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Arsenic ion Detection via Electron Chemical Reaction Mechanism Based on Interdigitated Electrode (IDE)

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Abstract. In recent days, both raw and treated water being consumed by human and animal posed serious threat to the consumer. Due to heavy industrialization water easily carries heavy metals that are harmful to consumers. Heavy metal is from metal or metalloid which found in environmental surroundings that has its potential toxicity. Most case, it is taken undetected due to absences of able sensor to detect it. Thus, this study posed to design and characterize nano interdigitated electrode (Nano-IDE) surface modified using Mercaptopropyltriethoxy silane (MPTES) to create binding chemistry for the enhancement of electrochemical activities that will allow specific and selective detection of arsenic ions in water. This result of the study has shown the potential of the proposed device.

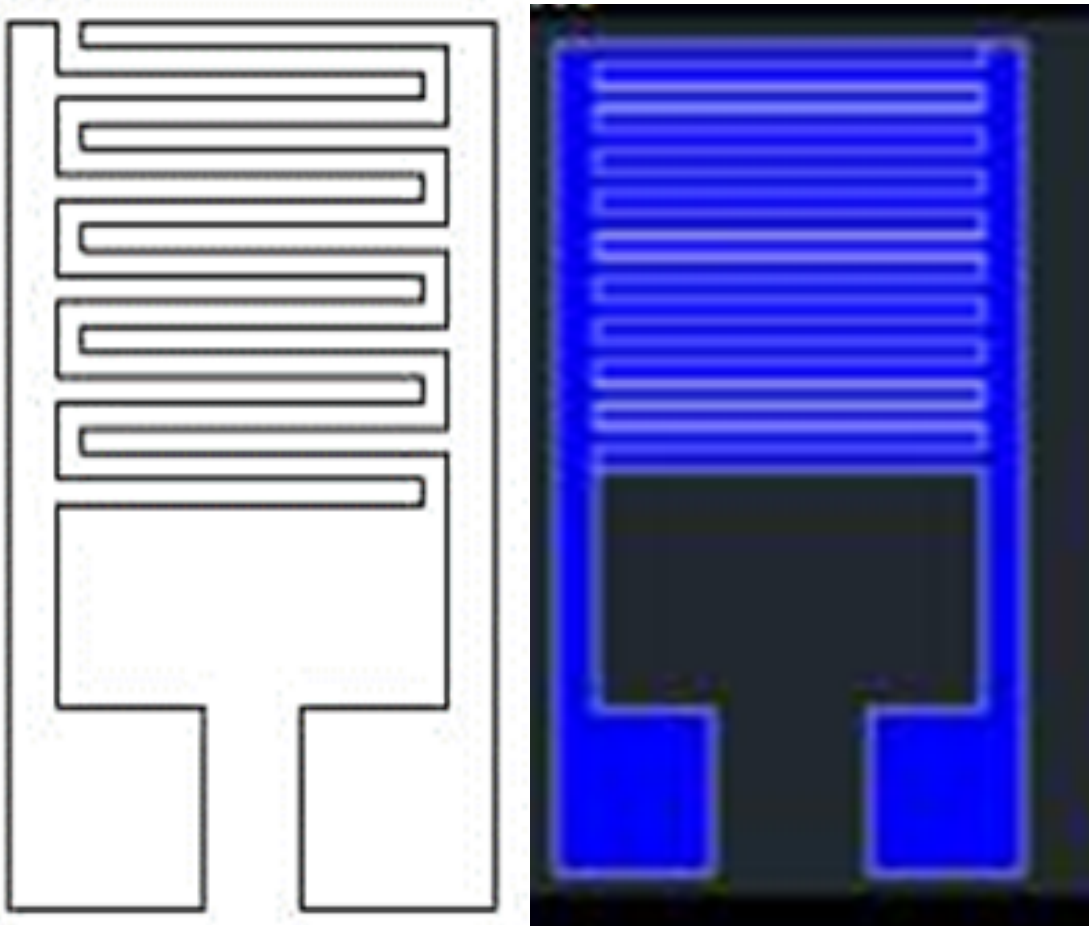
1. Introduction

Electronic chemical sensor based on interdigitated electrode (IDE's) was very important in many of industries today[1-5]. IDE was widely used whether in chemical or biological industries[6]. The chemical sensor was the self-contained analytical device that allow several information on chemical composition of the environment either in liquid or gas phase[7-10]. Besides, the information was provided in the form of a measurable physical that correlated with the concentration of a certain chemical species that was also known as analyte[11-15]. There were two main steps involved in the functioning of a chemical sensor which were recognition and transduction respectively[16]. Interdigitated electrode was known as a device that composed of two interdigitated electrodes with two connection tracks on a glass substrate[17-23]. In the other word, it was known as two or more things that interlocked like the fingers of two clasped hands (interdigitating metal bars) [28]. Furthermore, there were some advantages of the IDE such as working with low volumes of sample and avoiding tedious polishing of solid electrodes[24]. Moreover, interdigitated configuration was typically enhanced sensitivity and detection limits[25]. It was suitable for decentralized assays to develop specific biosensors and other electrochemical studies. In addition, there were some applications of interdigitated metal electrodes[26]. It also was sidely used for various sensor applications such gas sensors, humidity sensors and biosensors[27]. IDE usually chosen as a component for sensing operation where the electrical signals occurred by sensing materials that were

detected via interdigitated electrode[28]. There were some processes that had been done in forming an interdigitated electrode[29. It was fabricated by photolithography [30]. Photolithography was generally used for fabrication of microstructures. It required many process steps including photoresist coating, exposure, development and etching to generate patterns after thin film deposition[31. Based on the demand of low-cost manufacturing and a shorter product development time, an alternative simple method had been proposed, especially for printed electronic application[32]. A direct and additive fabrication technology was recently interested for the micro-patterns like inkjet printing[33]. There were several advantages including low cost and low temperature microfabrication on flexible substrates which were attractive for paper electronics and identification tags as well as disposable electronic devices[34-40]. Then, the ink consumption of this technique can be reduced based on the drop-on-demand process which allowed the delivery of precise amount of variety of solution-based materials like nanoparticle