Journal of Applied Sciences Research, 8(9): 4759-4769, 2012
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

A Review on the Label free Nanowire based Biosensor

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ABSTRACT

Advancement in nanotechnologies has encourage researchers to conduct studies related to nanowires formation. Studies regarding the types of nanowire based biosensors have been conducted and reported in this papers. Methods to synthesis or fabricated the nanowires such as silicon nanowires, zinc oxide nanowires and Titanium dioxide nanowire have been reported and describe in detail in this paper. Vapor-Liquid-Solid (VLS) mechanism, Vapor-Phase(VP) mechanism, sol-gel technologies, thermal annealing mechanism which contribute for nanowire formation or growth is reviewed. Further studies to improve the methodology in synthesizing the nanowires which improve better performance is conducted. Application of the nanowire for biosensor and surface functionalization procedure for detecting biological compound such as DNA and protein is studied. Various method is applied to functionalize the fabricated nanowire for detecting complex biological compound which is applicable in medical fields. This paper have reviewed the types of material is used as the base in nanowire synthesis.

Key words: Nanowires, sensors, surface functionalization, DNA, protein, biosensors,VLS mechanism, VS mechanism, thermal annealing, nanotechnology.

Introductions

Sensors are devices which the main task is to detect the present of any stimulus in the external environment and generates an output signal simultaneously. Sensor consist of two main component that is the active sensing materials with a signal transducer. The performances rate of the sensors is depends on the size and the developing structure of the devices. Development of nanotechnology has contribute a wide production of sensors in nanoscale. Researcher in these recent years are more interested in manufacturing the sensors which is associated with nanostructure. Sensor development in nanostructure responds a high demand due to its sensitivity and portable characteristic. Sensor consist of two major type that is electrochemical sensor and biosensor. Biosensor has become a major interest with the development of nanotechnology. Biosensor is a device which able to detect inorganic components such as uric acid, protein, DNA, pH, temperature and etc. Biosensor sensor is very applicable in fields ranging from clinical diagnosis to homeland securities. Major interest of development biosensor is for medical field. One of the pioneers application of biosensor is the detection of glucose level in the blood volume. The blood glucose biosensor was developed by Leland C. Clark in 1962. The main purpose of this biosensor development is to detect the presents of glucose level in the blood and aware the diabetes patients about their current health situation. The examples of nanostructures based biosensors are nanogap, nanobelts, nanoparticles, nanowire, nanorods and etc. These nanostructures acts as transducer which generates electrical signal when it interfaces with an inorganic material or analyst.

2. Types of Biosensors:

According to the transducer used, the biosensors can be classified as optical (measurement of luminescence, fluorescence and elipsiometria), resonance (relates the oscillation frequency of piezo electric crystals with a variation of the mass), magnetic, piezoelectric, thermal and electro chemical (potentiometric, amperometric and conductivity). In other words, biosensor is classified based on types of tranducer used.

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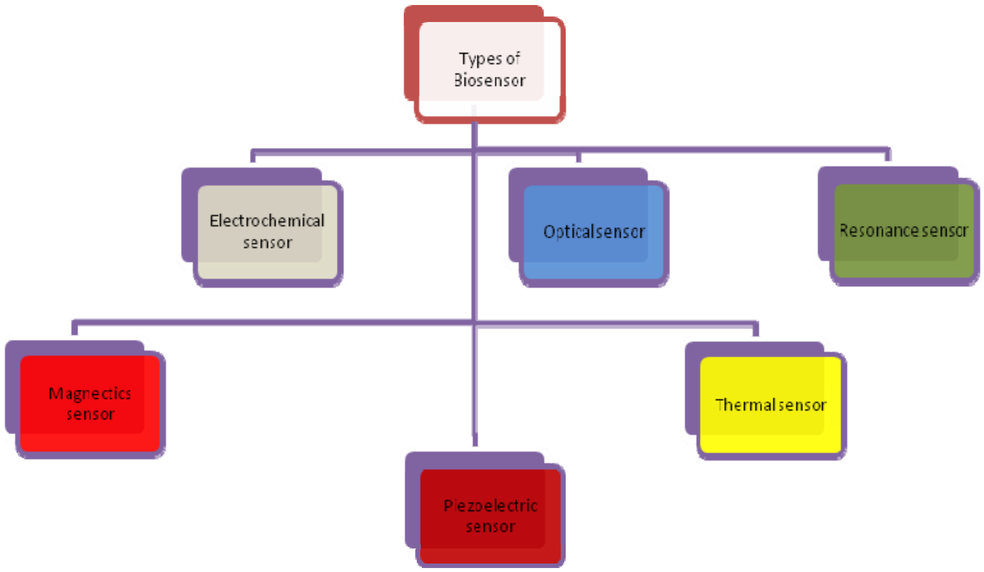


Fig. 1: List of types of biosensor.

