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GHz RANGE SAW TRANSDUCERS USING ELECTRON BEAM LITHOGRAPHY

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ABSTRACT. Nanometer electrodes of the order of 0.085 μm width have been fabricated using direct electron beam lithography, normal lift-off techniques and O_2-plasma cleaning system. These techniques have been applied to Inter-Digital Transducers (IDT) as surface acoustic wave (SAW) transducers in the GHz-range. We performed SAW filter experiments at GHz-range. Filters with minimum insertion loss of 16.0 dB at the center frequency of 5 GHz and 27 dB at 11 GHz were obtained.

1. INTRODUCTION

Surface Acoustic Waves (SAW's) have been applied in various electronic devices, e.g. various kinds of filters, stable high frequency oscillators, real time signal processing devices, convolvers and correlators used in spread spectrum communication systems, etc.

SAW devices can be fabricated by applying integrated circuit (IC) fabrication techniques. Devices operating at higher frequencies in the GHz range having better performance and greater density of packaging are in heavy demand for electronics devices and new communication systems.

We describe SAW filters in the GHz range which require nanometer width of interdigital electrodes (IDT's). We fabricated nanometer electrodes utilizing direct electron beam lithography with the earth electrode on a resist for dielectric materials, ordinary lift-off techniques and O_2-plasma cleaning system. These techniques have been applied to the IDT in the GHz range.

2. FABRICATION OF NANOMETER ELECTRODES

Direct wafer electron beam writing techniques give finest line width. There are various processes for fabricating nanometer line width and in all of them, lift-off techniques are more successful than chemical and dry etching techniques. Lift-off techniques have properties of no mechanical damage on the surface in contrast to the dry etching techniques, and almost no surface contamination as compared to other etching processes.

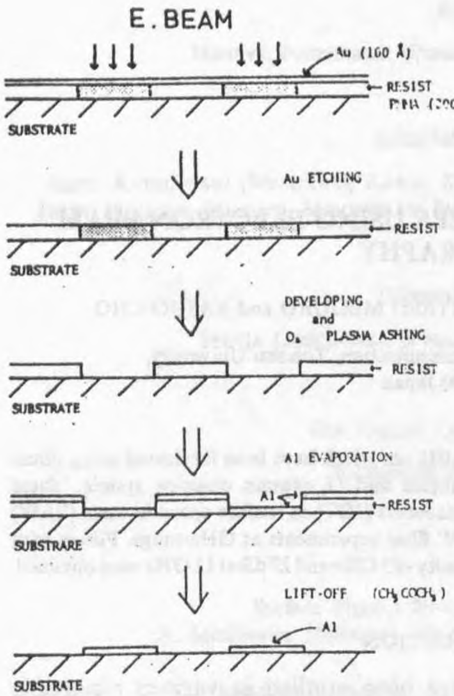

Fig. 1. Flow chart of new direct writing electron beam exposure and lift-off techniques for dielectric materials.

Figure 1 shows the flow-chart of our lift-off technique used in the fabrication of devices of nanometer order of line width. An earth electrode is required for a current pass of electron beams in the direct writing for the insurater. We reported the method [1] using thin metal film (Cr) on the dielectric materials as the earth electrode. Now we propose new techniques with thin metal film (Au) on a resist as an earth electrode (shown in Fig. 1). In this case, the damage of the resist is smaller than before. Also, in a normal lift-off technique, the developed portions of the pattern are left with some resist on them: this remaining resist is one of the obstacles in the formation of fine pattern. The O_2-plasma ashing technique is used to remove the left-over resists and clean the surface of the substrate. The conditions of ashing are as follows, (i) RF power, 250 watts, (ii) in pure O_2 gas, (iii) ashing time of a few seconds, and (iv) with Al-holder to avoid the degeneration of the resist pattern and to control the ashing depth of PMMA.

3. SAW DEVICES

We performed experiments of the conventional types of IDT's at 5 GHz and 3-pairs groups and 4-pairs groups combined type IDT [2] that can suppress the TTE (Triple Transit Echo in Band), shown in Fig. 2 and 10 GHz range conventional IDT. Figure 3 shows one of the IDT patterns used in the experiments. The pattern of this filter is fabricated by direct writing of electron exposure (minimum beam spot size of 0.02 μm of beam) on PMMA resist using old lift-off techniques [1] with O_2-plasma ashing on 128 Y–X $LiNbO_3$. The electrode widths and gaps are 0.187 μm, as shown in Figure 3. Figure 4 shows the configuration of 10 GHz conventional IDT. The IDT is fabricated by new lift-off techniques shown in Fig. 1 and minimum spot size of 0.008 μm of beams. Substrates used for the filter are also 128° rotated Y-cut X-propagating $LiNbO_3$. Figure 5 shows the frequency response of the filter using 3–4 pair IDT at the

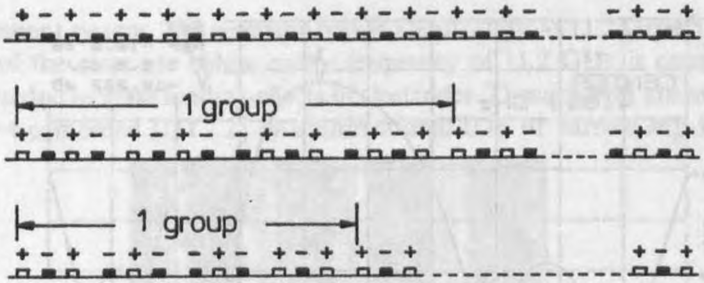

Fig. 2. 3-pairs-groups and 4-pairs-groups combined IDT's.

