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Analysis of SAW Resonator on $SiO_2/Al/LiNbO_3$ Structure by using FEM/SDA

FEM/SDA を用いた $SiO_2/Al/LiNbO_3$ 構造 SAW 共振器の解析

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1. Introduction

Because of their low insertion loss, high out-of-band rejection and high power durability, miniature surface acoustic wave (SAW) duplexers are widely used in mobile phones based on the universal mobile telecommunication system (UMTS). Substrate materials mainly limit and determine the performance of SAW duplexers; for their application to Band I with large pass-band widths and wide frequency separation between the Tx and Rx bands, a larger coupling coefficient K^2 is of primary importance. For one of the large K^2 solutions, a SAW filter on a $Cu/LiNbO_3$ structure was discussed [1)]. In spite of its large K^2, however, a $LiNbO_3$ substrate has poor TCF. Although SiO_2 film / thin Al electrode[2)] and flat SiO_2 film / Cu electrode[3)] / $LiNbO_3$ substrate structures were reported for improved TCF, we have experimentally developed a shape controlled SiO_2 film/Al electrode / $LiNbO_3$ substrate structure for Band I duplexer. This is because the structure possesses large K^2 with improved TCF and is effective in the suppression of Rayleigh-mode spurious responses[4)]. In this paper, we report the analysis of a SAW resonator on the SiO_2 film / Al electrode / $LiNbO_3$ structure by using FEM/SDA.

2. Analysis of $SiO_2/Al/LiNbO_3$ structure

First, we analyzed a SAW resonator on a flat $SiO_2/Al/LiNbO_3$ structure by using FEM/SDA[5-7)]. **Fig.1** shows the K^2 and SAW velocity v_a at anti-resonance as a function of the SiO_2 thickness h. Here, the cut angle of Y-cut $LiNbO_3$ is 5°, and the Al thickness is 0.08λ. The value of h should be more than 0.4λ to make the SAW velocity smaller than the slow shear wave velocity in $LiNbO_3$ shown by the dashed line. However, K^2 also decreases with an increase in the SiO_2 thickness and becomes as small as 0.08 for the SiO_2 thickness of 0.4λ. For Band I applications, K^2 of 0.08 is definitely too small.

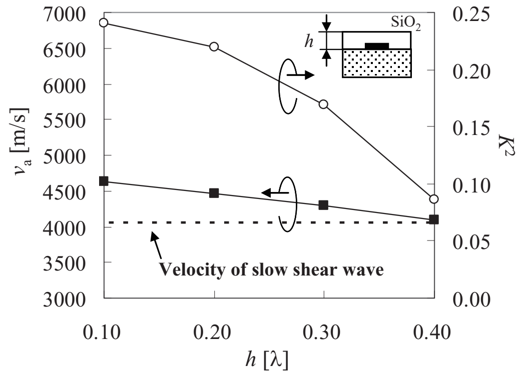

Fig. 1 K^2 and v_a as a function of h on a flat $SiO_2/Al/LiNbO_3$ structure.

The analysis on the flat $SiO_2/Al/LiNbO_3$ structure shows that it is difficult to obtain large K^2 with suppressed bulk wave radiation.

Next, a similar analysis was made on a non-flat $SiO_2/Al/LiNbO_3$ structure, where the non-flat SiO_2 shape is expected to reduce the SAW velocity by the grating effect. **Fig.2** shows K^2 and the SAW velocity at anti-resonance as a function of the convex height d for SiO_2 deposited above IDT fingers (see the insertion in Fig. 3). Here, the cut angle of Y-cut $LiNbO_3$ is 5°, the Al thickness is 0.08λ, and the SiO_2 thickness between two IDT fingers is 0.2λ. As shown in Fig.2, the value of v_a monotonically decreases with an increase in d. In particular, when d is increased up to 0.08λ, v_a already becomes sufficiently smaller than the slow shear wave velocity in $LiNbO_3$ shown by the dashed line. It is confirmed that the non-flat SiO_2 shape is effective in reducing the SAW velocity. Furthermore, K^2 of 0.153 (for $d=0.08\lambda$) is large enough for Band I applications. It is suggested that the non-flat $SiO_2/Al/LiNbO_3$ structure may be useful for obtaining large K^2 with suppressed bulk wave radiation.

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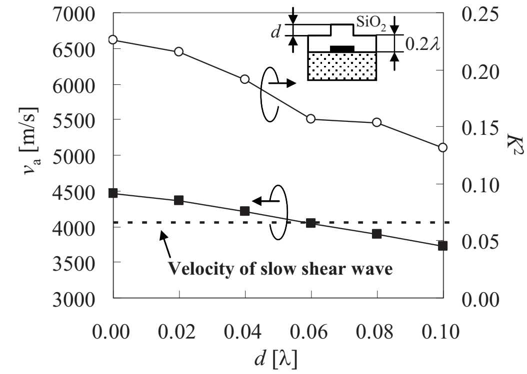

Fig. 2 K^2 and v_a as a function of d on a non-flat SiO_2/Al/$LiNbO_3$ structure.