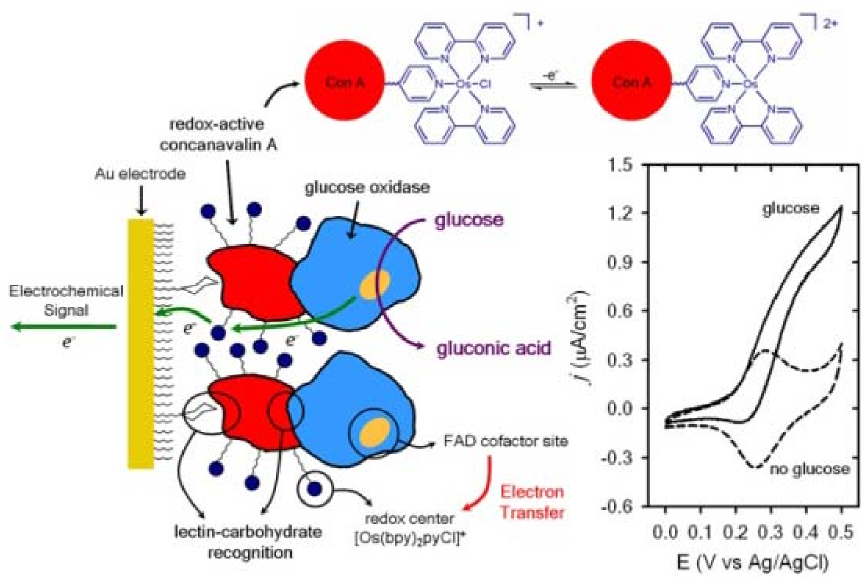


Fig. 2.1: Functional biointerfaces and electrochemical sensor. (Devi, R.,)

2.1 Electrochemical Biosensor:

The most common biosensor is electrochemical biosensor. Electrochemical biosensors are related on enzymatic catalysis of a reaction that produces or consumes electrons (such enzymes are rightly called redox enzymes) (Devi, R.; Han, H., 2008). The sensor substrate are associated with three electrodes; a reference electrode, a working electrode and a counter electrode. The target analyte is involved in the reaction that takes place on the active electrode surface, and the reaction may cause either electron transfer across the double layer (producing a current) or can contribute to the double layer potential (producing a voltage). We can either measure the current (rate of flow of electrons is now proportional to the analyte concentration) at a fixed potential or the potential can be measured at zero current (this gives a logarithmic response). Note that potential of the working or active electrode is space charge sensitive and this is often used. Further, the label-free and direct electrical detection of small peptides and proteins is possible by their intrinsic charges using bio functionalized ion-sensitive field-effect transistors.

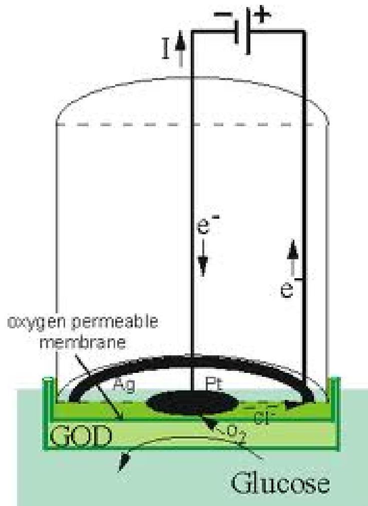


Fig. 3: Amperometric biosensor. (LÃ³pez, M. S. n.-P., 2006).

Amperometric device is also known as a type of a electrochemical biosensor. The working mechanism of amperometric device is measuring the current resulting of oxidation and reduction of an electro-active species of a biochemical reaction. A mathematical modeling of a sandwich type of biosensor is prepared (LÃ³pez, M. S. n.-P., 2006; Tsai, H.-c. 2005). The model considers that the enzyme reacts according to a ping-pong mechanism and that it is entrapped into a so-called enzymatic matrix placed between two diffusion membranes.

