5 GHz Low-Loss SAW Filters

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Abstract

A new electrode thickness difference type of single phase unidirectional surface acoustic wave (SAW) transducer (ETD-SPUDT), which has λ/4 narrow-gap electrodes is investigated. The ETD-SPUDT is fabricated by cutting a part of a meander-line electrode by using the shadow of the resist pattern. The theoretical and experimental results show the low loss and large directivity. The low loss filter on 128° Y-X $LiNbO_3$ is fabricated by optical photo-lithography techniques in 2 GHz-range and by electron beam exposure in 5 GHz-range. The results show 2.2dB insertion loss at 1GHz,3.0dB at 2GHz and 4.1dB at 5 GHz.

Introduction

Recently, the requirements of high frequency SAW devices have increased in mobile communication systems and will spread to many other regions in the future. It is very important for GHz-range SAW devices to develop a wide band low-loss unidirectional interdigital transducer (UDT) based on the ultra-small fabrication techniques. One of the important terms of GHz range single phase UDTs (SPUDT) is that the configuration is similar to conventional 2 fingers/λ IDT, because it has high efficiency in radiation and wide electrodes of λ/4. In order to obtain such an ideal SPUDT, different thickness electrodes are useful because they can shift only the center of the reflection keeping the radiation state high efficient. Recently, we have reported a practical fabrication process of bimetal electrodes, which have different reflectivity, and SPUDT applications[1]. The floating electrode type of UDT is also useful for wide band filters because floating electrodes have large reflectivity on large electromechanical coupling substrates.

In this paper, we investigate a new electrode thickness type SPUDT(ETD-SPUDT) and floating electrode type FEUDT (FE-SPUDT) with the electrode pattern width of about λ/4 and its fabrication processes. Experimental results in 1~5 GHz range show high efficiency and low loss characteristics.

λ/4 ETD and FE-SPUDTs

Figure 1(a) shows one of the split finger IDT configuration with unidirectional characteristics by different reflection coefficients of the different thickness or of different material electrodes. The mechanism of the unidirectionality for this transducer has been described by C. S. Hartmann and P. V. Wright[2]. It is excellent characteristics of high efficiency (large G/ω C(=1/Q)), and it is easy to fabricate them at GHz range if we use electrochemical fabrication techniques[1].

On the other hand, Figure 1(b) shows a new λ/4 electrode thickness different type SPUDT(ETD-SPUDT), which has a narrow gap structure of Figure 1(a) made by using anodic oxidation techniques[3]. The mechanism of its unidirectionality is the same as that of Figure 1(a), and the radiation characteristics are the same as the conventional narrow gap IDT. It is the feature of the IDT that it can be applied to high frequency range because the electrode width of (b) is twice as wide as that of (a).

The λ/4 ETD-SPUDT is fabricated by the narrow gap IDT fabrication process and oblique angle evaporation process using the shadow of the photo resist. Therefore, only the λ/4 line and space process is used, and any accurate alignment exposure is not required. Both input and output IDT can be made at the same time of one sequence in this process.

Experimental Results

Figure 2 shows the directivity of λ/4 ETD-SPUDT as the function of the film thickness. 128°Y-X $LiNbO_3$ substrate and Al electrodes are used, and frequency is 500MHz. It shows that 40 pairs IDT has a large directivity more than 8dB within the practical thickness. If much directivity is required in small pair of fingers, Cr/Al electrodes, which have large reflectivity, will be useful for the requests.

Figure 3 shows the radiation conductance as the function of the pair number. The doted line shows the calculation result of equivalent circuit model for conventional uniform 2 pairs/λ electrodes IDT. It shows that λ/4 different thickness type has large radiation conductance. The Q(=ω C/G) value from our experiments is 1.6, which is normalized by the conventional uniform 2 electrodes/λ IDT. It shows the very high efficiency of this IDT compared to the conventional SPUDTs.

Figure 4 shows the 2GHz range (λ=1.86μm) filter characteristics. The (a) is the measured response and (b) is one of a matched result from the S parameter of (a). Minimum insertion loss of 2.2 dB is obtained. Al thicknesses are 120 nm (6.4 %) and 40 nm (2.1 %). Pair number is 45. Figure 5 shows 5 GHz range (λ=0.74μm)

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filter characteristics. Al thicknesses are 60nm (8.1 %) and 40nm (5.4 %). Pair number is 30. The (a) is the measured response. The (b) and (c) are some results assuming that ideal matching circuits are added. Depending on the matching condition, the filter responses are changed such as low loss characteristics (Figure(b) and small ripple characteristics (Figure(c)). In these cases, the value of directivity is about 15dB. On the other hand, Figure 6 shows the frequency response of the filter with the directivity of about 7dB. It is assumed that ideal matching circuits are added. Although Al thickness for wavelength is very large, no ripple and wide band low-loss characteristics are obtained. Al thicknesses are 70nm (9.5 %) and 50nm (6.8%).

