Effects of Gold Nanoparticle on Surface and Electrical Characterizations of Functionalized Interdigitated Electrode (IDE) for biomolecules detection.

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Abstract— **Usually biomolecules such as proteins, RNAs, aptamers and other nucleic acids are detected using conventional lab methods. Nowadays, biosensors are emerging as an alternative way for diagnosis purposes. Linearity, high throughput detection and lower response time are some of the reasons biosensors are ideal mediums for detection of biomolecules. Among all other biosensors, electrochemical biosensors have picked up the interest of many researches due to their sensitivity and selectivity. Interdigitated Electrode (IDE) is classified under electrochemical biosensor and is known for its specificity. On the other hand, metal nanoparticles have been under intensive investigation due to their potential as conductive layer on biosensor surface. Gold nanoparticle, in particular, is an active catalyst for biosensing applications. As a present work, an IDE was successfully designed and fabricated composed of microelectrodes joined together with a series of finger-like structures prior to functionalization with gold nanoparticles on its surface. Later, electrical measurements as well as surface characterizations were recorded for both bare IDE and gold nanoparticle-functionalized IDE for comparison purposes via current-voltage measurements and Scanning Electron Microscope respectively.**

Keywords— Biosensor, Interdigitated Electrode, gold nanoparticle, biomolecule, photolithography

I. INTRODUCTION

Biomolecules can be classified as molecules that are found in living things. Some of the examples include DNA, RNA, aptamer, protein and metabolites. As a component in living things, they represent the identity and rather conformation of the living thing itself. Therefore, the detection and identification of biomolecules in various fields such as pathology, pharmacology, agriculture, horticulture and medical is very important [1]. Confirmatory tests use a few conventional methods such as Polymerase Chain Reaction (PCR), agglutination tests, Enzyme-linked Immunosorbent Assay (ELISA) and colorimetric assays to characterize biomolecules but all of them are labour-extensive and costs high and has low limit of detection. Due to these facts, an electrochemical biosensor i.e. Interdigitated Electrode (IDE) is presented in this study as a model for detecting biomolecules. Biosensors are sensing devices that turn any biological or chemical signal into electrical signal. Biosensors consist of three main parts: a) the receptor which accepts the biological analytes; b) the transducer, which is considered the most crucial part in a biosensor because of its role of translating the information of biological components into electrical data; and c) the processor which displays the electrical signal in an easily detectable manner. There are different types of biosensors based on the types of transducers. There are optical, mass and electrochemical biosensors. Electrochemical biosensors are known for its low-cost detection and its rapid and convenient target recognition. Among many electrochemical biosensors, IDE is chosen for its linearity, low ohmic drop and rapid rate of reaction kinetics [2]. For further enhancement, in this study, gold nanoparticles are coated on the biosensor surface because of the inert metal's excellent bioaffinity, high surface to volume ratio and remarkable optoelectronic properties [3]. Recently, gold nanoparticles have been shed light by many researches due to its extraordinary physical and chemical properties and also its flexibility as biomolecular tools. Novelty in this study includes the comparison of electrical characterizations between a bare IDE and gold-coated IDE for biomolecule detection. In this case, *Ganoderma boninense* DNA is chosen as a target for detection on Gold coated Interdigitated Electrode (IDE).

II. MATERIALS AND METHODS

A. IDE design specifications

An interdigitated Electrode (IDE) is designed in such a way that a pair of microelectrode pads are connected together by a series of finger or rather comb-like structures to enhance the specificity of the biosensor [4]. Designing of the electrode is done with the aid of a computer software namely AutoCAD. Fig.1 shows the IDE measurements.