Amperometric devices can be very applicable in medical fields. Amperometric device is able to detect the glucose level in the blood. One of the example is the amperometric glucose biosensor based on polymerized ionic liquid micro particles (LÃ³pez, M. S. n.-P., 2006). The present of glucose is detected by immobilizing the glucose oxidase in microparticles. The glucose oxidase is prepared by polymerization of the ionic liquid 1-vinyl-3-ethyl-imidazolium bromide (ViEtIm+Br−).

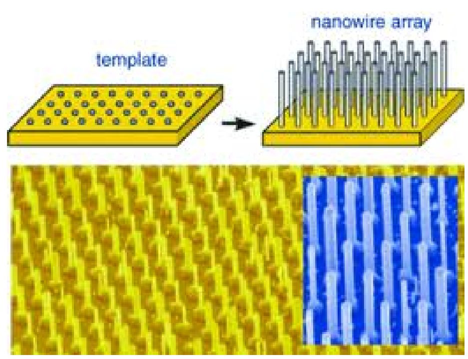


Fig. 4:

3. Nanowire biosensors:

Studies relates to fabrication and characterization of nanowire have given great contribution in bio-sensing development. Nanowire will acts sensing electrode and generates electrical signals. Fabrication of nanowire structure has become very essential in biosensor due to its sensitivity and selectivity. It is able to detect any small changes due to its nano scale in size. There are various material used for nanowire fabrication. Other material for nanowire structure formation is Zinc Oxide (ZnO), titanium Oxide (TiO_2), nickel (Ni), platinum(pt) and gold nanowires (Au) nanowire. Each material has its own unique characterisitcs in terms of electrical and physical characteristics. The most common material used as nanowire structure is the silicon nanowire. The nanowires could be used, in the near future, to link tiny components into extremely small circuits. Using nanotechnology, such components could be created out of chemical compounds. Nanowire commonly manifest a high ratio of length-to-width with around 1000 and above . Nanowires are referred as 1-Dimensions structure which is associated with quantum properties due to it scale size. Nanowire can be applicable in future technology in medical fields.

3.1 Method of nanowire synthesis:

Various method in growing and synthesis nanowire have been done. The synthesis method of nanowire is used depending on the material that will used as nanowire structure. The essential factors that need to be considered in synthesizing the nanowires is that the dimensions, properties and the morphology should be able to be controlled. Quasi one dimension nanostructure is developed by many methods. Spontaneous growth and template-based are known as the bottom-up approaches for nanowire synthesis and lithography is the top-bottom technique for the 1-dimension nanowire synthesis.

3.1.1 Silicon nanowire synthesis:

One of the most common method used for nanowire synthesis is the VLS (Vapor-Liquid-Solid) method. Silicon nanowire is synthesized by using VLS mechanism by using conventional chemical vapor deposition furnace (Wang, Z. L., *et al*.,). Silicon nanowire was developed by using Au catalyst on the Si (111) substrate. Direction growth of Silicon nanowire is perpendicular which the size and the dimension is controlled.

Silicon nanowire is developed by using Au nanoparticles associated with pure silane precursor gas. The nanowire were grown by using high frequency plasma enhanced chemical vapor deposition via a vapor-solid-solid mechanism (Hamidinezhad, H., *et al.*,). High frequency enhanced plasma was able to synthesis an excellent quality with higher length of nanowires. This methods also able to grow the nanowire in lower temperature compare with other common growing method. The involvement in various frequency for this PECVD method was able to lower the temperature level for the nanowire growth process. This mechanism is know as VHF-PECVD via VLS mechanism. Nanoneedles have become an attraction nanostructure by many researchers. Nanoneedles will be used as the building blocks for the development of nanotechnologies. Nanoneedles is also been synthesized by using the VHF-PECVD mechanism (Hamidinezhad, H.,).

Silicon nanowires has unique electrical, mechanical and optical properties which can be applicable in the development of micro-electro-mechanical system. Unfortunately, the synthesis of the nanowire requires are high temperature which can cause defect or damage the pre-existing of microelectronics. Alternative method is used for silicon nanowire synthesis. The approach is based on localized resistive heating of microstructures in room temperatures (Englander, O., 2003). Localized resistive heating method will activate the silicon nanowire growth process through the VLS growth mechanism.

