IOP Conference Series: Materials Science and Engineering

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IOP Conf. Series: Materials Science and Engineering **454** (2018) 012184 doi:10.1088/1757-899X/454/1/012184

Mercaptopropyltriethoxysilane (MPTES) Concentration Effect on Selectivity and Electrical Response of Nanostructure

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Abstract. The surface modification by on Mercaptopropyltriethoxysilane (MPTES) done to enhance electrical behavior of nano-IDE -based sensor, silicon based active area was coated with MPTES. The electrical properties of modified nano-IDE were tested using impedance analyser by observing the changes in impedance with the frequencies There was increase as the concentration of the MPTES increase from 1 to 5%. The electrical conductivity increases as mobility increase with the surface attenuation by the MPTES. This increase in concertation observed increase of the electrical conductivity with carrier mobility increment, this indicate decrease of the Si–arsenic bond length, which caused the bandgap to be shortened, likewise, The device behaviour to surface modification was capacitive reactive in natured.

1. Introduction

The electronic chemical sensor based on Interdigitated Electrode (IDE), the biosensor presented in this paper operates in the non-faradaic mode based on changes in capacitance between interdigitated electrodes to indicate molecular binding events at the electrode surface[1-7]. Biosensors operated in the faradaic mode were often based on electrochemical impedance spectroscopy (EIS) by measuring electron transfer resistance and double layer capacitance within a frequency range[8-15]. Comparing to capacitive biosensors, biosensors based on EIS had been widely explored for their ability to capture complex resistance changes due to binding events at biosensor's electrode sites. However, they were more complex from an electronics and experimental protocol perspective, required a wide-range frequency sweep and the use of a potentially hazardous redox couple[16-25]. In medical field, capacitive biosensors developed for DNA/RNA classification and pathogen detection had focused on improving the electrode surface modification process, achieving better transducer sensitivity, and increasing detection circuit sensitivity and signal-to-noise ratio (SNR)[26-30]. A label-free capacitive detection method for DNA detection and pushed the limit of detection down to 25 complementary DNA targets per mL. The used of an inexpensive Al/Al2O3 hybrid electrode to achieve good sensitivity. Several important details relevant to charge-based capacitance measurements and provided insights into CMOS compatible implementation for integrated electronics[31-35]. A capacitive biosensor design with a detection range of 330pF to 10mF with good linearity. CMOS circuitry based on charge/discharge the dry for detecting capacitive signals to demonstrate it stability to detect 2nM of target nucleic acid from H5N1 Influenza viruses and achieved multiplexed detection using an interdigitated electrode array, with 25pg/mL sensitivity to the complementary target [8]. The use of interdigitated electrodes (IDEs) for the development of sensors has been receiving growing interest during the last two decades[33]. The fabrication of the IDEs by means of lithography allows for the development of sensitive, low cost and miniaturized chemical sensors and biosensors. The IDEs are usually fabricated by lithography techniques on Si and glass substrates and have typical electrode width and spacing, which vary from tenths of nanometres to tenths of microns[34]. Au, Ti, Pb and Al are some of the most commonly used metals for the electrode's fabrication. In the field of interdigital capacitive (IDC) sensors, the principle of detection is based on the change of the dielectric constant of the interdigitated capacitor. The capacitance of a sensor is a function of the dielectric permittivity of the sensor materials and the geometric characteristics of the electrode. Gold interdigitated electrodes made on a glass substrate, with two available dimensions for bands/gaps : 5 µm and 10 µm[30-40]. They allowed working with low volumes of sample, being suitable for decentralized assays, to develop specific (bio)sensors and other electrochemical studies. Moreover, interdigitated electrodes made up of two individually addressable interdigitated comb-like electrode structures that had frequently been suggested as ultra-sensitive electrochemical biosensors. Since the signal enhancement effected due to cycling of the reduced and oxidized species were strongly dependent on the interdigitated electrode distances, since the nature of the enhancement was due to overlying diffusion layers, interdigitated electrodes with an electrode separation of less than one micrometre were desired for maximum signal amplification. Fabrication of submicron structures can only be made by advanced lithography techniques. By used of electron beam lithography we had fabricated arrays of interdigitated electrodes with an electrode separation distance of 200 nm and an electrode finger width of likewise 200 nm. The entire electrode structure was 100 micrometre times 100 micrometre, and the active electrode area was dictated by the opening in the passivation layer, that defined by UV lithography. Here we reported the measurements of redox cycling of ferrocyanide by coupled cyclic voltammograms, where the potential at one of the working electrodes were varied and either an oxidising or reducing potential was applied to the complimentary interdigitated electrode. The measurements show fast conversion and high collection efficiency round 87% as expected for nano-interdigitated electrodes [35-40]]. Arsenic threatening most populous people in the world specially the developing countries, which depends heavily on groundwater either drinking or cooking. Arsenite and arsenate is the most identified in groundwater, which considered a toxic inorganic arsenic, causes serious health effects to humankind. The research shown that is 105 countries with population more than 200 million has exposed to arsenic contamination. The high vulnerable from arsenic toxicity counties and more risky is the south-east Asian countries such as India (the Ganga–Meghna– Brahmaputra) and Bangladesh. In the last years, there was several investigations have been undertaken to find the relationships between many diseases and the arsenic exposure. Studies find that exposed to arsenic methylation capability can be cause of many diseases such as bladder cancer, skin and risk of carotid atherosclerosis[40-44]. Others studies have indicated that a higher amount in urine of inorganic arsenic (iAs) and monomethyl Arsonic acid (MMA) could be a risk of skin lesions, lung cancer and decrease the birth weight for pregnant women. In contrast, low amount increased the length of newborns. Several research indicated that due to toxicity of arsenic metabolism could be serious factor for lung cancer and skin lesion. It confirmed that if adolescence people who exposed to arsenic raised the risk of heart attack, a hypertension and mortal cancer. It was reclaimed still need more researches about arsenic effect of humanity health because whatever done was little is known about the the relationships between arsenic and diseases[45]. The IDE nano device surface is usually active, it can response to various analytes, however, to enhance it electrical response capability and specialties, it need to be surface modified, this is done with present of Mercaptopropyltriethoxysilane (MPTES). The specific heavy metal detection was performed once the IDE nano device is surface modified, the detection. Repetitive detection was conducted to validate the sensor performance toward repeatability in detecting heavy metal arsenic[46-49].

