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A New Technique for Suppression of Spurious Responses in an Aluminum Nitride Based Thin Film Bulk Acoustic Resonator

窒化アルミニウムを用いた圧電薄膜共振子におけるスプリアス抑制手法の提案

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1. Introduction

A thin film bulk acoustic resonator (FBAR) is suitable for GHz band applications, and accepted for commercial duplexers [1]. The FBAR has a sandwich-like structure, which composed from top and bottom electrodes and a piezoelectric film.

Aluminum nitride (AlN) is adopted generally as a piezoelectric film for the FBAR, since it is relatively easy for AlN to be deposited with highly c-orientaion by a reactive sputtering. Furthermore, AlN doesn't contain a metal which plays a recombination center in a semiconductor. It open a possibility up for integration of active circuits and acoustic devices.

However, in the dispersion relation of the AlN plate, an S_1 mode which is used in the FBAR mainly has a negative group velocity in the vicinity of cutoff frequency. Therefore the AlN based FBAR suffers from many spurious responses (*SRs*) beneath the resonance frequency. When such FBARs are applied to a ladder type filter, *SRs* from series resonators are allocated within the pass band, and deteriorate an insertion loss and a skirt steepness of the filter.

In this report, suppression technique of *SRs* was discussed using a 2-dimensional (2D) finite element method (FEM) and a dispersion diagram. Finally, new technique for *SRs* suppression was proposed.

2. Calculation model

Figure 1 shows geometry of FEM models. At first, resonance characteristics against the electrode size (W) were calculated using the model as shown in Fig. 1 (a). Results were plotted in **Fig. 2**. In this report, *SRs* were evaluated using the sum of spurious intensity by 3rd order.

It was observed from Fig. 2 that resonance characteristics fluctuated for the W, and its cycle length was about 1 μm. This is corresponding to the half wavelength of an A_0 mode as shown in **Fig. 3**. It was interpreted from these results that the fluctuation was originated from the phase of the A_0 mode on the electrode edge.

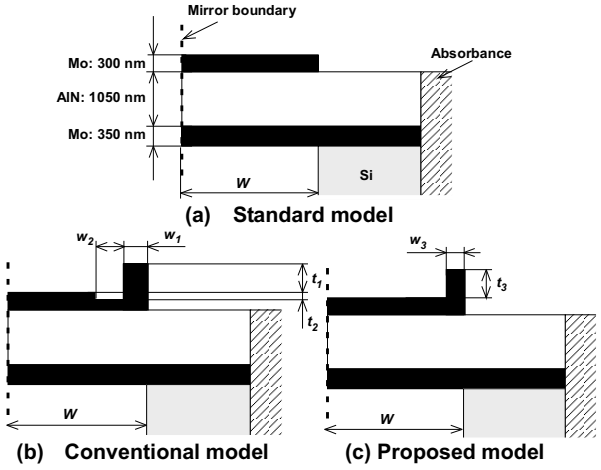

Fig.1 Simulation models for the FEM analysis

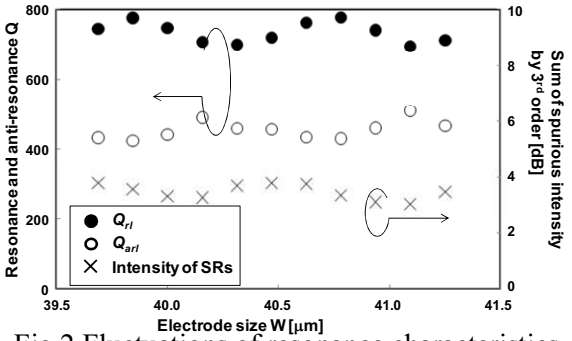

Fig.2 Fluctuations of resonance characteristics against the electrode size

The shape of FBAR is designed to elliptical or non-orthogonal square practically in order to apodize the *SRs*. So the fluctuation is also equalized. Therefore characteristics were evaluated using average values for the W in this report.

3. Conventional technique

Conventionally, *SRs* can be eliminated by the double step edge of electrode as shown in Fig. 1 (b) [2]. In this structure, selecting the right width of w_2, the phase of the S_1 mode on the electrode edge is adjusted to obtain the "piston mode", and *SRs* are strongly suppressed.