A new facile method is introduced in silicon nanowire synthesis. Facile method have attracted many researchers as it is inexpensive, and uses low toxicity material. Hence, it offers a safe, high energy efficiently (Pattison, J. W., 2009). In facile method, a known duo-chamber vessel is applied for vapor-liquid-solid mechanism. The advantages of using the duo-chamber vessel is that it requires low flammability phenylsilanes which does not require the use of silane for silicon nanowire growth.

3.1.2 Zinc Oxide nanowire synthesis:

Studies on Zinc Oxide nanowire have became an attractive subject by many researchers in the nanotechnologies development. Zinc Oxide material has its own unique physical and optical characteristic. Zinc Oxide material has wide band gap approximately 3.37eV, a large exciton binding energy of 60 meV, and an exciton Bohr radius range of 1.4 – 3.5 nm (Alison Goodsell, 2007). Zinc Oxide is applicable in medical fields due to its bio-degradable, bio-compatible and bio- safe characteristic. Therefore, Zinc oxide material is widely used as biosensing material in biosensor fabrication. Studies on synthesizing zinc oxide nanowire is essential as the performances and the structural properties of ZnO nanowire is optimized. The method used for developing or growing the Zinc Oxide nanowire is depends on the application of the nanowire.

One of the most common method used in Zinc Oxide nanowire growth is through VLS(Vapor-liquid-solid) mechanism. Although VLS is the most convenient method, it has some negative aspect such as it requires high temperature for the growing process. Therefore, studies has been reviewed on VLS mechanism to alter the steps to improve the VLS method for Zinc Oxide nanowire growth.

Zinc oxide nanowire is developed for protein detection by using Vapor-phase (V-P) method (Jin, L., 2007). Working principal of Zinc Oxide nanowire is by incubating the IgG(Immunoglobulin) on the surface of the zinc oxide nanowire. Vapor-phase method is used to developed Zinc Oxide nanowire associated with high temperature. Therefore, an improve method for V-P mechanism is studied and reviewed.

Studies regarding the parameters that involve in VLS (Vapor-liquid-solid) mechanism for Zinc Oxide nanowire growth is conducted to optimist the VLS mechanism. Flow time of Argon gas which is also a parameter for VLS mechanism is investigated (Yang, J., 2008). It is resulted that the most suitable period time of Argon gas flow is 90s. The Zinc Oxide nanowire is exhibited at hexagonal shape after 90s of Argon gas flow during the VLS growing process.

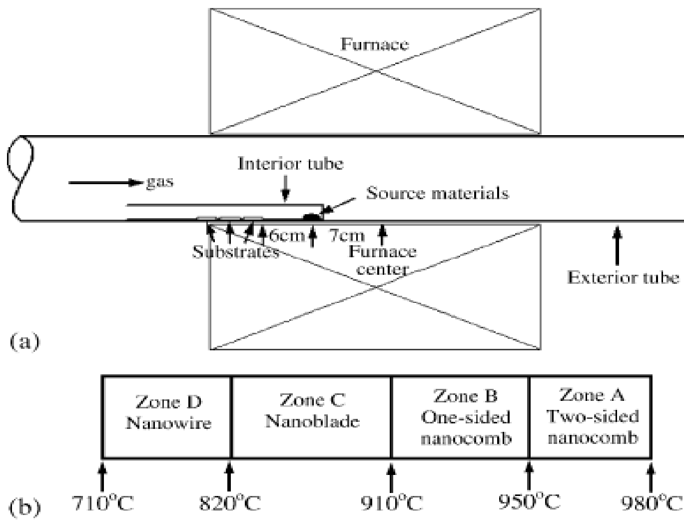


Fig. 5: (Hsueh, T.-J., 2007).

Zinc Oxide nanowire based CO gas sensor was synthesis by self-catalyst Vapor-liquid-solid mechanism (Hsueh, T.-J., 2007). No catalyst is required in this method. Double-tube vapor-phase transport method was used to synthesis Zinc Oxide nanowire to reduce the temperature for the growing process (Chen, Y.X., 2005). Double-tube vapor method also able to synthesis other nanostructures in zinc oxide such as nanoblades, one-sided nanocomb and two-sided nanocomb. These nanostrucutres are synthesized by elevated temperature. Nanowires are synthesized in temperature ranging from 710^0C-820^0C.