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2. Methods

The nanostructure was prepared with clean booth for pattern transfer, this was followed by trimming and indentation using deep RIE coupled with oxidation furnace. Upon, trimming the structure, the devices were keep in cabinet at 70^0C, this is done in order to keep away from the humidity. This prciess was followed by the MPTES preparation and the Mercaptopropyltriethoxysilane (MPTES) of different concentrations were prepared and applied on to the Nano-IDE active domain of 0.5 x 0,5nm spotted. The Effect of each concentration was tested on selectivity and electrical response of the nanostructure. Five (5) concentrations were prepared with 1, 2, 3, 4, 5 moles. The Mercaptopropyltriethoxysilane (MPTES) 1, 2, 3, 4, and 5% were prepared by dilute it with ethanol coupled with citric acid, the citric acid was used to main the Ph level of solution. The reaction was monitored as the colour change gradually due to reaction from clear to milky white, creamy gelly was obtained. The prepared Mercaptopropyltriethoxysilane (MPTES) at 1, 2, 3, 4, and 5% deposited on the IDE active domain

3. Results and Discussion

The figure 1 show the MPTES and is found to be have change structure of $3OCH_3$, Si, HS , which allow integration structure with various non ion element and compounds. It have been proved by several with other such as TiO_2 were modified a surface of aligned TiO2 nanotubes by Cu2O nanoparticles to enhance the photo electrochemical properties and hydrogen generation application. They were synthesized a cuprous oxide (Cu2O) nanoparticles modified vertically oriented aligned titanium dioxide (TiO2) nanotube arrays through wet chemical treatment of TiO2 nanotubes and their multi-functional application as enhanced photo electrochemical and hydrogen generation. The photocatalytic performance and hydrogen generation of as synthesized Cu2O nanoparticles modified aligned TiO2 nanotube was found to highly depend on the Cu2O content. The optical characterizations reveal that the presence of Cu2O nanoparticles extends its absorption into the visible region which improves the photocurrent density in comparison to pristine aligned TiO2 nanotubes electrodes due to enhanced photoactivity and better charge separation. The optimum photocurrent density and hydrogen generation rate has been found to be 3.4 mA cm2 and 127.5 mmole cm2 h1 in 1 M Na2SO4 electrolyte solution under 1.5 AM solar irradiance of white light with illumination intensity of 100 mW cm2.