colloids, polymers, organic semiconductor and organometallics. Moreover, there are several advancement and various sophisticated systems monitoring especially but unfortunately, for detection little progress is made because sensor are marred by low sensitive and costly[41-45]. It was very expensive which caused some clinics and hospitals were not well equipped as they cannot afford an expensive equipment [46]. This could be a burden for any patient that cannot afford to use the well sophisticated equipment in the hospitals[47-48] Today the sensor was too big and not portable. In this case, if there was an emergency in the hospitals or clinics, it is quite difficult for the medical practitioners if the equipment's were not portable to bring anywhere. There also some sensors that less sensitivity which could bring a big problem if the nurses and doctors could not detect the impurities in the water [49]. Thus. Thus, this study posed to design and characterize nano interdigitated electrode (Nano-IDE) surface modified using Mercaptopropyltriethoxy silane (MPTES) to create binding chemistry for the enhancement of electrochemical activities that will allow specific and selective detection of arsenic ions in water.

2. Methods

The process started with fabrication followed with the process of washing using IP to remove the impurities. After the washing is dried by using 110^0C temperature based on photolithography. Photolithography was generally used for fabrication of microstructures. It required many process steps included photoresist coating, exposure, development and etching processes to generate patterns after thin film deposition. Lithography was the process for pattern definition by applying thin uniform layer of viscous liquid (photoresist) on the wafer surface. The photoresist was hardened by baking and then selectively removed by projection of light through a reticule containing mask information. Took the chrome mask and put the design on it. Then enter the clean booth to do the photolithography process. After that, it followed by the process of coating, drying, soft baking, expose and hard baking as shown in. The mask was produced with the pattern of the sensor as shown in figure 1 below:



(a) (b)

Figure1. The design of the sensor (a) design (b) mask

Moreover, for fully dry fabrication, it used the contact printing. In etching process, the dry etching to remove the impurities manually. Etching was a process which selectively removing unwanted material from the surface of the wafer. The pattern of the photoresist was transferred to the wafer by means of etching agents. A size of considered minimum 1 micron (either use wet or dry etching). It was deep into buffered oxide etch solution (BOE solution) in the etching process. After that, was exposed silicon to oxide, then the oxide penetrates silicon. Deposition of the films of the various materials was applied on the wafer. For this purpose, mostly two kinds of processes were used which are physical vapour deposition and chemical vapour deposition. The chemical mechanical polishing in the oxidation process oxygen (dry oxidation) or water (wet oxidation) molecules converted silicon layers on top of the wafer to silicon dioxide. Meanwhile, ion implantation was widely used technique to introduce dopant impurities into semiconductor. The ionized particles were accelerated through an electrical field and targeted at the semiconductor wafer. The size reduction technique required the smallest size. So, in every etch process, after the measurement, the morphological was obtained using SEM. For the active device, considered it at any thickness and measured the ratio in about five minutes. Lastly, the temperature was set 75-degree celcius in about 35 minutes to the removed the bubble or gaseous left on the device specimen.