However this technique suffers from the

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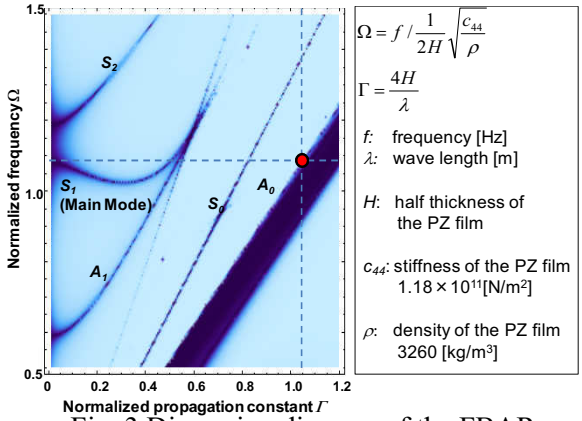

Fig. 3 Dispersion diagram of the FBAR

degradation of Q factors because the main mode is spent partially for the phase adjusting [3]. Futhermore, this structure needs multi step lithography to fabricate, and leads the high manufacturing cost.

Figure 4 shows characteristics of the conventional model against the width of w_2, when t_1, t_2 and w_1 were fixed to 0.1 μm, 0.025 μm and 2 μm, respectively. It was confirmed that *SRs* was strongly suppressed but Q factors were degraded.

4. Proposed technique

From Fig.2, it was observed that the A_0 mode influences the resonance characteristics. If the A_0 mode can be used to induce the piston mode, *SRs* are cancelled without the degradation of Q factors.

Figure 5 shows characteristics calculated using the model as shown in Fig. 1(c). This structure is used to obtain the high anti-resonance Q in conventional [3]. However, *SRs* can be reduced with the same structure by decreasing the w_3 to lower than λ/2 of the A_0 mode.

Figure 6 shows a comparison of each structure as shown in Fig. 1. It was comfirmed that *SRs* were reduced without shriveling the Q-circle in the proposed technique.

5. Conclusion

Suppression of supurious responses (*SRs*) in the AlN thin film bulk acoustic resonator (FBAR) was discussed using a 2-dimensional (2D) finite element method (FEM) and a dispersion diagram. In this report, it was confirmed that the A_0 mode influences the resonance characteristics, and we proposed the technique in which the A_0 mode was used to obtain the "piston mode".

In this technque, the Q didn't deteriorate against the conventional technique though suppression of *SRs* was weak. This is suitable for the ladder type filter in which an excellent steepness is demanded on the high band edge.

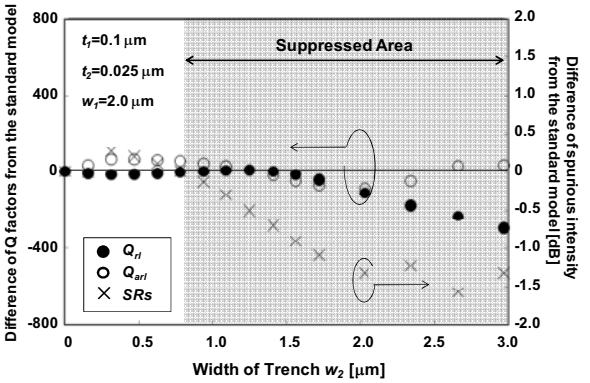

Fig. 4 Relative variation of the resonance characteristics in conventional technique

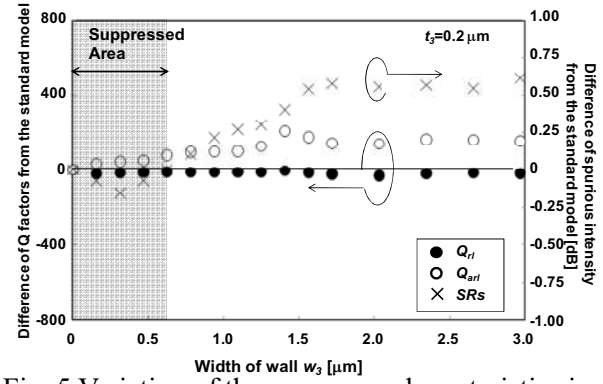

Fig. 5 Variation of the resonance characteristics in proposed technique

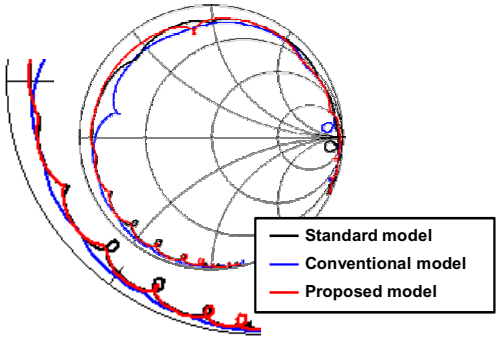

Fig. 6 Q-circles of FBARs

Moreover this technique can contribute to the cost reduction of the filter because high Q and small *SRs* were achieved indipendently under the same fabrication process.

Acknowledgment

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