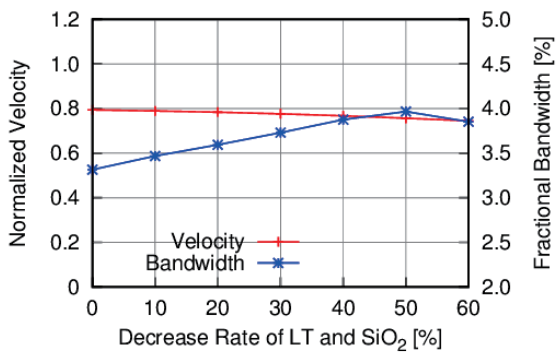

Fig. 3 Simulated variation of velocity and fractional bandwidth with LT and SiO_2 thickness.

First, calculated data of the SAW velocity at the resonance frequency and fractional bandwidth with the variation of the Pt thickness is shown in **Fig. 2**. With the increase of the Pt thickness, SAW velocity decreases monotonically. Employing the Pt thickness of 4.0% in wavelength ratio, SAW velocity is expected to be reduced approximately 20%. On the other hand, the fractional bandwidth becomes smaller compared with that of the conventional structure when the Pt thickness is larger than 2.0%. This degradation is not acceptable for the replacement of conventional normal I.H.P. SAW (NM-I.H.P.).

Next, variation of SAW velocity and the fractional bandwidth with respect to the LT and SiO_2 thickness, where the Pt thickness is 4.0%, is shown in **Fig. 3**. In this calculation, LT and SiO_2 thicknesses are reduced while keeping their ratio. In

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this result, the fractional bandwidth becomes large with the decrease of LT and SiO_2 thickness, and the variation is large enough to recover the degradation of bandwidth due to the influence of Pt layer.

3. Experimental Evaluation

On the basis of the calculation data in Sect. 2, two one-port SAW resonators are fabricated and their characteristics are evaluated. Structure parameters of the fabricated resonators are shown in **Table I**. The structure of resonator 1 is conventional type and that of resonator 2 is proposed for the low velocity I.H.P. SAW (LV-I.H.P.). In these structures, actual thicknesses of the substrate layer are fixed and the thicknesses in the wavelength ratio are adjusted by the grating period of the IDT.

Figs. 4(a) and **4(b)** shows the measurement result of impedance characteristics and Bode-Q of the fabricated resonators. In these figures, the red lines show the NM-I.H.P. of resonator 1 and blue lines show the LV-I.H.P. of resonator 2 with Al/Pt electrodes. The horizontal axis shows the frequency normalized by the resonance frequency of the resonator 1.

Fig. 4(a) indicate that the velocity of I.H.P. SAW is reduced approximately 20 % by employing heavy Al/Pt electrodes as expected. In addition to that, Bode-Q of the LV-I.H.P. is not deteriorated or is somewhat improved compared with the NM-I.H.P.

Table II shows the measured values of fabricated resonators. The fractional bandwidth of LV-I.H.P. is also not deteriorated as estimated by the FEM simulations. With regard to the Temperature Coefficients of Frequency (TCF), although the absolute values at the resonance and the anti-resonance frequencies are slightly larger than those of NM-I.H.P., they are sufficiently with in the allowable range.

Table I Structure parameters of the one-port SAW resonators.

	Resonator 1 (NM-I.H.P.)	Resonator 2 (LV-I.H.P.)
Substrate	50LT	
LT Thickness (in wavelength ratio)	600 nm (30.0%)	600 nm (15.0%)
SiO2 Thickness (in wavelength ratio)	667 nm (33.4%)	667 nm (16.7%)
Wavelength	2.0 µm	4.0 µm
Film thickness (in wavelength ratio)	Pt : 0 nm Al : 145 nm (7.25%)	Pt : 120 nm(3.0%) Al : 145 nm (3.13%)
Metallization ratio	0.5	
Electrode overlap length	40.0 µm	
Number of electrode pairs	94	
Number of reflector electrodes	15	
IDT-reflector gap	1.0 µm	2.0 µm

4. Conclusion

In this work, velocity reduction of I.H.P. SAW using heavy Al/Pt electrode was studied. First, using the FEM simulation it was indicated that, using heavy electrode and thin LT/SiO_2 layers, velocity reduction keeping fractional bandwidth can be achieved. And then realization of velocity reduction keeping bandwidth, Bode-Q, and TCF was confirmed experimentally.

References

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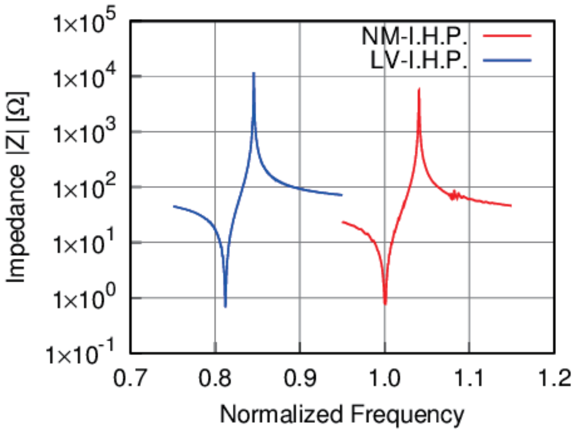
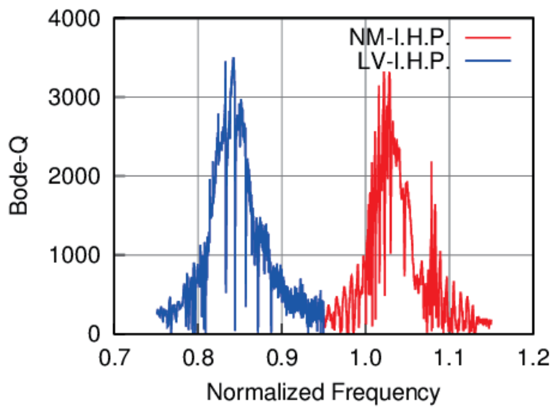


(a) Impedance |Z|



(b) Bode-Q

Fig. 4. Measured characteristics of fabricated resonators.

Table II Measured values of fabricated resonators.

	Resonator 1 (NM-I.H.P.)	Resonator 2 (LV-I.H.P.)
V [m/s]	3791	3076
Fractional bandwidth [%]	4.0	4.1
Qmax	3113	3504
TCF@fr [ppm/°C]	11	15
TCF@fa [ppm/°C]	-12	-13