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Experimental Studies of Q Deterioration in SH-Type SAW Resonators Employing an Apodized Interdigital Transducer

アポダイズドIDTを用いたSH型SAW共振器におけるQ悪化に関する実験的検討

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1. Introduction

Surface acoustic wave (SAW) filters are now widely used in mobile phones because of their small sizes and excellent frequency characteristics. Recently, Y-cut $LiNbO_3$ substrate is received much attention for its hig h electromechanical coupling coefficient (K^2)[1)], and SiO_2 is often deposited on it for its temperature compensation[2),3)]. In such configuration, apodized interdigital transducers (IDTs) are commonly adopted for suppressing series of spurious responses caused by the transverse modes. However, it is empirically known that the apodization causes additional losses and degrade the filter performance[3)].

This paper investigates this additional loss mechanism. First, series of SAW resonators with different design are fabricated, and discusses how the apodization influences to the resonance characteristic. Then the optical measurement is performed for these devices to identify the loss mechanism.

2. Influence of IDT Aperture Widths

We prepared SAW resonators with various apertures using the SiO_2/Cu/0°YX-$LiNbO_3$ structure. Thicknesses of SiO_2 film and Cu electrodes are 0.3λ and 0.06λ, respectively. Two kinds of samples were prepared; one employed the apodized IDT while another did the unapodized IDT (Fig. 1). The aperture width and the number of the electrodes were adjusted so that all the resonators possess the same static capacitances.

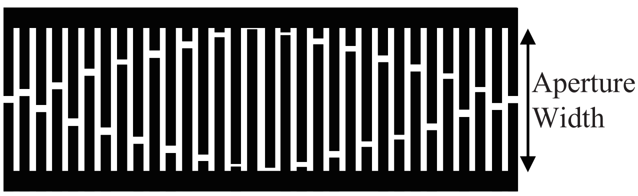

Fig. 1 Apodized IDT structure

Fig.2 shows how the normalized Q factor $\hat{Q}$ at the anti-resonance frequency changes with the normalized aperture $\hat{W}$. It is clear that the apodization deteriorates $\hat{Q}$, and its influence becomes large when $\hat{W}$ is small.

For the apodized case, the $\hat{W}$ dependence seems to be divided into the three regions, i.e., Region A where $\hat{Q}$ is small and increases gradually with $\hat{W}$, Region B where $\hat{Q}$ increases rapidly with $\hat{W}$, and Region C where $\hat{Q}$ is large and almost constant.

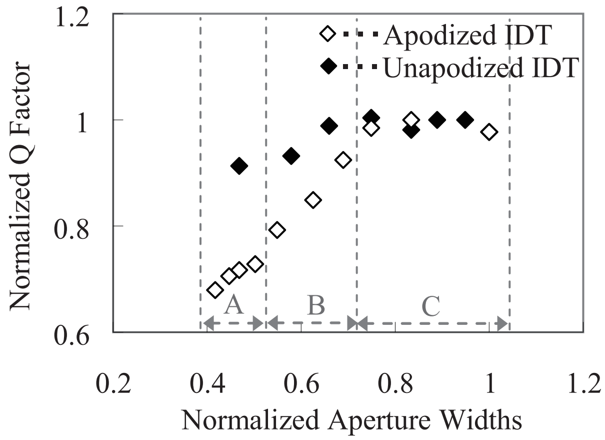

Fig. 2 Relationship between normalized Q factor and normalized aperture widths

3. Optical Measurement

3.1 Setup

A shear horizontal (SH) wave possesses the particle displacement parallel to the surface and generates shear strain. The author (SM) reported an optical measurement of shear strain by the photo-elastic effect and is intrinsically suited for detecting SH waves [4),5)].

The optical measurement system is shown in Fig. 3. The laser light (He-Ne laser) is focused using the objective lens (Obj.) to the sample, and transmitted light is collected by another objective lens. During the transmission, the laser beam experiences polarization change through the photo-elastic effect, and the change proportional to the shear strain is selectively detected by a photo detector in combination with the analyzer. The sample is mounted on a three-axis motorized stage.

