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Morphological and Electrical Characterization of 130nm Interdigitated Electrode (IDE)

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***Abstract*— Biosensor is the application of sensor that widely applied and still progressing until today. One of the applications of biosensor is Interdigitated Electrode (IDE) that composed of finger of electrodes and a pair of pad. Nanogap is the gap between the electrodes that can determine the sensitivity of the device. In this experiment, 130nm of IDE is tested with the electrical measurement and showed the positive result which is $2.0\mathrm{x}10^{-10}$ at 0.2 V. The Scanning Electron Microscopy (SEM) of the device showed the small gap is used for better sensitivity without deposite anything on the probe. In the future, this IDE can be used for coating with metal oxides for better performance of the device.**

Keywords*— Interdigitated Electrode (IDE), Electrode Gap, Electrical Measurement (I-V), Scanning Electron Microscopic (SEM).

I. INTRODUCTION

Interdigitated Electrode (IDE) is currently installed in many sensing devices such as surface acoustic waves (SAW) sensors, chemical sensors and recently Micro-electrical Systems or known as MEMs biosensors. IDE is consists of electrode pads and electrode fingers that carefully designed considering the area, bandwidth and the gap between the electrode fingers to give the output for signal strength [1]. IDE is developed to be more sensitive as the distance between the finger electrodes is minimized for capacitive detection. IDEs is functioning to detect the electric signals generated by the sensing material [2]. IDE is made as multiple electrode configurations for increasing sensitivity as well as minimizing interferences [3].

According to the research, the more number of electrode fingers and the finger widths, the signal literally increased. The appearance of IDE is like comb structure between the electrode known as electrode gaps. Basically, photolithographic process is the process to generate IDE by a lift-off process. Photolithography required steps such as photoresist and etching solution are among the expensive facilities and extreme processing conditions [4]. IDE is build for its capacitance structure because of the low energy consumption of capacitive transduction mechanism and its compactness, high contact area and ease of manufacturing. Many researchers also studied to improve the performance of the device by designing other construction such as spiral electrodes and concentric rings [5].

The design of IDE can be obtained by the photolithographic process with size limited feature even to few micrometers which can give the effect in term of sensitivity of the device and allowing extremely low concentration of analyte can be detected [6]. The other method for IDE fabrication is by stamp method [7]. In the previous research the functionality had been highlighted for gas sensor application and electrochemical sensors. However, in the recent works, IDE also focused on biosensor [8]. Biosensor is the capability of device to recognize the specific bio-analyte integrated with a transducer to covert the biological signal to electrical signal [9].

II. MATERIALS AND METHODS

A. Photolithography Process

The making of IDE is through fabrication method of photolithography process. Photolithography processes additionally involving complex steps of processing material including photoresist and etching solution conditions [10]. Inkjet printing had been used for the recent years to fabricate sensors and other functional device which offering the great advantages of patterning ability, the efficiency of material, low cost of the process and thin films can be printed on the substrate.

B. Electro Gap

The key point of this experiment lay on the nanogap of the IDE which is as small as 0.130 μm (130nm) which can generate geometric parameter of the strength of the electric field and the current density compared than width and height of the IDEs [11]. In this case the small nanogap is needed for a fewer molecule or a single molecule is be able to connect between two electrodes [12]. For many years, numerous efforts had been calculated to accomplish the nanogap biosensor for low cost, less time consuming, high integrability and high sensitivity devices [13].

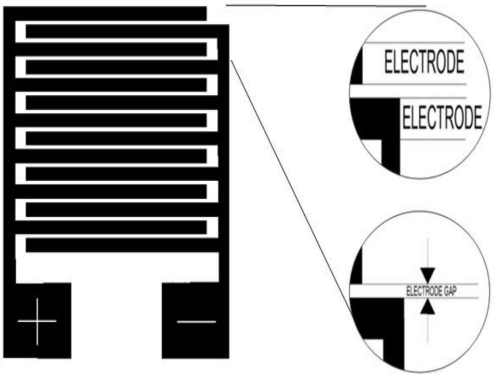


Fig. 1. The illustration of electrode and electrode gap of IDE device.

C. *Electrical (I-V) Measurement*

The electrical (I-V) measurement is taken by two point probe as shown in figure 2. The reading is set to find the voltage value as the amount of current is being put. The equation of the current-voltage relationship is according to the Ohm's Law as below:-

$$V = \frac{I}{R} \tag{1}$$

V stands for voltage value meanwhile *R* is resistance and *I* is he value of current. The final reading of the measurement is set at 1 V with step (V) is 0.1 which means the reading started at 0.1 V made the overall points of reading is 11 times. The objective of the experiment is to determine the value of current flow with the amount of voltage being charged through the device.