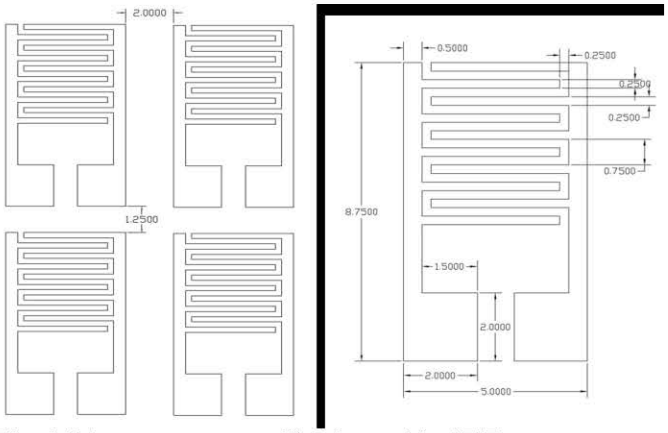

Fig. 1. Measurements specifications of the IDE

B. Fabrication process

Photolithography technique is used to fabricate Interdigitated Electrode (IDE). Prior to fabrication, an aluminium layer is deposited on top of the electrode surface to create a conductive layer. The photolithography process involves a series of processes via several machines such as mask aligner, spin coater and thermal evaporator. First, the aluminium deposited silicon wafer is cleaned using RCA1, RCA2 and ethanol to eliminated unwanted particles. Then it is coated with a fresh layer of negative photoresist layer before passing it through UV light using mask aligner to attach the patter onto the wafer surface. Later, the pattern is developed using RD6 developer by immersing the wafer in it for about 30 seconds. After ensuring the pattern is well etched onto the wafer surface, the resist layer is removed by rinsing with acetone and the wafer was hard baked for 90 seconds at the temperature of 110^{o}C. Finally, Aluminium etch solution was used to immerse the sample for approximately 30 seconds to remove the aluminium elsewhere but on the IDE pattern.The flow chart is illustrated in Fig.2. Later, the fabricated IDEs were accordingly diced was biomolecules detection purposes. A single IDE is shown in Fig. 3.

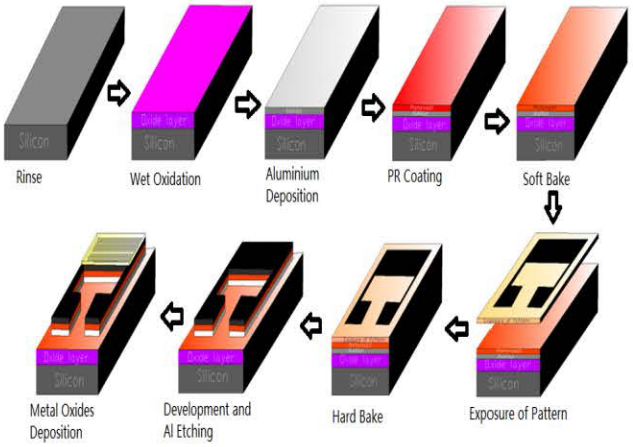

Fig.2. Fabrication process

Fig. 3. An IDE sensor

C. Functionalization

Purchased gold nanoparticles were coated on the Interdigitated Electrode (IDE) by immersing the IDE in colloidal gold nanoparticle solution. Later, the IDE was hard baked to ensure the gold nanoparticle does not etch off easily from the microelectrode. The next step was to immobilize *Ganoderma boninense* DNA on bare IDE and gold nanoparticle-coated IDE respectively. Immobilization process was done by dropping 10µl of probe DNA on the IDE surface prior to incubation at room temperature for 4 hours. After that, the IDE was rinsed with Phosphate Buffer Saline (PBS) and distilled water and was dried air blown.

D. Characterizations

Surface characterization is done by Scanning Electron Microscope and High Power Microscope whereas electrical characterization is done by Kiethley 6487 Picoammeter to test the current-voltage (I-V) relationship.

III. RESULTS AND DISCUSSION

A. Surface Characterizations

As stated above, surface morphological characterizations were done by High Power (HPM) and profiler. Fig. 4 shows the High Power Microscope (HPM) images for bare IDE and IDE coated with gold nanoparticle.

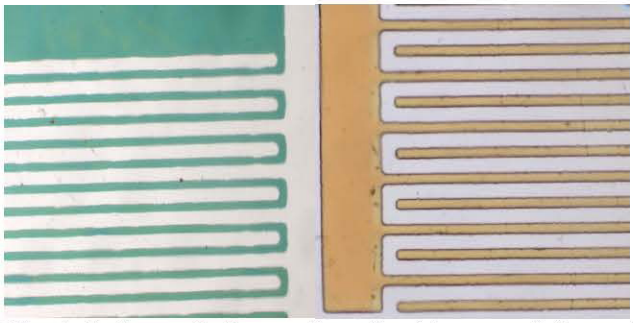

Fig. 4. Before and after coating of gold nanoparticles on IDE surface.