3. Results and Discussion

The characterization of the device was done with low power microscope and scanning electron microscopes from the figure 2 the device was clear revealed by the LPM, however, details information on the electrode, active domain can be seen. From the LPM image, the electrode consist of square pad with straight projected arm which connected the ide fingers with electrode pad, it also clear that, the active for the sensor is quite visible and arrays of fingers can be seen , its cab be observed the design of the device as shown in the image is typical IDE configuration . The IDE structure configuration is quite very important part of sensing mechanism. Its function is to convert electrical energy into detectable energy, and vice versa, for generating and detecting signal based on the impedance changes. As mentioned earlier, the structure of the IDE is typically fabricated onto the thin film that has been deposited onto the surface of a piezoelectric substrate using lithography steps. An IDE excites an acoustic wave in the piezoelectric substrate when a voltage signal is applied to it. This varying voltage results in varying deformation of the piezoelectric substrate leading to generation of an wave wave. The wavelength of the wave excited by the IDT is equal to the periodicity of the IDE pattern. Operation frequency, bandwidth, and electrical impedance depend on parameters of IDE design including electrode width, spacing, width of IDE, delay path length and number of finger pairs.

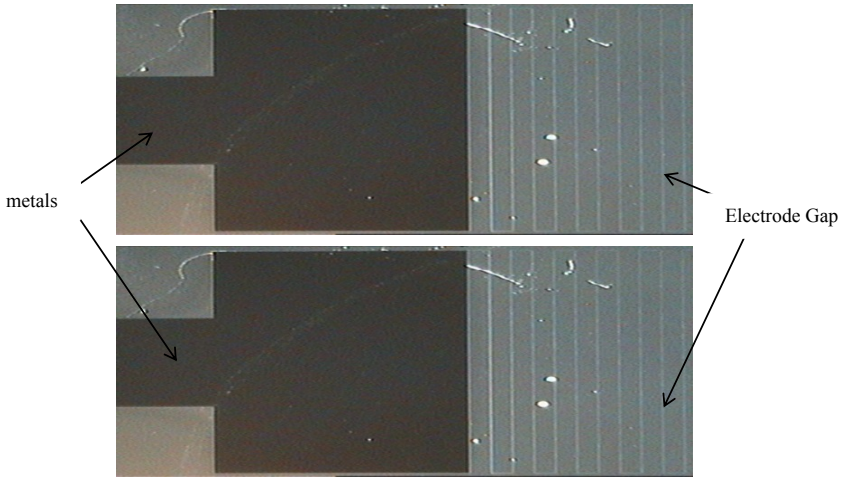


Figure 2. Fabricated device Nano-IDE

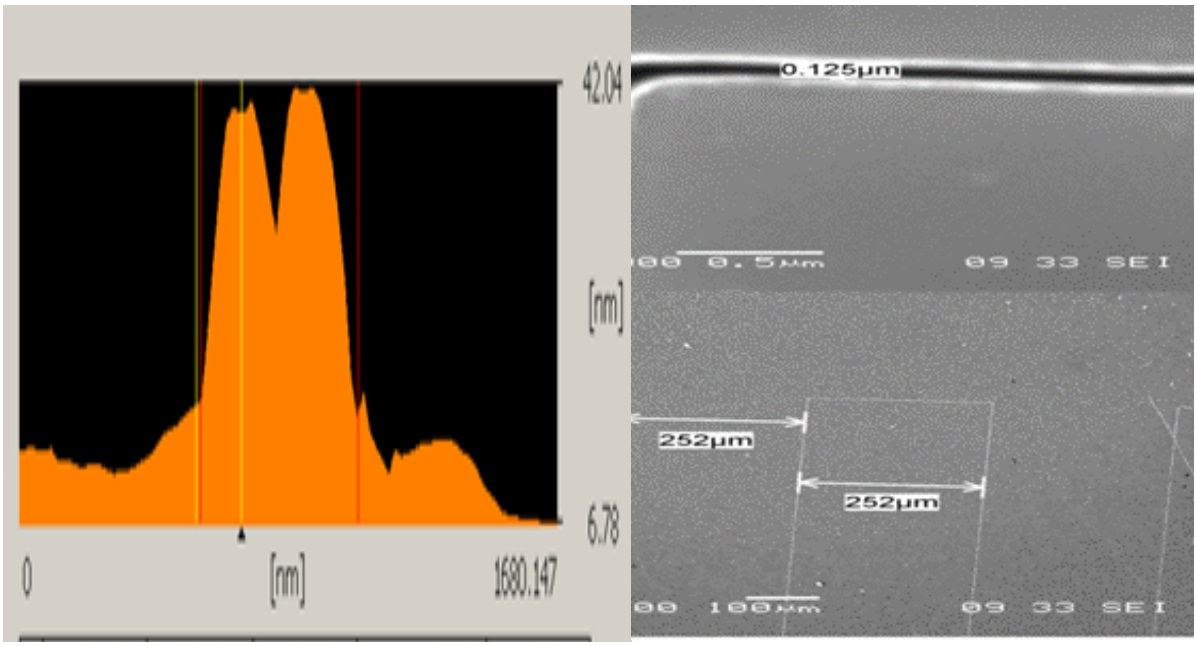


Figure 3. AFM image of fingers gap (b) SEM image of the fingers gap

Figure 3 show the SEM image of the IDE, the device finger pair geometry was shown clearly. As can be seen here, the fingers and probe are connected are Using SEM, It is equally, observed details about the IDEs can be seen on designed. The device purely response based on electrical changes, therefore, the characterization for its electrical parameters such as conductor, capacity etc. are very important. Thus, this process was conducted using impedance analyzer. The impedance analysis was conducted to understand response of the device to the pH levels. The chosen smaples was water and tested. The testing started with bare device to define the reference value. This followed by the subsequence sample measurements as shown below.

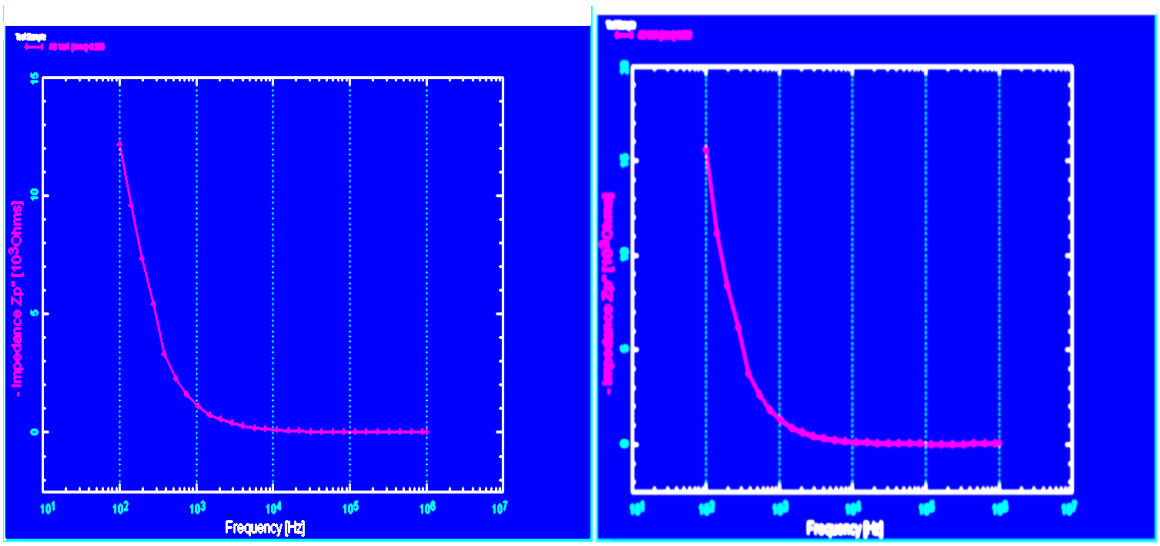


Figure 4. (a) The bare device of interdigitated electrode (b) tested with surface modified