3. Experimental result of non-flat SiO_2 structure

Having controlled the SiO_2 shape[4], we have developed a Rayleigh-mode spurious suppression technique. In practice, the SiO_2 becomes almost in a shape of a trapezoid. So, we expanded FEM/SDA to process the SiO_2 film of a shape of a trapezoid. **Fig.3** shows the simulated and experimental results of the normalized admittance of a SAW resonator fabricated on the non-flat SiO_2/Al/$LiNbO_3$ structure. In the figure, the SiO_2 shape ratio *SR* is defined as the ratio of the upper to lower bases of the trapezoidal SiO_2 film region. As shown in Figs. 3(a) and (b), the Rayleigh-mode spurious response was observed between the resonance and anti-resonance frequencies in both simulated and experimental results. In Fig.3(c), where *SR* was reduced to 0.38, the Rayleigh-mode spurious response was no more observed. The experimental result also confirms that the admittance characteristic at anti-resonance was not badly affected by bulk wave radiation. Furthermore, K^2 was experimentally estimated to be about 0.15. It is concluded, therefore, that the non-flat SiO_2/Al/$LiNbO_3$ structure is able to support high coupling SAW of SH type with suppressed bulk wave radiation.

4. Conclusion

We made an analysis of a SAW resonator on a SiO_2/Al/$LiNbO_3$ substrate structure by using FEM/SDA. For the SAW resonator on a flat SiO_2/Al/$LiNbO_3$ structure, it is difficult to obtain large K^2 with suppressed bulk wave radiation. We showed that the non-flat SiO_2/Al/$LiNbO_3$ structure is useful for obtaining large K^2 with suppressed bulk wave radiation. The experimental result of the SAW resonator fabricated on the non-flat SiO_2/Al/$LiNbO_3$ structure was in good agreement with the simulation.

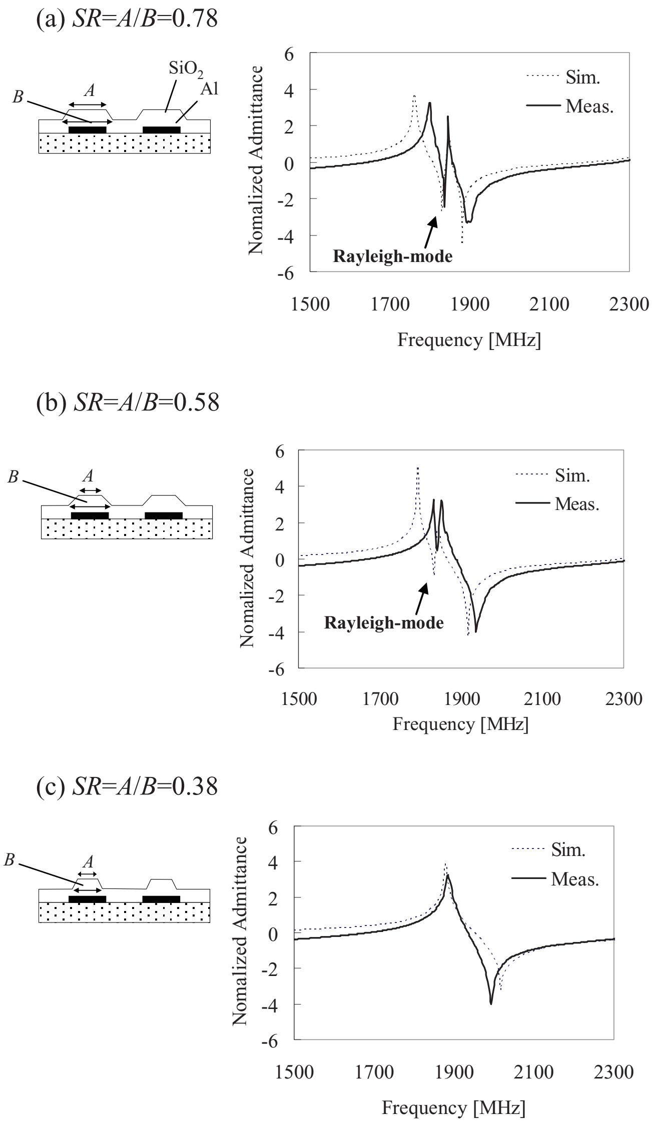

Fig. 3 Simulated and experimental results of a SAW resonator on a non-flat SiO_2/Al/$LiNbO_3$ structure.

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