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Simulation of 1GHz Center Frequency SAW Using CST Software for Biosensor Application

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Abstract: Surface Acoustic Wave (SAW) is a one of the essential components that used for sensor application to detect in various fields. The high center frequencywill improve the sensitivity of SAW biosensor. Therefore, it's very important in designing the SAW structure to improve the performance sensor in biomolecule detection. In SAW device, the IDT is a one of major factor can improve the performance device in term of sensitivity and accuracy detection. In this project, a miniature SAW IDT is designed and simulated by using CST software for achieving 1GHz of center frequency.The IDT Design and the width of IDT finger was varied to achieve the target. From the simulation results, found that this software able to calculate the center frequency and single split finger with size 1µm has achieved 1GHz center frequency.

Key words: Surface acouststic wave · Biosensor · IDT · Biomolecules · Calculate

INTRODUCTION

The Biosensor has become an important technology in a wide range field such as medical, biological, environmental, food analysis and in communication fields. From many of technologies sensor, found that the Surface Acoustic Wave (SAW) is a one of sensor devices can be used in all fields mentioned above [1]. In Bimolecular research, highly sensitive and selective or accuracy of the sensor is greatly important. In the intervening time, the SAW Biosensor type has proven to have a sensitivity and excellent accuracy makes it suitable for use in Bimolecular detection [2]. Analysis of the Surface Acoustic Wave (SAW) with making the innovative design for Bimolecular by make improvements in detection performance and in same time reduce costs.

In a SAW device, there are three important parts that influence performance of sensing as called, substrate piezoelectric, sensing area (delay line) and InterDigital Transducer (IDT) [3]. The IDT provides the cornerstone of SAW technology. The IDT is the most important component in designing the SAW device where this element is used as an interface between the electrical circuit and the acoustic delay line. The basic configuration of SAW device consists of two IDT called as input IDT and output IDT to control the acoustic wave. The acoustic wave generates starting in the input IDT then travel through sensing area and reaches the output IDT. It means, the input IDT will convert the energy of electrical to acoustic and vice versa at output IDT. The basic structure of the SAW device is shown in Figure 1.

In order to achieve good SAW performance, the combination of substrate piezoelectric films and finger IDT is one important factor. The most commonly used piezoelectric materials for these sensors are quartz, Lithium Tantalate (LiTaO3), Lithium Niobate (LiNaO3), Zinc Oxide (ZnO) and Aluminum Nitride (AlN) [4]. ZnO has a high piezoelectric coupling coefficient, high phase velocity which can be used in surface and bulk acoustic wave [5]. In this project, the combination of ZnO piezoelectric and gold IDT will use to improve the performance device. The most important specification for SAW device design is the center frequency, which determined by the period of the IDT fingers and the acoustic velocity of the piezoelectric material.

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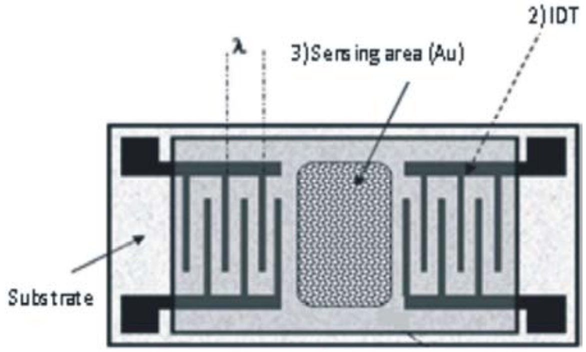

Fig. 1: The conventional SAW device structure with 2 IDT's and Aurum Sensing area and silicon substrate.

Higher center frequency and low insertion loss will have higher sensitivity of SAW Biosensor [6]. This paper describes the design and simulation of The IDT SAW Biosensor was simulated by using CST software to study the center frequency response. This is a first time simulation of SAW device using CST software.

Saw Device Design: In designing SAW devices, design procedure for the acoustic sensors can be done in numbers ways, however, is mainly device and application specific. This involves issues such as acoustic modes election and sensitivity based on parameter which is more potentially unavoidable, substrate selection, transducer geometry and the selective (bio)chemical film deposition technique which are necessary to be considered when design and investigating SAW device designs. The final operational environments also an important influence in the design procedure to some consideration of gas/liquid application systems need to be made, especially area where for integrated flow chambers are necessary.

