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Design and Fabrication of IDT SAW by Using Conventional Lithography Technique

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Abstract: The Surface Acoustic Wave (SAW) devices, using interdigital electrodes, play a key role in today's telecommunication systems and are widelyused as electronic filters, resonators, delay lines, convolvers or wireless identification systems (ID tags). The geometry of the device play greater role in determing its optimum performance. Hence.The purpose of this study is to investigate the behavior of fingers various for surface acoustic waveinterdigital transduction which could be subsequently used in biosensor application. Two groups of miniature SAW biosensor IDT fingers are successfully designed and fabricated using conventional lithography method. The combination of ZnO as a piezoelectric substrate and aluminium as an IDT show a good result in term of electrical characterization and frequency response. From the result, shows that increasing number of SAW IDT has higher 2.40 MHz center frequency and hence can improve the sensitivity. It shows that these designs are suitable to apply in the SAW biosensor application.

Key words: IDT SAW design・SAW device・Biosensor

INTRODUCTION

For decade, many types of Biosensor have been developed.These sensors had been developed using different methods and technique, mostly based on radiochemical, enzymatic, fluorescence, electrochemical, optical and acoustic wave [1]. However, the result of some biosensor had been reported that there is a lack using the sensor in term of high complexity, separate labelling process, equipment to simulate the transducer and thus higher cost to conduct analysis [2]. In Biosensor device, it's very important to have a sensor with high sensitivity and have good accuracy detection. When comparing to other method, sensor based acoustic wave had many more advantages such as high sensitivity, reusable, versatile, reliable and easy designed for responding to various measurement. It's also reported the acoustic wave proven powerful and sensitive devices for the detection of Biomolecule interaction [3].

The surface Acoustic Wave (SAW) is generated from a device that know as interdigital transducer (IDT) that's been fabricated on a piezoelectric substrate. In developing SAW sensors, IDT is an important part of generating SAW. It functions by converting electric energy into mechanical energy and vice versa in order to generate and detecting the SAW. IDT structure was developed using a common fabrication method, which is used photolithography steps. It is typically designed as a thin-film layer is placed on the surface of the piezoelectric substrate [4]. When the signal voltage is applied, an IDT will generate acoustic waves in a piezoelectric substrate. Acoustic waves generated vary depending on the applied voltage signal and the deformation of the piezoelectric substrate. The wavelength of the wave excited by the IDT is equal to the periodicity of the IDT pattern. The interdigital transducer (IDT) can be developed in different structure according to the different characteristics that needed [5]. This paper focused on designing the IDT for achievinghigher center frequency.

Theoretical Background: In SAW device, the center frequency is the most important specification. When center frequency is high, the sensitivity also will be improved [6]. In order to design a SAW device with higher center frequency, parameter such as number of IDT finger (*N*), finger width and spacing between IDT,aperture length *(W)*, and wave length (λ) are very important. Center frequency can be obtainedby using Equation 1.1.

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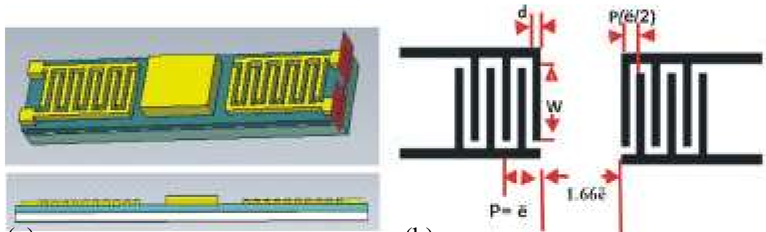

(a) (b)

Fig. 2: Structure of conventional SAW Biosensor a) full structure and crossection of SAW Biosensor b) IDT design SAW

$$fo = \frac{Vs}{\lambda o} \quad (1.1)$$

Where, f_o is central frequency, V_s is an acoustic velocity of ZnO piezoelectric (3954 m/s) substrate and λo is the wavelength. Number of fingers, (*N*) can be determined using Equation 1.2

$$N = \frac{2fo}{NBW} \quad (1.2)$$

Where, NBW is NullBandWidth of fractional frequency. IDT is behaving as a capacitance system. The capacitance voltage can be calculated by using the Equation 1.3 and 1.4. The SAW device sensitivity and stability are strongly dependent on the capacitance value.

$$C = \frac{\varepsilon_o A}{d} \quad (1.3)$$

Where, C = capacitance, ε_o= 8.854 X 10 $^{-12}$ F/M, A = area of overlap of two plates, d = separation between the plates. To get more accurate values of capacitance and center frequency, Equation 1.4 can be applied.

$$Ct = \frac{1}{2\pi foZ} \quad (1.4)$$

Where, C_t is a capacitance, *fo* = Center frequency, Z=Impedance. In order to achieve good SAW performance, the combination of substrate piezoelectric films and finger IDT isan important factor. Between of these, the IDT is the most important parameter for realizing low insertion loss, improving device stability and sensitivity [7]. In this paper, several IDT designs have been proposed to study the performance device in term of electrical properties and frequency response into biosensor application.[8] The combination of SAW IDT with ZnO piezoelectric substrate will be explained in detail in this paper. Figure 2 shows the structure of the SAW biosensor device.