Whereas Fig.5 shows the profiler results which shows the difference in thickness of the IDE.

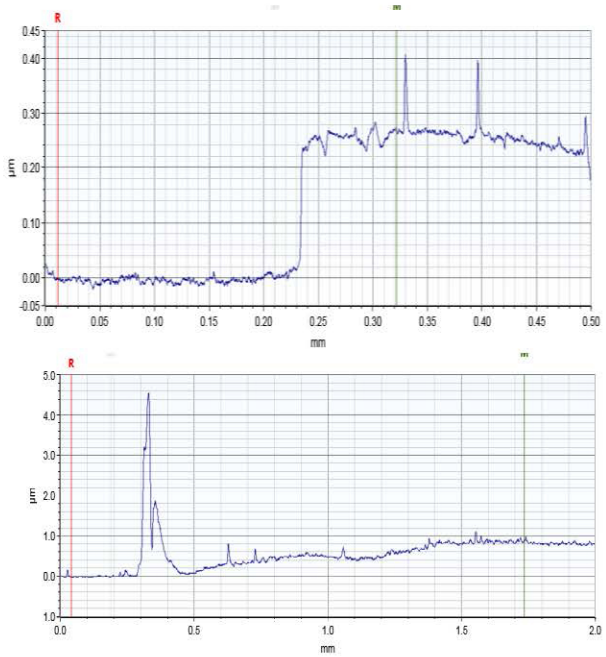

Fig. 5. Aluminium IDE compared to gold coated Aluminium IDE

B. Electrical Characterizations

The Current-Voltage (I-V) test was done as aforementioned to examine the current flow between the microelctrodes with and without gold nanoparticles in biomolecule detection.

Fig .6 shows the electrical measurement of both bare IDE and IDE coated with gold nanoparticle after immobilization of DNA.

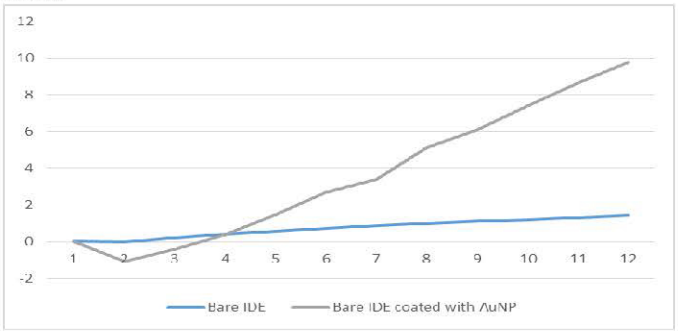

Fig. 6. Comparison in DNA detection between bare IDE and IDE coated with gold nanoparticle.

According to Fig. 6 a very low current is recorded for bare IDE because of its reduced enhancement compared to that of gold nanoparticle-coated IDE which has high chemical stability and the ability to facilitate transfer of electrons between the non-organic sensor surface and the organic DNA because gold can form bonds with a few compounds through Au-S, Au-Cl or electrostatic charges through its negative charges [5]. Bare IDE can only induce a very low current and it does show some charge as can be observed by the graph. However, it was justified through this experiment that doping or any metal coating would increase the biocompatibility and in turn, would increase the current flow which seemed to be stable and also consistent. Therefore, it can be said that gold nanoparticle would aid in any sensor's repeatability and reproducibility.

IV. CONCLUSIONS

In this study, an electrochemical biosensor i.e. Interdigitated Electrode is designed and fabricated via the method of photolithography for biomolecule detection especially DNA. Furthermore, functionalization of the IDE is done by coating its surface with gold nanoparticles for further enhancement in detection. The functionalized IDE generated higher current for DNA detection and its surface characterizations and electrical measurements were observed and recorded. The detection threshold for the functionalized sensor was proven to be high and can be reduced if hybrid of gold and other metal colloidal nanoparticle is used to coat the sensor surface.

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