There are several available parameters that influence of the center frequency of SAW device. The parameters and dimension of interest is the number of finger pairs (N), finger spacing, delay line distance, aperture (W) size, finger width (d) and period [7]. Reducing the size of the width and aperture (W) finger will give impact on the higher center frequency. Reducing the width of the IDT finger or choosing the piezoelectric material with higher phase velocity can increase the frequency of operation in the GHz range. SAW The governing equation that determines the operation center frequency is The center frequency can calculate by using formula 1.1.

$$f_0 = \frac{V_s}{\lambda_o} \qquad (1.1)$$

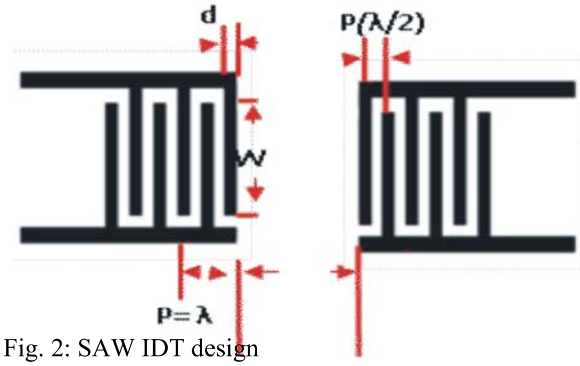

Fig. 2: SAW IDT design

where, V_s is the velocity of ZnO piezoelectric and . is the wavelength of IDT fingers. IDT can be produced by any type of designing patterns. The different design of IDT can give different output for the pulse and wave. Figure 2 shows the inter digital transducer (IDT). In the figure, (W) is the aperture, (P) is the periodicity of the transducer. Acoustic wavelength is equal to the periodicity.

Simulation of Saw Device: Simulation is the process which is the most important things to do before the fabrication process. Through the simulation process, it can help in order to determine the best design for the IDT. The measurement of the SAW properties in simulation initially focused on the center frequency, S-parameter and phase magnitude of IDT design. The center frequency is one of the important parameters in studies the SAW device performance. Commonly, software such as, COMSOL, SPICE and ANNSYS were used to simulate the SAW device and these software very difficult to simulate center frequency. CST is one software commonly famously used in the communication fields and found that this software is able to calculate and simulate the center frequency. Therefore, CST is a one software can overcome this problem and this first time simulation of SAW device using this software.

For the simulation studies, the size of fingers was varied into multi size and several designs was proposed to study the effect of the IDT design to the SAW device performance. A miniature IDT SAW device is designed and simulate to have a 1 GHz for use in Biosensor applications.

The simulation works has divided into two parts. For the first part, the simulation focused on studies the parameter for the conventional SAW device. The parameter such as finger length and finger spacing was varied to study the effect to the center frequency response. In this work, a miniature SAW IDT finger with a size of 0.5 μm for Design 1 (D_1), 1 μm For the second

Table 1: Parameter for simulate conventional saw structure devices

Substrate Material	First Design (D_1)	Second Design (D_2)	Third Design (D_3)
Finger length	16μm	20μm	30μm
Finger width/spacing (d)	0.5μm	1μm	2μm
Finger thickness	2μm	2μm	2μm
Wavelength	2μm	4μm	8μm
Acoustic aperture (W)	8μm	8μm	8μm
Number of IDT finger (N)	10	10	10

Table 2: Parameter used to simulate second design saw biosensor device

Substrate Material	Single Finger (S_1)	Double Finger (S_2)	Triple Finger (S_3)
Finger width/spacing	1μm	1μm	1μm
Finger thickness	2μm	2μm	2μm
Acoustic aperture (W)	8μm	8μm	8μm
Number of IDT finger	10	20	30

design (D_2) and 2 μm for Design 3 (D_3) are designed and simulated. The variable of the finger above are respectively designed and simulate with the aperture (W) with 8μm and the total number of fingers (N) is 10. The IDT design is fabricated using gold layer and was fabricate onto ZnO piezoelectric and silicon substrate, respectively. All parameters used to simulate the first design are summarized in Table I.