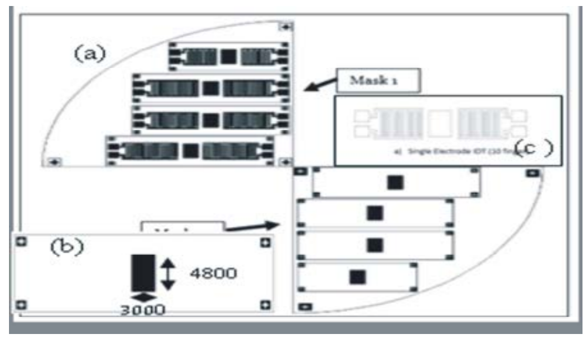

Fig. 2: Maskdesign of SAW Biosensor a) full design, b) Sensing area design c) IDT mask design.

Table 1: The IDT parameter and size

IDT Parameter	First Design (D1)	Second Design (D2)
Size of finger width/spacing (µm)	300	300
Size of finger length ((µm)	4500	4500
Number of IDT finger	10	16
Acoustic aperture	8	8

Mask Design: In this project, Auto CAD software is used to design the mask for the fabrication process. Two masks, called sensing area and IDT were successfully designed. Sensing area is one important part of the SAW Biosensor device where this sensing area will detect the target on the sensor. This sensing area is designed in rectangular shape with the size of 4800 µm x 3000 µm. This sensing area is located in the center of IDT input and output SAW device.[9] The design of sensing area is shown in Figure 2(b). Second maskis designed for the SAW IDT. The interdigital transducer (IDT) mask has been designed in two types of IDT with is conventional IDT and split IDT. For the conventional IDT, it wasdesigned in single finger electrode with a different number (N) of fingers as shown in Figure 2(c). The Figure 2(a) shows the full mask device layout design, this design consist of four designs of biosensor devices and it is arranged with various IDT sizes and arrangement of the electrode fingers. All dimensions are in micrometre. The parameter of the SAW Biosensor device is summarized in Table 1.

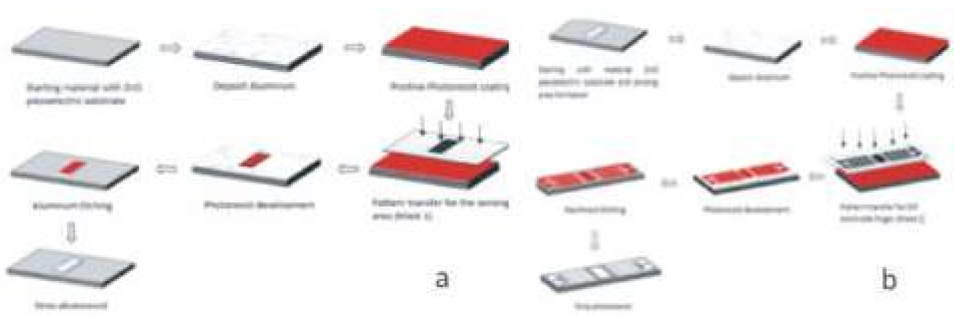

Fig. 3: Fabrication process of SAW Biosensor, a) Sensing area formation process #flows, b) IDT finger formation steps.

Saw Fabrication Process: There are four important process steps that need to be followed in fabricating theSAW biosensor. The component consists of preparation of piezoelectric substrate,fabricate the sensing area and Interdigital transducer electrode preparation [10]. All these components must be fabricated in several stages. For the first stage, the wafer starting with cleaning by using standard cleaning procedure then continue with the oxidation process. Where, the oxide was grown on the wafer surface with the thickness around 1000 Å. The oxide is grown by using dry oxidation furnace for about 1 hour. The samples then deposited with Zinc oxide (ZnO) in order to form a layer of piezoelectric substrate. The sol-gel technique was used for growth ZnO layer on the sample surface. The third stage isto fabricate the sensing area on the sensor samples. The aluminium with thickness 500 Å was deposited onto sensor surface by using a thermal evaporator.Then the 1st mask is used for fabricating the sensing area pattern on the biosensor surface. The final stages are followed by fabricating the Interdigital transducer electrode finger. The sample then deposited with another aluminium layer with a thickness of 200 Å for IDT electrode. The 2nd mask then was used to transfer IDT pattern on the biosensor samples. The overall procedure process is summarized in Figure 3.

RESULT AND DISCUSSION

This chapter discusses about the result of the SAW IDT biosenssor device. The result is divided into optical result and electrical result. Figure 4 shows the optical resultof conventional IDT for Design 1 and Design 2 using process steps in methodology. These two designs consist of single electrode finger arrangement and the different between two designs is the number of electrode finger with design 1 consists of 10 fingers and Design 2 consists of 16 fingers.

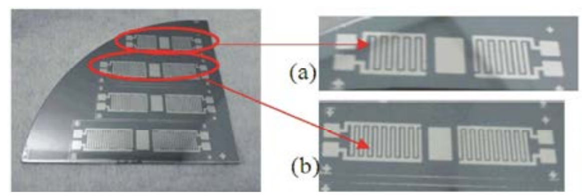

Fig. 4: Conventional SAW Biosensor a) IDT with 10 fingers, b) IDT with 16 fingers.

