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Development of Transverse-mode Spurious Suppression Technique for SAW Resonator with Zero Temperature Coefficient of Frequency on a SiO_2/Al/$LiNbO_3$ Structure

零温度特性を有するSiO_2/Al/$LiNbO_3$構造SAW共振器の横モードスプリアス抑圧技術の開発

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1. Introduction

The surface acoustic wave (SAW) duplexer is a key device of mobile phones for miniaturization and high performances. In the universal mobile telecommunication system (UMTS), Band II, III, and VIII systems have narrow duplex gap. To realize the high performance duplexers for these applications, SAW resonators with small temperature coefficient of frequency (TCF) are required in addition to moderate electromechanical coupling coefficient (K^2). The authors demonstrated that the SAW resonator with a moderate K^2, a zero TCF, and no Rayleigh-mode spurious response can be realized by optimizing the SiO_2 shape above the IDT and the SiO_2 thickness on a SiO_2/Al/$LiNbO_3$ structure, where λ is the SAW the wavelength[1)]. To make a zero TCF SAW resonator on a SiO_2/Al/$LiNbO_3$ structure fit for practical use, it is also necessary to suppress the transverse-mode spurious responses.

This paper describes an approach of the suppression of transverse-mode spurious responses for a zero TCF SAW resonator on a SiO_2/Al/$LiNbO_3$ structure. It is shown that they can be suppressed well by applying the SiO_2 selective removal technique and optimizing SiO_2 thickness on the dummy electrodes regions.

2. Transverse-mode spurious responses for a zero TCF SAW resonator

Fig. 1 shows a schematic of SAW resonator on a SiO_2/Al /5°YX-$LiNbO_3$ structure. Fig. 1(a) and 2(b) shows a top view and a cross-sectional view, respectively. Above the IDT electrodes (Al-alloy), the SiO_2 film is deposited. The convex top shape of SiO_2 film is controlled to suppress the Rayleigh mode spurious response.[1)] In the following experiments, the electrode thickness and SiO_2 thickness H were fixed at 160 nm (0.08λ) and 700 nm (0.35λ), respectively, where λ is the IDT period of 2.0 μm. The numbers of the IDT and reflector electrodes were 300 and 30, respectively, and the aperture length is 28.6 μm. **Fig. 2** shows the measured admittance (Y_{11}) of the SAW resonator with the conventional structure. Here, the horizontal axis is normalized by the resonance frequency. As shown Fig. 2, transverse-mode spurious responses appear between the resonance and antiresonance frequencies.

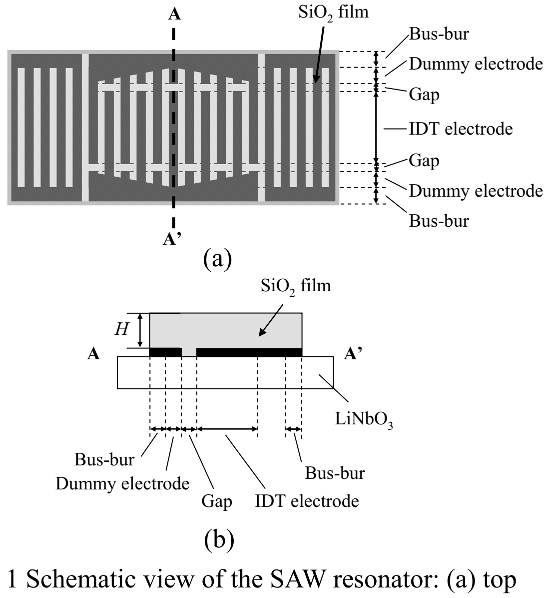

Fig. 1 Schematic view of the SAW resonator: (a) top view, (b) cross-sectional view.

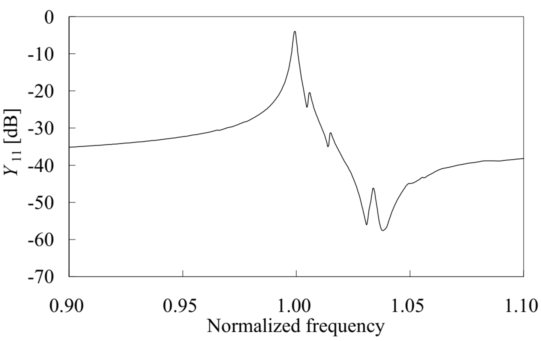

Fig. 2 Admittance (Y_{11}) of the SAW resonator with conventional structure.

