3P3-6

Analysis of Loss in I.H.P. SAW structure

I.H.P. SAW 構造のロス解析

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1. Introduction

Recent complicated the RF front-end portion in cellular phones due to such as multiband and multicarrier support requires further improvement of performances of each component. In this situation, reduction of losses in SAW/BAW devices which are some of the key component of RF front-end is strongly demanded.

I.H.P. SAW, which was reported in [1], has a great potential to realize extremely small insertion loss of RF filters. On the other hand, Plessky et al. reported that, even in the I.H.P. SAW structure, radiations to a substrate inside occur and they could be some of the causes of losses [2].

In this study, loss mechanisms of an I.H.P. SAW resonator is analyzed using an experimental and numerical data. In addition, loss difference between I.H.P. SAW and leaky SAW is quantitatively evaluated. As the result, it is shown that the loss due to the wave radiation in the I.H.P. SAW structure is markedly small compared with the leaky SAW structure.

2. One-port Resonator for Evaluation

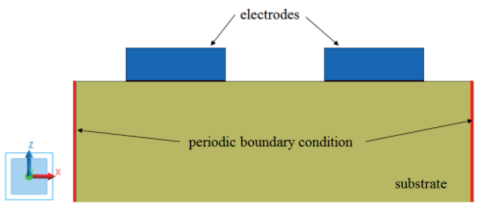
Table I shows the structure parameters of one-port SAW resonator using I.H.P. SAW used in this analysis. Resonance and anti-resonance frequency of this resonator is approximately 885 MHz and 920 MHz, respectively. In addition, another resonator using leaky SAW on $LiTaO_3$ substrate, which is designed in such a way that impedance characteristics of its IDT is almost identical as I.H.P. SAW resonator, is fabricated and used to compare the losses with I.H.P. SAW.

Table I. Structure parameters of one-port resonator

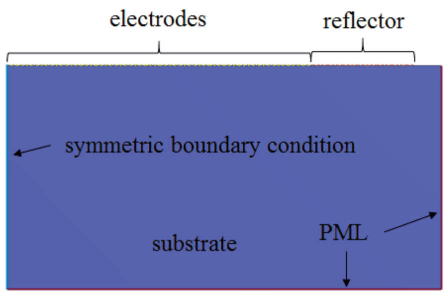
Substrate	LiTaO3-used I.H.P.
Wavelength	4.28µm
Film Thickness	Ti:30nm Al:383nm
Metalization ratio	0.5
Electrode overlap length	102µm
Number of electrode pairs	64
Number of reflector electrodes	21
Busbar Width	20µm

3. FEM Simulation Model

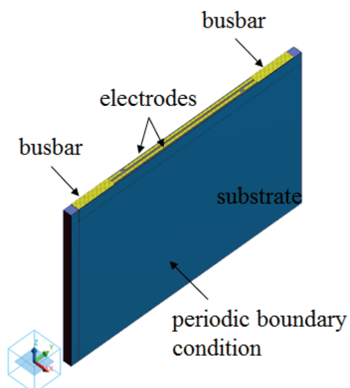
Fig. 1 shows the simulation models for FEM calculations. In this study, three models, (a)2D one-electrode-pair model, (b)2D multi-electrode model, and (c)3D one-electrode-pair model are used to calculate impedance characteristics of resonators for the evaluation.



(a) 2D one-electrode-pair model



(b) 2D multi-electrode model



(c) 3D one-electrode-pair model

Fig. 1 Simulation model for FEM

4. Results

Fig. 2 and **Fig. 3** show the impedance characteristics |Z| and return losses |S11| of fabricated one-port SAW resonators, respectively. In these figures, the black lines and red lines denote the I.H.P. SAW and leaky SAW, respectively.

Table II shows the return loss values of respective resonators at the resonance and the anti-resonance frequencies. The return loss of I.H.P. SAW is remarkably better than that of leaky SAW especially above the resonance frequency. Difference of losses at anti-resonance frequency is approximately 0.13 dB.