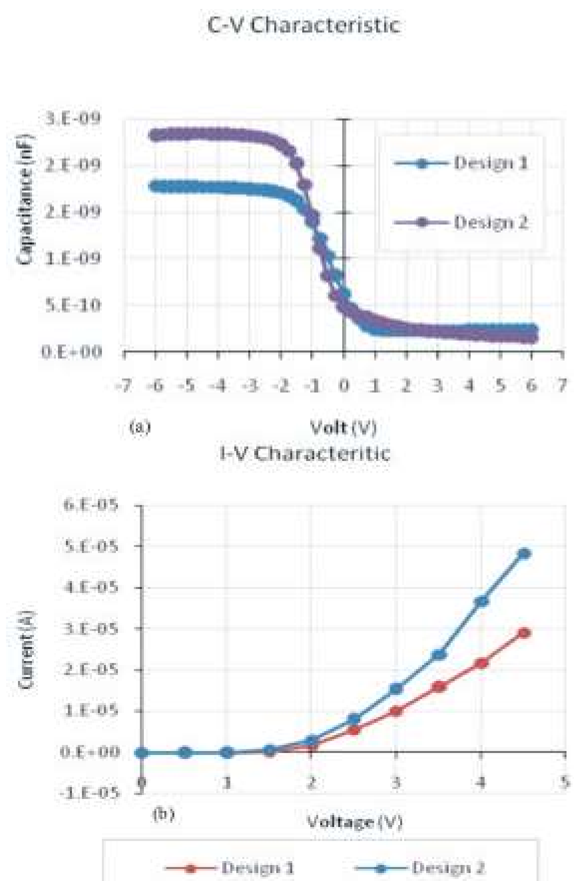

Fig. 5: Result of electrical characterizationthe IDTs design, (a) the graph of I-V characteristic, (b) the graph of C-V characteristic

Table 2: Comparison result between the center frequency values based on experimental and literature studies.

IDT Design	Capacitance value (nF)	Resistance Value (kΩ)	Capacitance value (nF)	(fo) From Eq. (1.1) (Mhz)	(fo.) From Eq. (1.4) (Mhz)
Design 1	1.62	147.1	1.62	3.3	1.92
Design 2	2.40	218.7	2.40	3.3	2.40

For the I-V characteristic analysis, it is conducted to find the relationship between the current and voltage of the IDT device. To measures the electrical properties of the semiconductor devices with the attachment of source meter Kiethly2400 (DC measurements such as I-V and resistivity) or Alpha A high frequency (10MHz- 1GHz) dielectric analyzer (AC measurements). The result of I-V curve is shows in Figure 5(a). Based on the I-V characteristic graph, it can see that the difference between the I-V curve for Design 1 and Design 2. The result shows, the current for the Design 2 is higher than the Design 1. This is because Design 1 and Design 2 is in the same IDT design. The only difference between these two designs is situated at the number of IDT electrode finger which is the number of electrode finger. From this I-V characteristic result can be seen that the design of IDT will is affected to the reliability of the Biosensor that will develop.

From the Figure 5(b) can be seen that, there are slightly different between the C-V curves of the IDTs for both conventional Biosensor SAW device. The capacitance value for Design 2 is much higher compare to Design 1 which is 2.40 *nF*while for Design 1 the capacitance is 1.62 *nF*.The difference between these two designs is the number of the electrode finger where the Design 1 is using 10 number of fingers and Design 2 using 16 number of fingers.This has happened because Design 2 using a single 16fingers IDT, so the spacing between positive and negative electrode is become smaller. The value of the capacitance can also be gained in theoretically by using a basic equation for capacitance value as shown in Equation 1.3 and Equation 1.4.

Based on the analysis of all of the out put result, it was found the total of number finger is one of the factors affecting the center frequency. This is because when increasing the number of fingers, the current and capacitance also increased. From the Table 2, when the IDT was changed from 10 to 16, the center frequency for both designs is increased from 1.92 MHz to 2.40 MHz respectively. This shows that, the SAW with many IDT fingers can be improve the performance SAW biosensor and hence will improve the sensitivity of the Biosensor.

CONCLUSION

In this project, the IDT with different number IDT fingers structure are designed, fabricated and investigated for improving the sensitivity biosensor. The sensitivity of biosensor was studied through the center frequency value. The higher center frequency will improve the sensitivity of biosensor device. The center frequency can calculate from basic the result of IV, resistivity and CV then proved by using braggtheories. From the theoretical, the number of IDTs is one of the parameters that affecting to the performance of SAW device. In this paper, the single IDTs were designed with the total of 10 electrode fingers and 16 electrode fingers. From the results, when the IDT with 10 number finger, the center frequency is 1.92 MHzwhile 2.40 MHz for 16 electrode finger. It shows that the center frequency for Design 2 with 16 fingers has higher compare to Design 1. It can be concluded, the Design 2 will have higher sensitivity compare to Design 1. It also shows that the number of finger is also affected to the device performance.

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