The results show the bare device of interdigitated electrode to see the reaction of the electricity of the device. An equipment called impedance/dielectric analyzer was used to see the electric behaviour of the device. From the igure 4, it can be seen the relationship between

impedance and frequency. So, it indicated the impedance increased as the frequency decreased until it become almost zero. This is typical example of capacitive effect of pair fingers. Secondly, we used acetone as one of the pH used to test the device electric behaviour. Based acetone was a colorless and flammable liquid that evaporated quickly.Acetone was one of an organic compound because the carbon atoms were present in acetone's chemical formula, which was (CH3)2O. it consisted of three carbon atoms, six hydrogen atoms and one oxygen atom. It was soluble in water. It did not have an OH- group to free up or an acidic hydrogen ion to lose in the water. Because of that, it did not have anything to change the OH- and H+ to balance the water. Then, its pH was neutral which was with this, the reaction of the water to the devices is obvious .

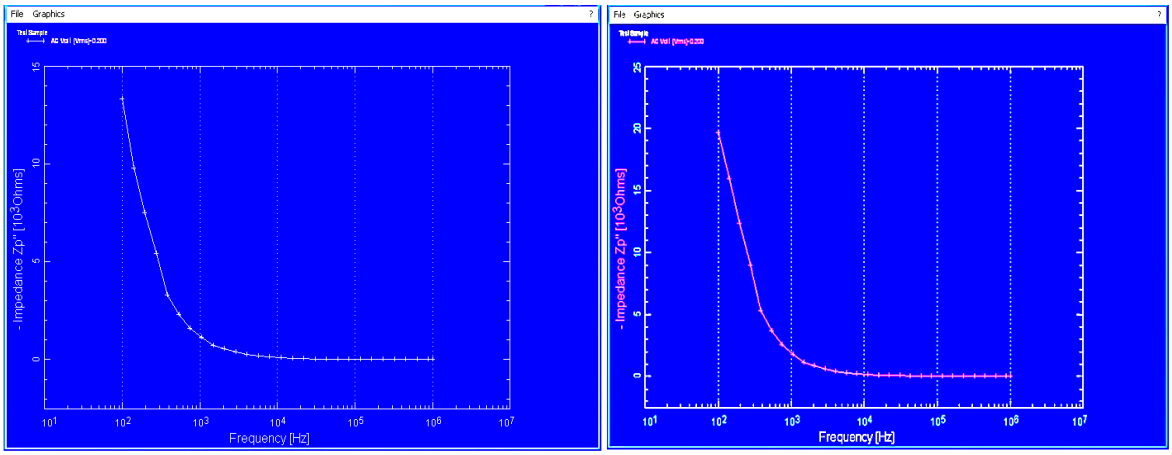


Figure 5. (a) The bared and (b) modified device against the arsenic ions

The ion with MPTES hydroxyl group caused the molecule react and produce the needed current response. The arsenic ion of 100% was 7.33 ration by weight as compared to water which was 7.00 by weight . In this case, the hydrogen of the hydroxyl group would react with a strong enough base so that could make the MPTES a weak acid which was much weaker than acetic acid. But in practical terms, it did not really happen as a result MPTEs only of as the with or without MPTES substance and it was not certainly a base support the impedance entire reaction . When the MPTES was diluted the acid based function between range of about 3.5-4.7. Meanwhile, the range of the pH of arsenic-based Mptes is around 4.1-4.6. because of that, the range of pH of wters are slightly on the acid side which between fall into the 4.3-4.9 when it came to acidity. Then it goes from 0-14, with the lower numbers being the most acidic and higher number being the less acidic. Besides, the acidity of fresh tomatoes could be nearly associated with their degree of ripeness. The mature and reaction component was, the lower its acidity, with the pH approaching 4.9. Thus, this verified the fact the Nano-IDE have capability discriminate different ions which could be used to identify various heavy metal from the water.

4. Conclusion

The study successfully design, fabricated and characterized nano interdigitated electrode (Nano-IDE), the surface modification was done to create surface chemical that could used to discriminate different ions, the test was done on the surface of modified Mercaptopropyltriethoxy silane (MPTES) IDE created both binding and reaction chemistry for the enhancement of electrochemical activities that will allow specific and selective detection of arsenic ions in water. This result of the study has shown the potential of the proposed device in discriminating the ions.

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