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3. Suppress of the Transverse-mode spurious responses for a zero TCF SAW resonator

Next, we applied the SiO_2 selective removal from the dummy electrode region to the current device structure. **Fig. 3** shows a schematic of SAW resonator when the SiO_2 selective removal technique is applied. The technique has already been successfully applied to the resonators with H=0.20λ and h=0λ for the Band I SAW duplexer with wide duplex gap[2,3]. **Fig. 4** shows the admittance (Y_{11}) of the SAW resonator with h=0λ. As shown Fig. 4, transverse-mode spurious responses remained and another spurious response newly appeared at frequencies lower than the main resonance. This result indicates that the SiO_2 full removal on the dummy electrode region is not effective for the current case.

Then we focused on the relationship of SAW velocity between IDT region and dummy region. We investigated to use thinning of SiO_2 on the dummy electrodes and studied how the transverse-mode responses change with remaining SiO_2 thickness h on the dummy electrode region. **Fig. 5** shows the admittance (Y_{11}) of the SAW resonator with h=0.20λ. It is seen that spurious responses including transverse-mode ones are completely suppressed in Fig. 5. Measured TCF was unchanged and almost zero because no structural modification was given to the IDT region. Thus the SAW resonator with zero TCF, no Rayleigh-mode spurious response, and no transverse-mode spurious responses is realized.

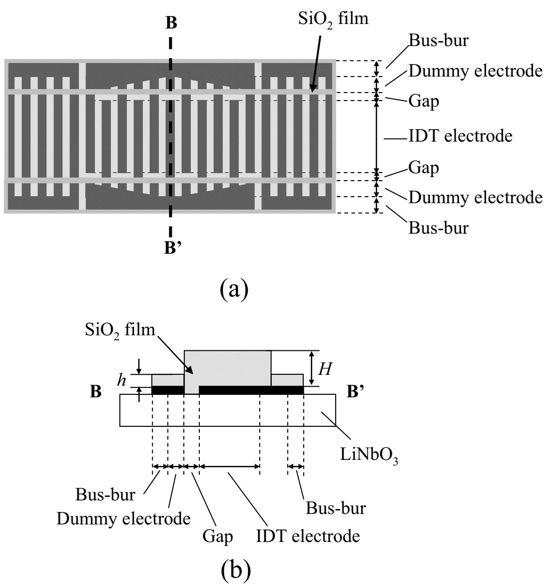

Fig. 3 Schematic view of the SAW resonator with applied SiO_2 selective removal: (a) top view, (b) cross-sectional view.

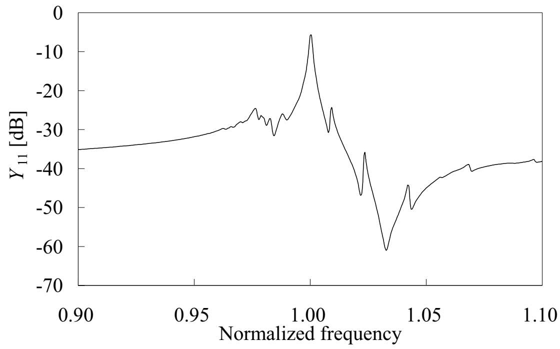

Fig. 4 Admittance (Y_{11}) of SAW resonator with h=0λ.

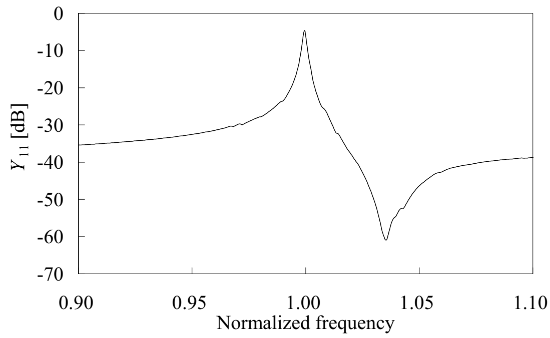

Fig. 5 Admittance (Y_{11}) of SAW resonator with h=0.20λ.

4. Conclusion

It was demonstrated that the selective SiO_2 removal is effective to suppress transverse-mode spurious responses for SAW resonators employing the $SiO_2/Al/LiNbO_3$ structure for wide range of SiO_2 thicknesses, provided that the SiO_2 thickness at the dummy electrode region is adjusted properly. This selective SiO_2 removal technique makes it possible to realize the SAW duplexers with narrow duplex gap on a $SiO_2/Al/LiNbO_3$ structure.

References

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