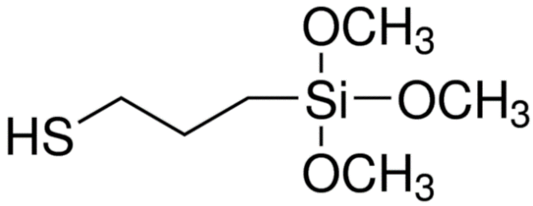

Figure 1. MPTES chemical structure

Researcher was proposed a fast, highly sensitive interdigitated capacitor sensor to detect wide range of temperatures using Graphene-Oxide-Containing dielectric membrane. The sensor proposed depend of capacitance changing when the IDE's temperature increase. The temperature-sensitive dielectric was prepared by the polymer mixture of Graphene oxide with polyvinylpyrrolidone as a detection solution. Then the solution was coated with the use of a spin coater on IDE. They claimed that the sensor has stable sensitivity over a broad temperature range, R2 it is correlation coefficient, also has a very good characteristic of reproduction, around 0.024 a relative standard deviation. They observed that the designed sensor has good performance and offer high sensitivity better than other sensors based on resistivity, the piezotronic effect, a graphene assisted microfiber, optical fiber wavelength shifting, a Sagnac loop using a long grating optical fiber, and an optical fiber probe. The IDE was used the responsivity of UV detectors based on selectively grown ZnO Nanorods. The IDE based on the metal–semiconductor–metal (MSM)-type ZnO nanorods was designed in a square form like a Wheatstone bridge in compact manner. The ZnO nanorods was prepared by method of hydrolysis with diameter of 20 to 70 nm. The device was made from a silicon wafer with its surface oxidized to SiO after it was coated a seed layer (ZnO) for the purpose of isolation detector from the silicon substrate and as the base ZnO nanorods for it vertical growth. After that, they arranged a square gold IDE by the photolithography. The recognition technique in that UV detector was by the nanonords surface linked with the absorption and desorption of oxygen molecules. The mechanism is absorption of oxygen with darkness phase. Moreover, several research communities designed gold nano-particle based Al interdigitated electrode electrical biosensor for specific ssDNA target detection. They was prepared a 'Al IDE' Aluminum Interdigitated Electrode biosensor with a gap of 1µm. the Al IDE was functionalized in the base on silanization by APTES, immobilized with amixture of Gold Nano particles (GNPs) and single stranded Listeria synthetic probe ssDNA with Au nano-particles and blocking with tween-20. The control of selectivity is electrically with change of current base variation of Listeria targets concentrations. the biosensor has the ability to detect concentrations between 10 fM and 10 µM. they claimed that The measured selectivity were confirmed the biosensor is adequate for detection specific target. Variations of current indicate variation of concentration of target Listeria probes that it is prove detection of Listeria bacteria in several concentration. The high sensibility of biosensor can detect up to µM concentration of targets it will have benefit for industrial rapid biosensor. Another group Designed and fabricated an Interdigitated Electrode (IDE) for detection of Ganoderma boninense, Thivina et al (2016) used a capacitive IDEs based on silicon as an electrochemical nanosensor for detection of Ganoderma boninense. They claimed that sensor have high level to detection of threshold and it can be varied by controlling the size of gap inter alia two microelectrodes. Tubia and his group (2018) produced a nonsensor used for Brettanomyces bruxellensis growth detection using interdigitated microelectrode-based sensors by means of impedance analysis. They present in their work a method of detection on base of analyzing the impedance spectroscopy by the use of sensor label-free interdigitated microelectrode (IDE) to detect spoiled yeast. To evaluate the behavior of the growth they tested many conditions (static and stirring) of Brettanomyces cultivation inside the reactors. The results shown a quick response and an increment by 8% with relation of modification the impedance by stirring situation sequentially of the superficial formation biofilm on the sensors. Under the condition dynamic the analyzation the circuit equivalent proven that the variation due to the larger formation biofilm as shown in figure 2.