For the second design, Three IDT sensors of different configurations have been simulated and designed. Each sensor has the same finger length, finger width and acoustic aperture. The only parameter that has been changed is the design of the IDT. The Sensor_1 (S_1) was designed same as conventional IDT (D_2) with the finger width 1μm, while the Sensor_2 (S_2) and Sensor_3 (S_3) were designed with the double split and triple split finger respectively. The parameter for second design is summarized in Table II and the structure of the device is shown in Fig. 5 in result discussion.

RESULT AND DISCUSSION

The simulation result of center frequency for all designs using the CST software will be presented in the result and discussion. This is a fist SAW device simulate using software CST. The center frequency is related to the IDT wavelength and the piezoelectric substrate that relate to the phase velocity will explain details in this part.

Result of Conventional SAW: Fig. 3 shows the device structure of the conventional SAW device simulated using CST software.

Frequency response simulation of the conventional SAW device is shown in Fig. 3, where the graph represents the S-parameter magnitude versus the center

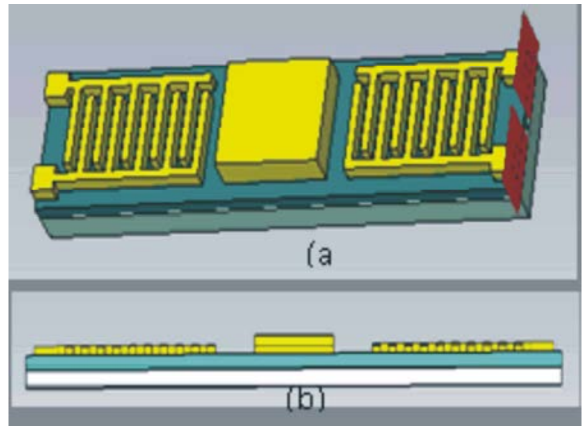

Fig. 3: Device structure of conventional SAW device (a) Structure with 1 μm width Gold IDT onto ZnO and silicon substrate, (b) crossection of SAW device.

frequency. The first design (D_1) consisted with parameters for width 0.5μm, aperture 8μm, the finger spacing 0.5μm. The finger thickness is 2μm and the total number of IDT is 10. The center frequency result represents for the design (D_1) is shown in Fig. 3 (a). From the result, value of center frequency is shifted from the expected calculation in equation 1.1 from 1.9124 GHz to 1.977GHz. For the second design (D_2), the center frequency is around 0.85753 GHz and shows in Fig. 3(b). Based on the equation (1.1), the result is around 0.988GHz. This second design was consisted with parameters for width 1μ, aperture 8μm, the finger spacing 1μm. The finger thickness is 2μm and the total number of IDT is 10. While, for the third design (D_3), the width of a finger is 2μm, aperture 8μm and the finger spacing is also 2μm and others parameter are keep same. From the result in Fig. 3(c), the value of center frequency is 0.58215 GHz. Based on the equation (1.1), the result should get 0.51GHz.

From the result, the Design 1(D_1) has a higher center frequency and its prove with the theoretical that smallest finger width (d) will give a higher frequency response. From the simulation result, found that the result almost same as calculation result. This show that this software is able to simulate the center frequency of SAW device with the result along with the theoretical.

Design of Split IDT Finger: In this part, three IDT design has proposed to study the design structure to the center frequency. The simulation structure of the proposed design is shown in Fig. 4. The structure of Fig. 4(a) is for single split SAW Biosensor, while figure 4(b) and Fig. 4© for double spilt and triple split, respectively.