Development of sol-gel technologies has contributed the synthesis process for Zinc Oxide nanostructures. Nanowire of Zinc Oxide can be produced by using the sol-gel method. Zinc Oxide nanowire is grown hydrothermally through aluminum doped zinc oxide thin films (AZOthin film). AZO thin films acts as seed layer for the Zinc Oxide nanowire synthesis in hydrothermal method.

Pulsed laser deposition method is applied in zinc oxide nanowire synthesis. Zinc Oxide nanowire was growth by with Au coated (0001) substrates by using pulsed Nd:YAG laser (Son, H.J., K.A. Jeon, *et al*., 2007). Advantages of using pulsed laser deposition method is that the 1-dimension of nanowire can be development in the desired position. The size and the length of the nanowire can also be controlled. Length and diameter of zinc Oxide growth is depended to the distance between the target and substrate in the furnace.

Zinc Oxide nanowire have excellent electron mobility which is used for dye-sensitized solar cells. Facile hydrothermal method is the suitable method for synthesizing zinc oxide nanowire for solar cell application. Zinc oxide nanowire are developed by using chemical route method. Chemical route method is able to produce zinc oxide nanowires for photovoltaic application. Main purpose of using chemical route method is to synthesis nanosphere compound on the Zinc oxide nanowire. Nanospheres compounds is essential to be deposited on between the nanowires as it increases the light scateering and enhanced the photon absorption. Hence, the nanowires can perform well as photovoltaic application.

3.1.3 Titanium oxide (TiO_2) nanowire synthesis:

Quasi one dimension of Titanium dioxide (TiO_2) nanowire has attracted many researches due to its unique properties which is largely applicable in dye sensitized solar cell (Joanni, E., 2007). Indium-tin oxide nanowires was coated with titanium dioxide. The purpose to coat indium-tin oxide with titanium dioxide is to establish a conductive pathway. The next purpose to coat titanium dioxide is to reduce the electron-hole recombination to enhanced the electron mobility and improve the performances of the dye sensitized solar cell. Titanium dioxide also plays an important role in generating hydrogen energy by using Titanium dioxide anodes for water splitting.

Titanium dioxide (TiO_2) nanowires was developed by using thermal evaporation method. In thermal evaporation mechanism, titanium monoxide powder was used as a precursor (Shang, Z. G.,). Titanium dioxide nanowire which is synthesized by using thermal evaporation method is able to produce a confine nanowire which is free from contamination. Hence, thermal evaporation mechanism is a much more reliable method as it is able to produce the nanowire which can be applicable and able to integrate with modern silicon based semiconductor industry. The following advantages of using thermal evaporation method is that it does not require to used any catalyst such as Ni or Au catalyst which may reduce the performances of the Titanium dioxide nanowire. Therefore, thermal evaporation method is able to grow a pure titanium dioxide nanowire.

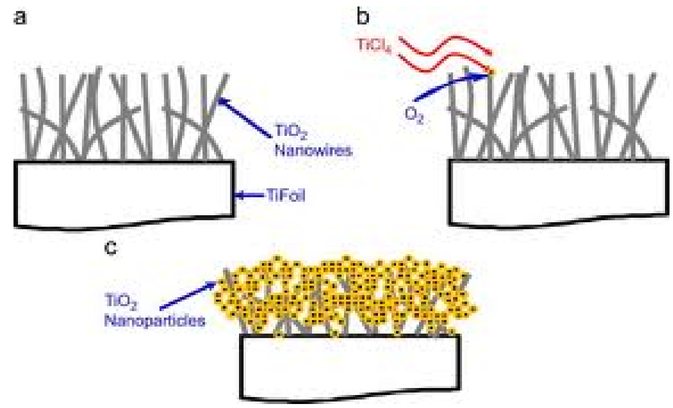


Fig. 6: TiO_2 nanowire was grown to capture $TiCl_4$ gas. (Hu, A.,).

Titanium dioxide nanowires can be applied as photocatalytic degradation for removal of organic pollutants (X. Zhang, 2009). Hydrothermal growth method is used to synthesis the free standing of titanium dioxide nanowire membranes for photo catalytic degradation of pharmaceuticals. In hydrothermal method, the titanium nanowire membrane was grow by using titanium substrate associated with various organic oxidizing agents. Hydrothermal growth mechanism able to synthesis high performance TiO2 nanowire membranes with millimeter level thickness for an evaluation of their application for microfiltration and photo catalytic degradation of several common PPCP contaminants.