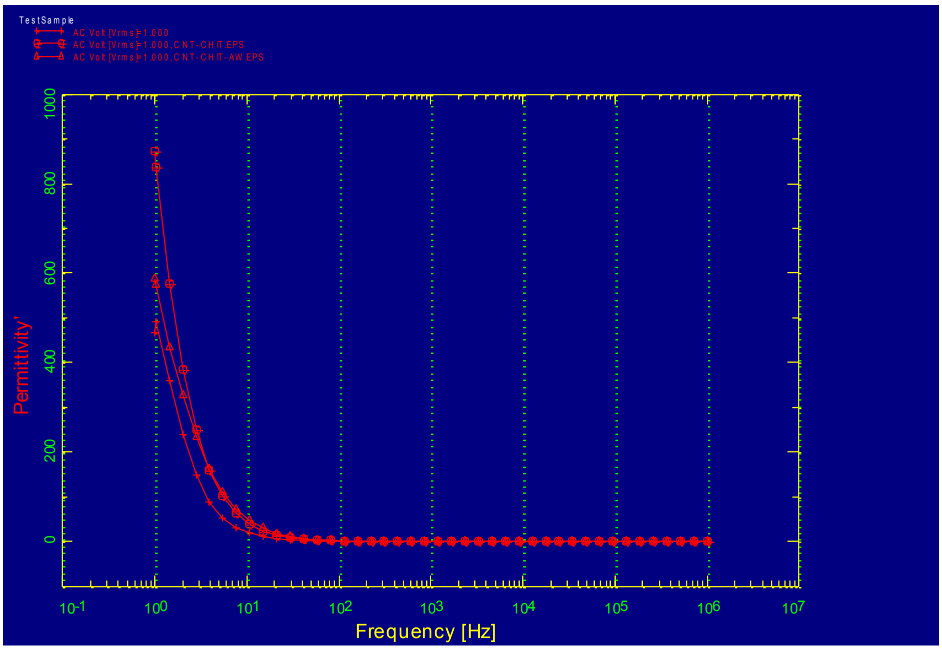

Figure 2. The device permittivity

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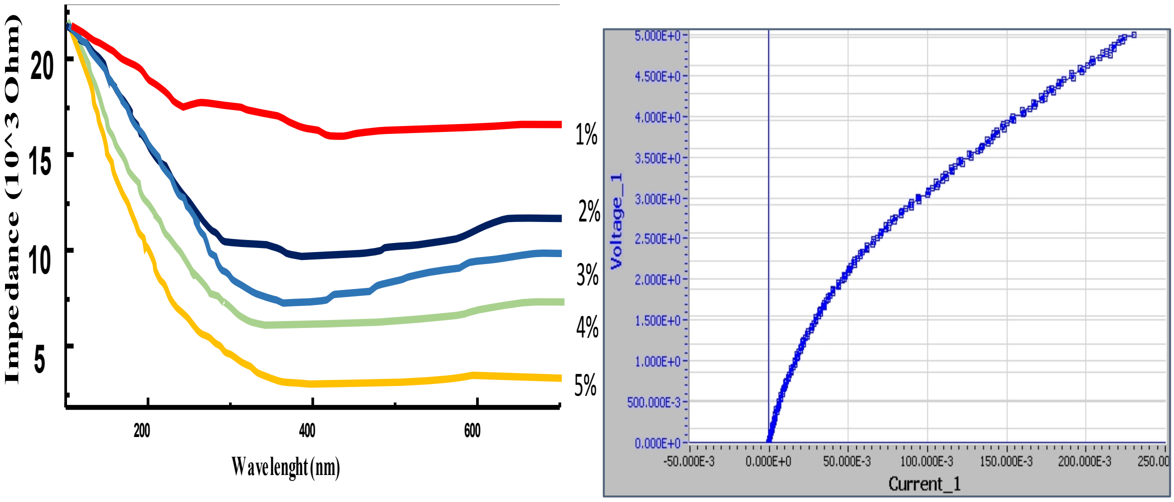

Figure 3. (a) The device impedance with the MPTES concentration (b) the individual fingers behaviour observed at onset of the modification

The figure 4a, show typical behaviour of the IDE, because, it can be seen that, the impedance is high when the at the lower wave length which is corresponding to the lower frequencies, in the other hand, the impedance tend drop as the wave length increase, this typical behaviour of capacitive reactive which influence. The figure 4b and b, show electrical conductivity increase with increasing at the onset of the surface modification which was attributed to the change of mobility within and at the surface of the device. This is indication for the finger behave like nanowires. Although, electrical conductivity depends on carrier concentrations which contributed as result of the surface modification, which enhanced on the carrier mobility. Thus, the electrical conductivity increase as mobility increase with the surface attenuation by the MPTES. Thus, this increase in concertation observed increase of the electrical conductivity with temperature increment, this is decrease of the Si–arsenic bond length, which caused the bandgap to be shortened.

4. conclusion

The study discussed the effect of the surface modification with surface modification by on Mercaptopropyltriethoxysilane (MPTES) done to enhance electrical behavior of nano-IDE -based sensor, silicon based active area was coated with MPTES. The electrical properties of modified nano-IDE were tested using impedance analyser by observing the changes in impedance with the frequencies There was increase as the concentration of the MPTES increase from 1 to 5%. The device show a typical capacitive reactive mode where the the impedance drop with frequencies. Thus, the study established that that nano-IDE behave like capacitive reactive model which easily demonstrate it performance which include sensitivity can be studied with refence to the capacitive model.

5. Acknowledgement

The author would like to acknowledge support from the Short-Term Grant under a grant number of 9001-00526, Universiti Malaysia Perlis (UniMAP).

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