Figure 7 shows calculation results of the directivity of Narrow Gap Floating Electrode Type Unidirectional Transducers with about λ/4 electrode width. Figure shows a good directivity.

Conclusion

New high efficient SPUDT, λ/4 ETD-SPUDT, on 128° Y-X $LiNbO_3$ at GHz range has been proposed. Its radiation conductance is as the same as that of conventional uniform 2 electrodes/λ IDT, and Q value is 1.6 in the experiments. It can be fabricated by using anodic oxidation techniques and new oblique angled evaporation techniques using the shadow of resist pattern and does not require the alignment exposure process to make different thickness electrodes. The filter characteristics in GHz-range are low-loss and wide band. The insertion losses are 2.2 GHz, 3.0dB at 2 GHz and 4.1dB at 5GHz.

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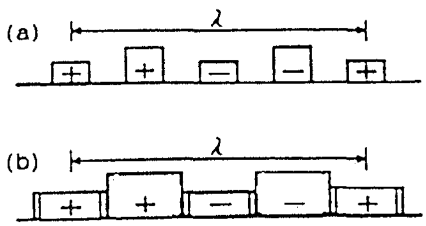

Fig.1 Configuration of ETC-SPUDTs
(a)Split finger type, (b)λ/4 type

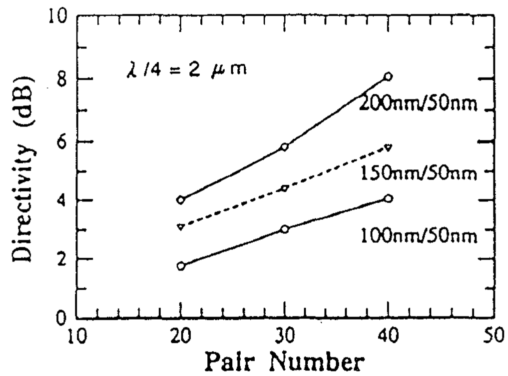

Fig.2 Directivity of ETD-SPUDT

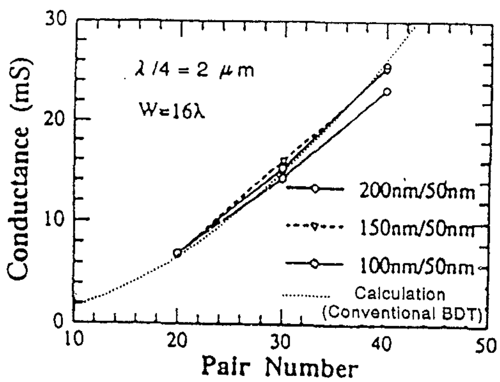

Fig.3 Radiation Conductance of ETD-UDT

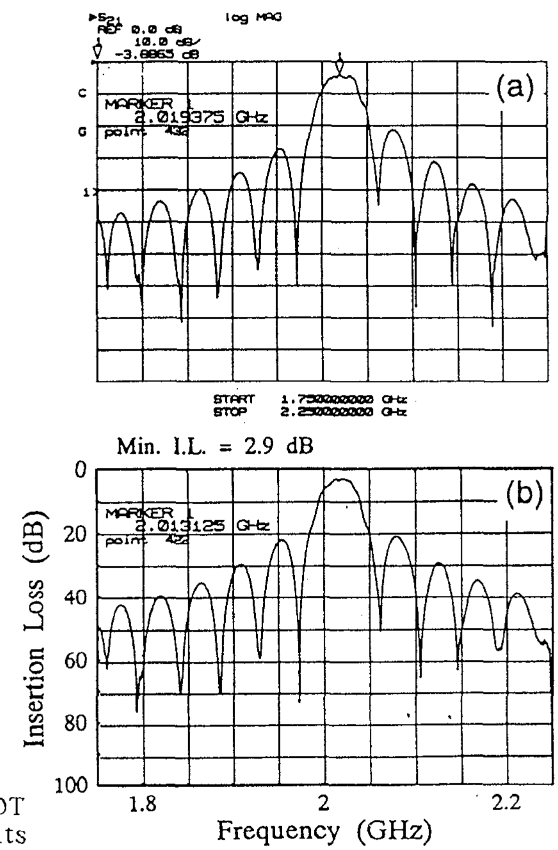

Fig.4 Filter Responses of 2GHz ETD-SPUDT
(a)Measured, (b)With matching circuits

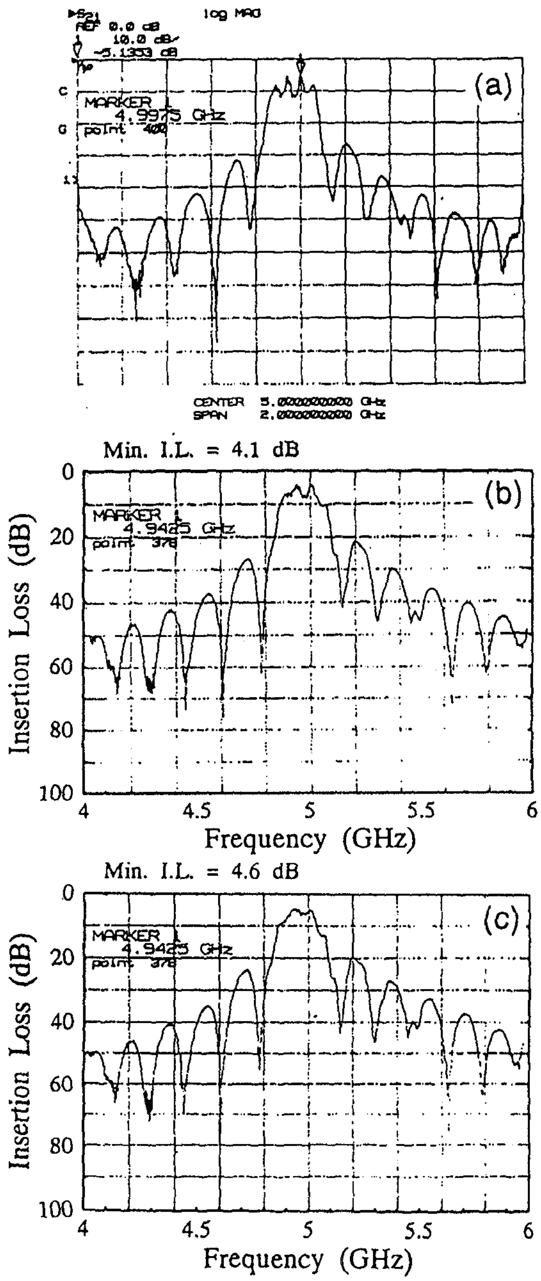

Fig.5 Filter Responses of 5GHz ETD-SPUDT
(a)Measured, (b),(c)With matching circuits

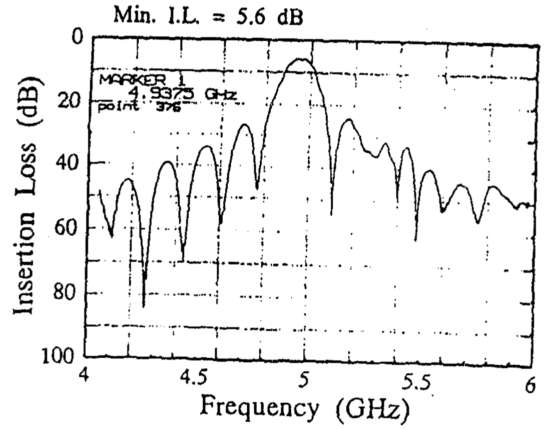

Fig.6 Filter Response of 5GHz ETD-SPUDT
(With matching circuits)

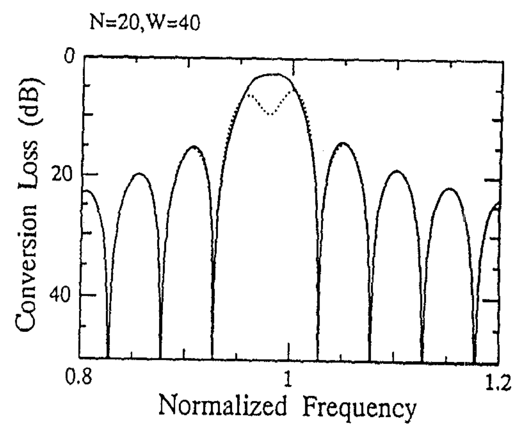

Fig.7 Calculation Result of Directivity of FE-SPUDT