Another method of synthesizing titanium dioxide nanowire for dye sensitized solar cell is by using solvothermal route. Titanium dioxide nanowires are growth vertically by using solvothermal route without template assist. Titanium dioxide nanowire has unique ability to constraint the movement of proton and electron in uni-direction. Solvothermal synthesis method is the most suitable and attractable method used by researchers to produces titanium dioxide nanowires because it is simple process, fast reaction velocity and the cost is low. Therefore, a large quantity of titanium dioxide nanowire can be produced in a small period of time. Studies related to solvothermal synthesis need to be reviewed because higher temperature and longer period of time is required to synthesis the single titanium dioxide nanowires. Further improvement is expected by fabricating titanium arrays compromise of thin nanowires separating apart from each other.

Thermal annealing method is known as the common method to synthesized titanium dioxide nanowires. Thermal annealing method is also able to develop other titanium dioxide nanostructures. Crystalline titanium nanowire is growth by heating titanium foils at temperature 850^0C. The titanium dioxides nanowire is able to transport electron charges without grain boundaries and junctions. The thermal annealing mechanisms is able to synthesis tree-like hetero-structure titanium dioxides nanowires which produces an excellent charge transport and avoid charge recombination. The advantages of using thermal annealing method for sythesizing titanium dioxide is that it does not required a complicated process route for the growing mechanism. It is a simple method to grow the nanowires.

A conventional method is used to synthesized anatase titanium nanowire which is known as microwave heating method. Microwave heating method is used to modify and convert the titanium dioxide nanoparticles to anatase titanium dioxide nanowires(Li, L., X. Qin, *et al*.,). Microwave heating method was given the first priority compare to other methods in synthesizing titanium dioxide nanowire. Microwave heating method is non-complex and effective process because it only requires the usage of P25 TiO_2 nanoparticles as the precursor. Microwave method also able to developed fined nanowires with small diameters which is suitable for photovoltaic device applications.

Most simple method for developing titanium dioxides nanowire is through using typical nano-synthesis. The nanowires which is fabricated from nano-synthesis method is used for formation of hydrophobic polymer matrices (Haroun, A. A. and A. M. Youssef 1920). Titanium dioxide nanowire were used to prepare hybrid PMMA nano-composite in presence of silver nitrate and/or polyaniline. Titanium dioxides nanowires has increased the conductivity of PMMA nanocomposites.

Hydrothermal method also able to synthesis ultrafine titanium dioxide nanowires. Initially, sodium titanium nanowires were prepared in a low concentration sodium hydroxide solution with the assistance of ethylene glycol (EG). They were then converted to anatase titanium dioxide nanowires through acid washing and postannealing. The advantages of this method is that it does not require high concentration of alkaline solution. The lower the usage of alkaline solution concentration, finer titanium nanowires can be synthesized because as the concentration of alkaline solution is reduced, the length of the nanowire synthesized is much more smaller and thinner.

Sol-electrophoretic deposition process has able to synthesis titanium dioxide nanorods. Titanium dioxide nanowires which is synthesized through sol-electrophoretic process contains a high morphological profiles. The growing mechanisms of titanium dioxides through sol-electrophoretic is that the nanostructure is grown from dilute aqueous solution with low concentration approximately 0.1 M.

Titanium oxide nanowire and nanorods have been fabricated by using template free oxidation of titanium in hydrogen peroxide solutions. Synthesizing titanium dioxide nanorods and nanowires through template free method has more advantages compare to other common growing method. The formation of the nanostructures through template free method has optimum electron mobility and the method is much more cheaper and less time consuming. Morphologically, Titanium dioxide nanowire and nanorods has grown in uniform orientation through this template free method associated with hydrogen peroxide solutions.

Photocatalytic activity of titanium dioxide nanowire is improves by synthesizing the titanium dioxide nanowire associated with SrO core shells nnaowire arrays. The main purpose of the development of SrO core shells in titanium dioxide nanowire is to improve the photovoltaic performances and enhanced the performances of the photocatalyst. SrO core shell also plays an important roles to increase the photo generated electron/holes separation efficiency.