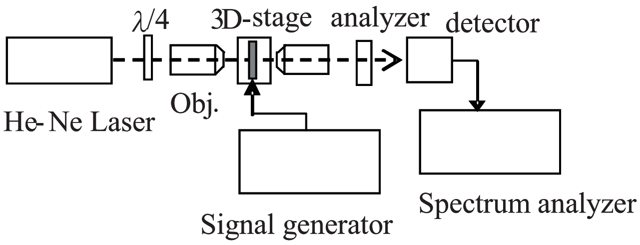

Fig3. optical measurement system

It should be noted that when the focal point of the laser beam is set inside of the substrate, we can observe radiation fields inside of the substrate[5].

3.2 Measurement results

The optical measurement was performed for three resonators having the apodized IDT with different $\hat{W}$; 0.42 (Region A), 0.63 (Region B), and 1 (Region C). The measurement frequency was chosen at the anti-resonance frequency.

Fig. 4a shows the result for $\hat{W} = 0.42$. Acoustic leakage and back-scattering are clearly visible at the IDT edges. The 3D scan indicated that the leaked energy mainly propagates along the surface.

Fig. 4b shows the result for $\hat{W} = 0.63$. Although SAW energy is well confined in the IDT, weak leakage and back-scattering are still visible from the boundary. The 3D scan indicated that the leaked energy propagates into the bulk.

Fig. 4c shows the result for $\hat{W} = 1$. In this case, acoustic leakage is scarcely visible.

From these results, it is concluded that the Q degradation is mainly due to the radiation of SH waves from the resonator. In the region B where the aperture width is moderate, generation of SH-type bulk waves from the IDT finger edges are predominant. In the region A where the aperture width is narrow, diffraction and back-scattering of the incident SH-SAW also contributes to the Q degradation.

This results imply that the Q factor is mainly governed by the steepness of (or angle) the apodization determining the oblique propagation direction of the SH-type SAW.

4. Conclusion

Based on the resonance characteristic it is shown that the apodization deteriorates the normalized Q factor at the anti-resonance frequency and its influence becomes large when aperture width is small. From the optical measurement, it is concluded that the Q degradation is mainly due to the radiation of SH waves from the resonator. The radiation consists of the bulk, diffraction and back-scattering waves and depends on the steepness of the apodization.

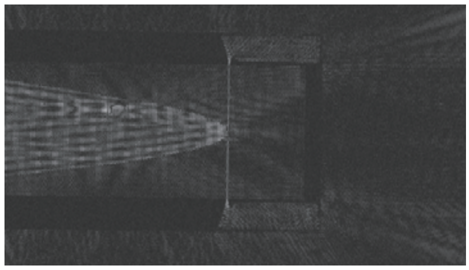

Fig. 4a measurement result in region A

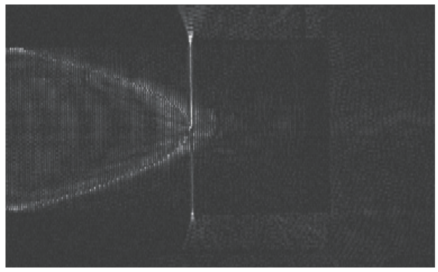

Fig. 4b measurement result in region B

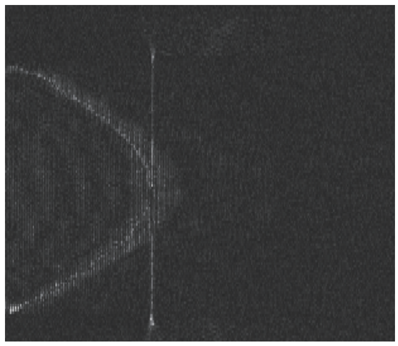

Fig. 4c measurement result in region C

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