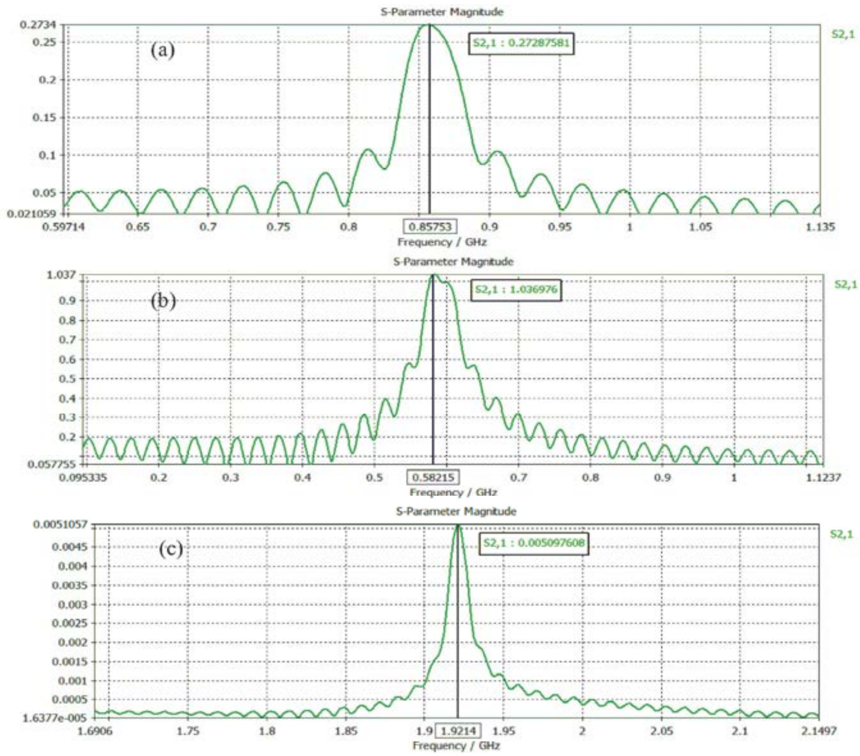

Fig. 4: Result of center frequency conventional SAW device with S21 magnitude versus Frequency, (a) result ofD-1 design, (b) D-2 Design, © D-3 design.

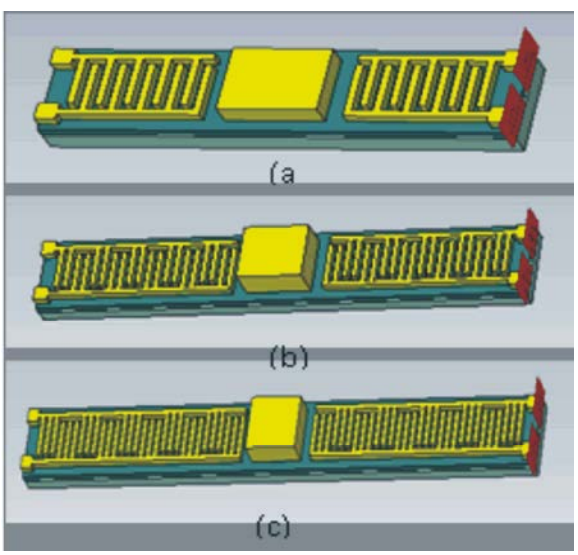

Fig. 5: Simulated structure of SAW device with (a) conventional SAW (b) double spit design, © triple split design

From the simulation result in Fig. 4, the Design 2 (D_2) was chosen for comparison with a second design because the result of center frequency is nearly to 1GHz. In addition, it’s very difficult to fabricate design with size 0.5µm in the fabrication process. So, for next result the single split IDT with width 1 µm were used for comparing to the double split and triple split.

Fig. 6 shows the simulated S21-Parameter Magnitude dB versus frequency response for three designs proposed. From the figure shows the insertion loss was approximately in the range 10-20db. It was found that, the center frequency of the SAW for single split (a) is 0.85784GHz, for a double split (b) is 0.72GHz and for a triple split © is 0.5GHz.