3.2 Electrical characterization of nanowire:

Advancement in nanotechnologies has introduced the fabrication and development of nanowires. Research in developing and fabrication of nanowires have become a great interest among researchers due to its unique electrical characteristic. One of the most essential characteristic is that nanowires should able to transport electrical and have a good electrical conduction. As for example, the nanowires, should able to act as transducer and generate electrical signals when there is interface with the stimulus. Structure of nanowires which is in nano scale have high sensitivity and can generate different signals according to the types and concentration of the particles. Therefore, various studies have been reviewed to improve the performances of the nanowires. Examples of the most common nanowires are silicon nanowire, Zinc Oxide nanowires, Titanium dioxide nanowires, Au nanowires, copper oxide nanowire and etc. Each of this nanowires has its own electrical characteristic which is suitable for certain applications.

Zinc Oxide nanowire is been developed through FIB method. The electrical resistances of the Zinc Oxide nanowire is been observed. The resistance value of the nanowire is in the range of 0.2-04 ohm cm (Yoon, S.W., *et al*., 2009). The electrical characteristic of the Zinc Oxide nanowire which is manufactured by FIB methos is enhanced by increasing the Rapid Transmission Annealing (RTA) temperature. As the RTA temperature increases, the resistances of the Zinc Oxide nanowire is decreases and the charge mobility of the nanowire have improved drastically. With increasing the RTA temperature, Pt nanoparticles grew up with sintering, the contents of carbon were reduced, and Au was diffused into the Pt junction. These micro structural changes resulted in the enhancement of the conductivity.

Single SnO_2 nanowires was fabricated for odor detection. The electrical characterization of SnO_2 was investigated in a vacuum, low-pressure oxygen environment which is associated with synthetic air mixed with various analytes (Sysoev, V.V., *et al*.,). The development of nanowire is in nanoscale which have an excellent electrical sensitivity which can detects and differentiate variety of gas content in the air by generating electrical signals. Resistance of SnO_2 nanowire exhibit different value when it interface with different reducing agents at low concentration.

Hence, each type of gas will exhibit different electrical signals. Hence, the SnO_2 nanowire have good electrical selectivity characteristic.

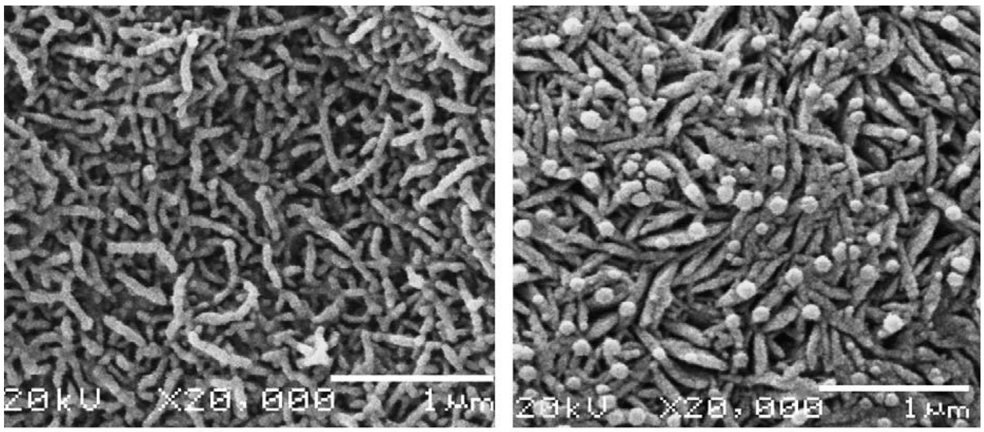
Silicon nanowire for field-effect transistor was fabricated by using conventional CMOS processes. The width of the nanowires of silicon which is fabricated by using CMOS process is almost similar. With similar width dimension nanowire, the silicon nanowire FET can behave as surface channel device. The electron mobility of silicon nanowire FET is increased by using conventional split-CV method. In conclusion, there are other more reliable method to fabricate the silicon nanowire FET to increase the electron mobility because the electron mobility have slightly degraded at elevated temperature.

Nano-manipulation method was used to fabricate Zinc oxide nanowire for field effect transistor. The electrical characteristic of the field effect transistor was examined by using a semiconductor characterization system.