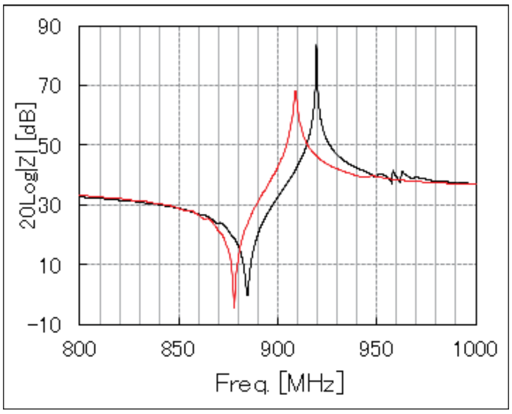


Fig. 2 Measured impedance characteristics of one-port resonators. Black line: I.H.P. SAW structure, Red line: leaky SAW structure.

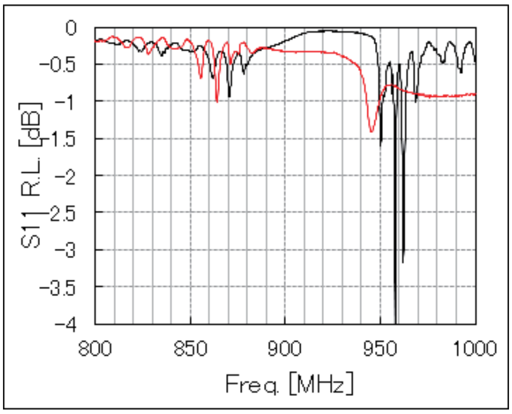


Fig. 3 Measured S11 return loss characteristics of one-port resonators. Black line: I.H.P. SAW structure, Red line: leaky SAW structure.

Table II. S11 return loss characteristics at resonance and anti-resonance.

	I.H.P. SAW	leaky SAW	
Fr	0.29	0.21	dB
Fa	0.06	0.34	dB

Moreover, **Table III** and **Table IV** show the results of loss analysis in each structure, which is estimated by the measured characteristics and the 2D/3D-FEM simulation. Influence of electrode resistance is estimated by from the measured data and equivalent circuit simulations. Radiation1 in Table IV means the radiation in the bulk direction and Radiation2 means the radiation in the plane direction.

At the resonance, loss due to the resistance component, which includes electrodes and wirings, is dominant in both I.H.P. and leaky SAW. It shows that it is approximately 84 to 85% of the total loss. The loss caused by others, which include influences of wave radiation and viscous loss of the materials, is very small compared with that caused by resistance.

On the other hand, at the anti-resonance, there is a large difference in the loss between I.H.P. and leaky SAW. Radiation component in the bulk direction (Radiation1) is 0.012dB in I.H.P. SAW and 0.187dB in leaky SAW, which are approximately 20% and 55% of the total loss, respectively. Radiation component in the plane direction (Radiation2) is 0.006dB in I.H.P. SAW and 0.032dB in leaky SAW, which are approximately 11% and 9%, respectively. Therefore, it shows that the difference in total loss between I.H.P. and leaky SAW is mainly caused by the wave radiation in the bulk direction.

Table III. Loss analysis of I.H.P. SAW and leaky SAW at resonance.

Fr	I.H.P. SAW	leaky SAW	
Resistance	0.24	0.17	dB
Others	0.05	0.03	dB

Table IV. Loss analysis of I.H.P. SAW and leaky SAW at anti-resonance.

Fa	I.H.P. SAW	leaky SAW	
Radiation1	0.012	0.187	dB
Radiation2	0.006	0.032	dB

5. Conclusion

In this paper, we discussed loss mechanisms of I.H.P. SAW and leaky SAW numerically. As the result, it concluded that, in leaky SAW structure, wave radiation in the bulk direction is one of dominant factors of losses at anti-resonance, and it is remarkably reduced in I.H.P. SAW structure. However, other factors of losses are still uncertain. We will analyze them in the future.

References

1. T. Takai ,et al.: IEEE Ultrasonics Symposium(2016) **DOI:** 10.1109/ULTSYM.2016.7728455.
2. V. Plessky, et al: IEEE Ultrasonics Symposium(2017) **DOI:** 10.1109/ULTSYM.2017.8091800.

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