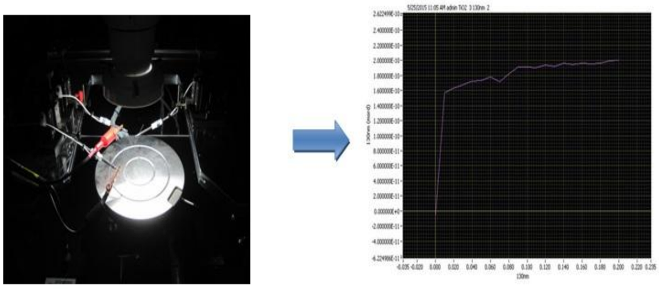
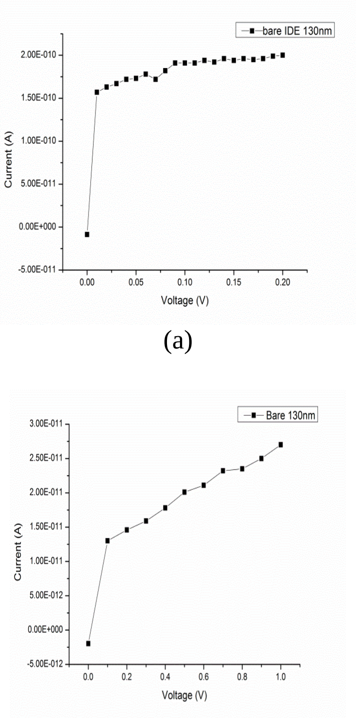


Fig. 2. IDE as a capacitance transducer to convert the signal to electrical output.

III. RESULTS AND DISCUSSION

A. *Current-Voltage (I-V) Relationship*

Figure 3 (a) and (b) showed the current-voltage (I-V) measured of IDE within the electrode gap of 130nm with stability achieved at 0.2 V and 1 V respectively. For figure (a) the stability achieved at 0.2 volt is 2.0×10^{-10} meanwhile for figure (b) the reading is stabilized at 2.7×10^{-11}.



(a)

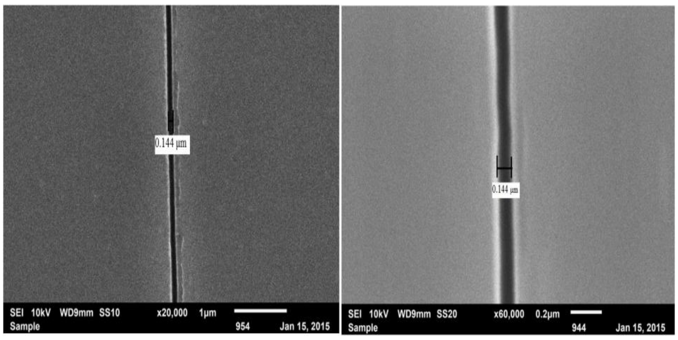
(b)

Fig. 3. Electrical measurement (I-V) for (a) bare 130nm IDE for 0.2 V (b) bare 130nm IDE for 1 V.

As shown in the figures the reading of I-V measurement changes with the limited voltage pressurized on the device. The reading as shown in (a) showed the reading keep on increasing and become stabilized after reaching 0.2 V. The same pattern showed in (b) voltage reading is increasing directly as current reading. As Ohm's Law stated in equation 1 when the voltage increases, the current of the device also increases. This result showed that the Interdigitated Electrode (IDE) of 130nm is functionalized with the positive results of the electrical measurement.

B. *Scanning Electron Microscopics (SEM)*

Figure 4 showed FESEM image of cross-section for 130nm IDE device. As clearly showed the gap between two electrodes is 0.144µm which is 144 nm. The gap becomes bigger because of the effect of aluminium (Al) etching during fabrication photolithography process. The IDE device is the combination of Silicon (Si), Oxygen (O) and Aluminium as an electrode. Aluminium is regarded as one of the high conductivity metal, high surface to volume ratio and be able to improve the mixing flow of complicated current-flow path [14]. In addition, aluminium is also low in cost and has high stability of electrode function [15].



(a) (b)

Fig. 4. Field Emission Scanning Electron Microscopy (FESEM) for a) 20KX and b) 60KX for magnified under lenses of top view IDE.

C. Cross-Section of SEM

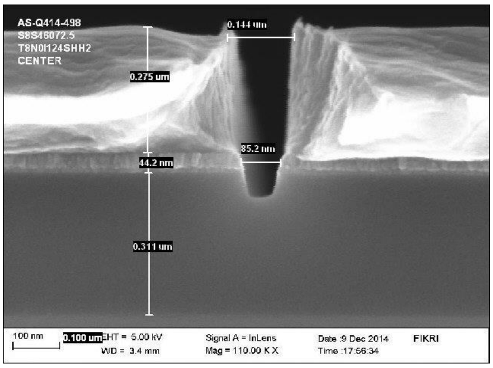


Fig. 5. Image of cross section bare 130nm under 110 KX magnified lenses.

The image in figure 5 showed the cross section of the thickness of the aluminium deposited on the SiO is 0.275µm with Oxide layer having the thickness of 0.044µm and Si layer with the thickness of 0.311 µm. The deposition of oxide on top of the Si is achieved by wet oxidation process meanwhile aluminum deposition is done by sputtering process [4].

IV. CONCLUSIONS

This experimental works is performed for the functionality of the IDE device that composed of very small gap of electrodes which is 130nm. The device also gave the positive electrical result by showing the reading at different voltage is pressurized on the device. Thus, this device is functionalized accordingly with the size of gap and hopefully the smaller gap is used for better sensitivity of the device even in a very low concentration of detection. In the future works, the device as IDE is beneficial for any kind of bioanalyte for biomolecules detection such as Deoxyribonucleic Acid (DNA), Ribonucleic Acid (RNA) or antibodies.

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