3.3 Morphological characterization of nanowire:

Studies related to morphological characterization have been conducted to improve the performances of the nanowire. Nanowire wires can perform in excellent rate as a sensing material or transducer if the nanowire's morphological characteristic is in optimum level. One of the most essential aspect for a nanowire is that the surface roughness and the surface topology of a substrate should be in uniform. Therefore the growing process of the nanowire on the template can be achieved in excellent rate without any disturbance.

As for example, $BaTiO_3$ nanowire have been synthesis by sol gel and microwave method (Fu, C., 2009). Shape and structure of the nanowire is observed by using atomic force microscopy. From the AFM test, it is observed that the structure of the nanowire is tetragonal perovskite structure. As the annealing process increases the length and the size of $BaTiO_3$ is degrading. Hence, to synthesis $BaTiO_3$ nanowire, timing for annealing process should be reduced.



(a) (b)

Fig. 3.3: SEM images of MnO2 fabricated using AAO template A (a) and template B (b).

MnO_2 nanowires was developed through sol-gel templates (Wang, X., *et al*., 2005). XRD test was conducted to investigate the morphological characteristic of the MnO_2 nanowires. The structural of MnO_2 nanowires is alpha-MnO_2 polymorph which it can behave as electrode for super capacitors application.

4. Application of nanowire biosensor:

General requirement for a biosensor is label-free, sensitive and selective characteristic. The sensitive and selectivity characteristic of a biosensor is defined in term as the sensor is able to detect slight changes in the stimulus and it is also able to generate signal for specific analytics. Hence, development of antigen-antibody sensor is used for producing biosensor which has increased selectivity characteristic. Silicon nanowire was synthesized for rapid detection of dengue virus. The device was selective to detect dengue by conducting surface functionalization on the silicon nanowire.

4.1 DNA biosensor detection:

Many researchers have enhanced and develop further studies on nanowires development which will behave as biosensors to detect certain DNA. Studies related to surface modification on the structural nanowires is reviewed to develop nano-biosensors for DNA detection. Silicon nanowire was surface modified by interfacing with gold nano particles to increase the sensitivity of the nanowire for label-free DNA detection. Gold nanoparticles which is embedded with silicon nanowire immobilize probe oligonucleotides. The target oligonucleotides will be complement with the probe oligonucleotides as generates signals to detect breat cancer. The complement process can be improved by doping low concentration of silicon nanowire. SiNW-based biosensors have been highlighted due to their high scalability, reliability, mass-producibility, and possibility of on-chip integration through highly matured semiconductor technology.

Silicon nanowire which is fabricated by top down approach is used for DNA sensing application. The performances of the silicon nanowire based biosensor is consider excellent because it provides a pathway to immunological assays, DNA forensics and toxin detection in modern biotechnology.

4.2 Protein biosensor detection:

Advancement in nanotechnology have attract researchers from forensic and bio-technology department to development electronic nano devices to detect the presents of protein. From various studies and review on nanostructure characteristic, nanowire was the most suitable nanostructure to perform as transducer in the formation of biosensor. Single nano polyaniline nanowire biosensnor was developed to detect immunoglobulin(IgG) and myoglobin. The nanowire was functionalized with monoclonal antibodies (mAbs) of IgG or Myo via a surface immobilization method, using 1-ethyl-3-(3-dimethyaminopropyl) carbodiimide (EDC), and N-hydroxysuccinimde (NHS). Various method of surface functionalization process is further reviewed to enlarge to scope for detecting various biological particles which is much more finer and smaller in scale by using the nanowires.

5. Conclusion:

Methods of synthesizing nanowires have been reported in this paper. Methods to improve the methodology in fabricating the nanowire for certain application is reviewed in detailed. The application for certain nanowire with different material such as silicon nanowire, zinc oxide nanowire and titanium dioxide nanowire have been discussed. Comparison among the methods to develop the nanowires such as vapor-phase method, VLS mechanism, thermal annealing and etc is reviewed and stated in detail in this paper.

Acknowledgement

I am absolutely grateful to my main supervisor Prof Dr Uda bin Hashim, Director of Institute of Nano Electronics Engineering(INEE), UNIMAP to motivate and guide to complete the review paper. Special thanks to UNIMAP portal to gain excess to view conferences and technical papers in IEEE, Sensors and ELSEVIER as references for completion of this papers.

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