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Transversal type BAW filter using polarization-inverted c-axis zigzag ScAlN multilayers

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1. Introduction

Transversal type surface acoustic wave (SAW) filters have a structure with input and output IDT electrodes on a piezoelectric substrate. They have been used to intermediate frequency (IF) filters due to their independent control of amplitude and phase characteristics [1]. On the other hand, for the RF filters in the mobile phone, SAW filters are gradually replaced by the bulk acoustic wave (BAW) filters due to their excellent power durability at high frequencies. However, transversal type BAW filters have not been reported. This is probably because of the difficulty in fabricating polarization inverted multilayers. In the recent years, we have reported various polarization inverted multilayer resonators such as: c-axis upside down inverted structure with thickness extensional mode [2,3], c-axis right-left inverted structure with pure thickness shear mode [4], and c-axis zigzag structure with quasi-thickness shear mode [5,6].

In this study, we report a transversal type BAW filter with c-axis zigzag polarization inverted ScAlN multilayers on both sides of a Z-cut quartz substrate, as shown in Fig. 1.

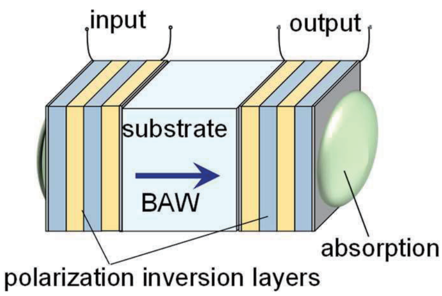

Fig. 1 Transversal type BAW filter based on c-axis zigzag polarization inverted ScAlN multilayers

2. Fabrication of transversal type BAW filter based on polarization-inverted c-axis zigzag ScAlN multilayers

A transversal type BAW filter was fabricated by a glancing angle RF magnetron sputtering deposition. c-Axis zigzag polarization inverted ScAlN multilayers were grown on both sides of a Z-cut quartz substrate whose shear mode acoustic impedance is close to the ScAlN layer to decrease the multiple resonance. The Z-cut quartz substrate was set to be 90° to the ScAl alloy target to obtain c-axis approximately 40°-tilted film which has a high electromechanical coupling coefficient $k'_{35}{}^2$.

Cross-sectional SEM images of the fabricated transversal type BAW filter were taken by FE-SEM (JSM-7001F). As shown in the Fig. 2, zig-zag orientation of the ScAlN thin films was observed on the (a)input and (b)output sides.

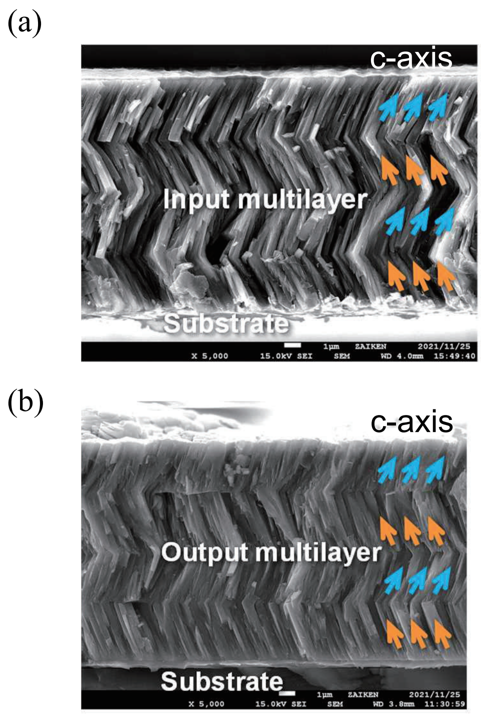

Fig. 2 Cross-sectional SEM images of (a)input and (b)output c-axis zigzag polarization inverted ScAlN multilayers

3. Simulation of transmission loss S_{21} by Mason's equivalent circuit model

The transmission loss S_{21} characteristics of a transversal type BAW filter were simulated by Mason's equivalent circuit model. The equivalent circuit of a transversal type BAW filter with c-axis zigzag polarization inverted ScAlN multilayers on the input and output layers on the front and back sides of the substrate is shown in the Fig. 3.