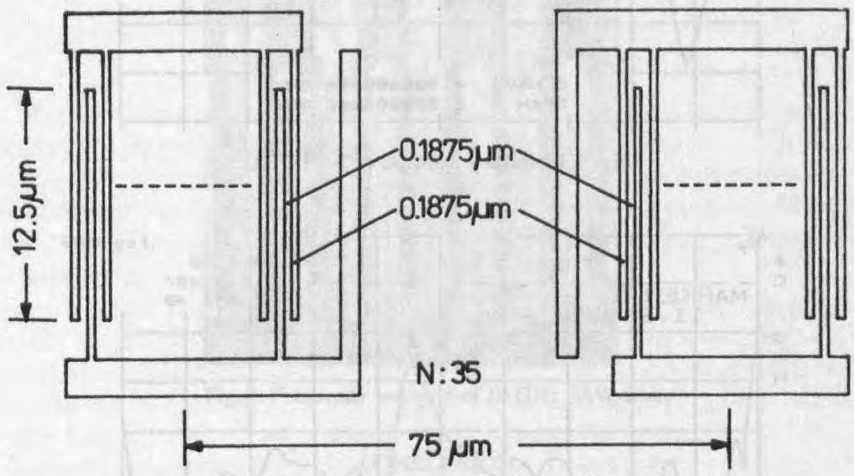

Fig. 3. Electrode pattern of 5 GHz range IDT.

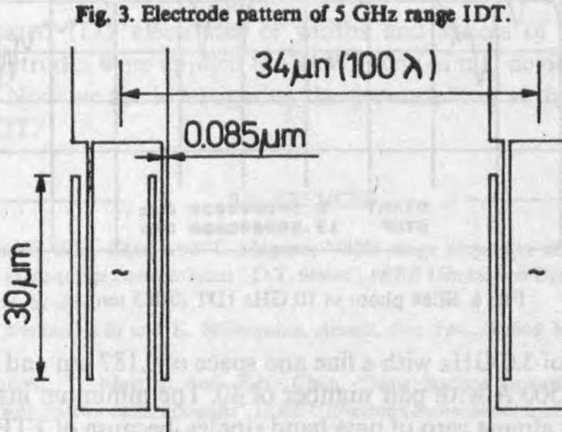

Fig. 4. Electrode pattern of 10 GHz range IDT.

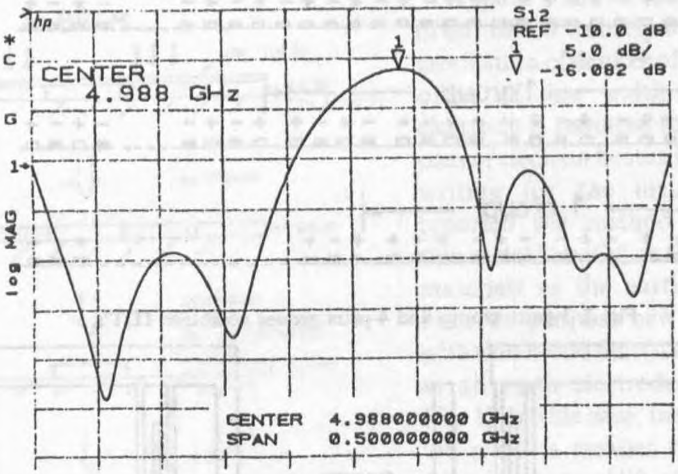

Fig. 5. Frequency response of 3–4 IDT's.

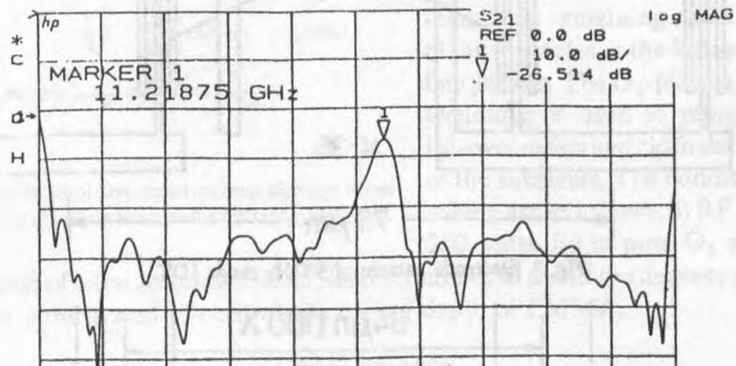

Fig. 6. SEM photo of 10 GHz IDT (0.085 μm).

center frequency of 5.0 GHz with a line and space of 0.187 μm and the electrode film thickness of 500 Å with pair number of 40. The minimum insertion loss is about 16 dB with almost zero of pass band ripples, because of TTE suppression type of IDT. Figure 6 shows SEM pattern of the 10 GHz IDT. The line widths and spaces are 0.085 μm, respectively. Figure 7 shows the frequency response of 10 GHz filter after removing signals of direct through and TTE using a time domain measurement system. The insertion loss is about 27 dB at 11.2 GHz. The lack of signals of the response below center frequency of 11.2 GHz is caused by the reflection due to mass loading effects of electrodes. These defects are removed by using 3–4 combined IDT [2] or unidirectional IDT or narrow gap I.D.T [3].

Fig. 7. Frequency response of 10 GHz SAW filter.

CONCLUSION

We fabricated IDT electrodes of widths and spaces of 0.085 μm. These nanometer electrodes were applied for SAW filters of real devices first proposed in this paper. Now we are investigating the generation of surface phonon using nanometer IDT.

REFERENCES

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