One of the important properties of channel is the center frequency and center frequency of a filter or channel is a measure of a central frequency between the upper and lower cutoff frequencies. It is usually defined as either the arithmetic mean or the geometric mean of the lower cutoff frequency and the upper cutoff frequency of a band-pass system or a band-stop system. As known, the center frequency is an important parameter in determining the sensitivity of a Biosensor. A higher center frequency provides better sensitivity and smaller device size. But its disadvantages are having higher reference noise, greater propagation loss and difficulty in the patterning of the IDT. When the insertion loss is high, the sensitivity will be reduced [8-11]. By observing from

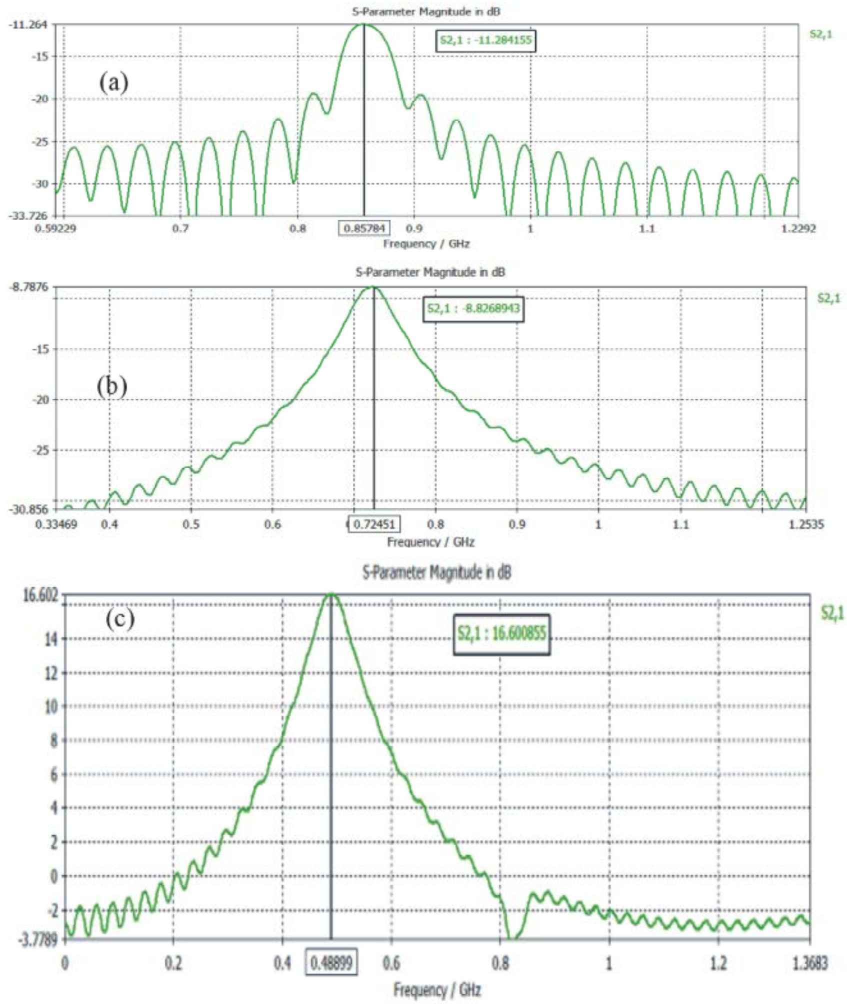

Fig. 6: Result of center frequency of SAW device with S21 magnitude dB versus Frequency, (a) S-1 design, (b) S-2 Design, © S-3 design

the results in Figure 6, it can be observed that single electrode IDT has a higher center frequency but insertion loss also high. From the simulation also, shows that double split IDT finger is also one alternative in designing the IDT. Even though has a low center frequency but it has satisfied insertion loss.

CONCLUSION

A SAW Biosensor was successfully designed and verified the center frequency using the simulation CST software. The center frequency is measured based on the IDT parameter. Based on the analysis of all of the output result, it was found the value of center frequency is affected by the width of a finger and also the value of fingers spacing of IDT SAW. This research also can conclude if more bigger the value of width fingers it is can produce less the value of center frequency. From the simulation shows that this software is alternative in simulation the SAW device and can achieve 1GHz center frequency. From the study showed that improvement in sensitivity is possible by changing the IDT structure and design based on the simulation result that has been provided.

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