The piezoelectric multilayered structure can be represented by connecting electrical circuits in series and mechanical circuits in parallel. Also, the polarization inversion can be expressed by reversing the plus and minus sign of the ϕ between odd and even layers.

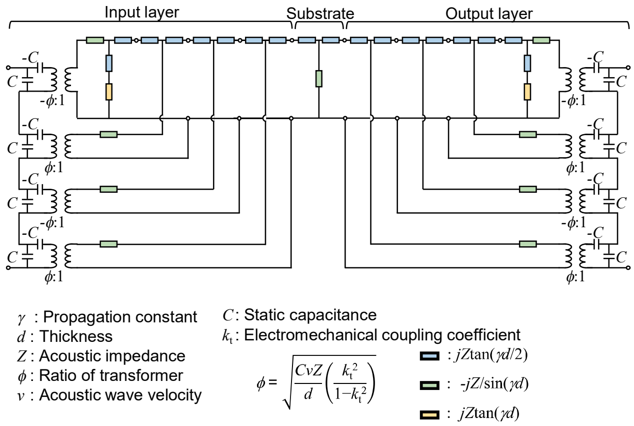

Fig. 3 Mason's equivalent circuit model of a transversal type BAW filter

4. Results and discussions

A comparison of the experimental transmission loss S_{21} characteristics of transversal type BAW filter with the theoretical transmission loss S_{21} characteristics simulated by Mason's equivalent circuit model was shown in Fig. 4 (a).

The influence of the multiple resonance is large. Therefore, the effects of the multiple resonance were removed by signal processing. The resulting experimental and theoretical transmission loss S_{21} characteristics were compared as shown in Fig. 4 (b). The measured transmission loss S_{21} characteristics after signal processing was approximately in good agreement with a theoretical one. The minimum insertion loss was obtained to be -11.3 dB at 466 MHz.

5. Conclusion

A transversal type BAW filter was fabricated by a glancing angle RF magnetron sputtering deposition. The transmission loss S_{21} characteristics of a transversal type BAW filter was simulated by Mason's equivalent circuit model. The experimental transmission loss S_{21} characteristics after signal processing was approximately in good agreement with a theoretical one. The minimum insertion loss was measured to be -11.3 dB at 466 MHz.

Acknowledgment

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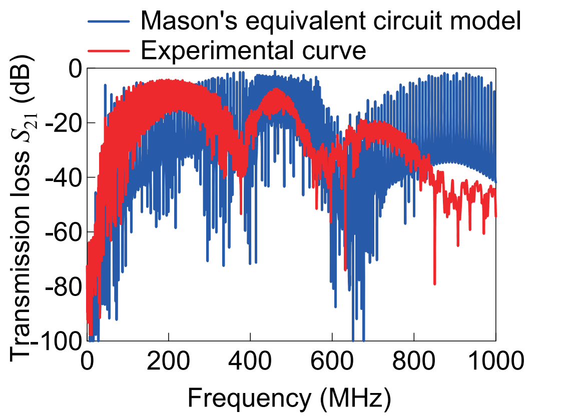
(a)



(b)

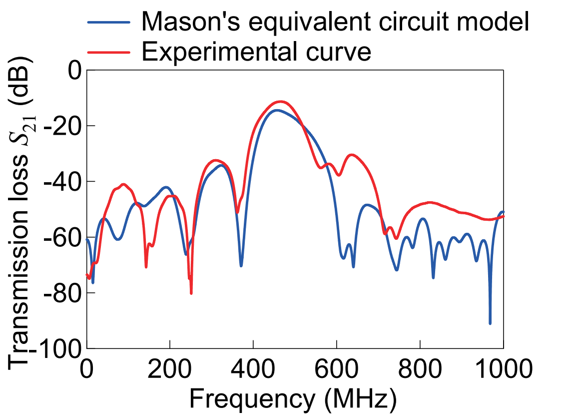


Fig. 4 Experimental and theoretical transmission loss S_{21} (a)without signal processing and (b)where multiple resonance is removed by signal processing

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