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Nanobiosensors: applications in biomedical technology

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Abstract

Biosensor devices are composed of bioreceptor, transducer and detector that detect and aid in measuring parameters of some primary metabolites, immunological molecules and many more materials. These devices are of various types including piezoelectric which exhibit high efficiency based on sensitivity, response time, selectivity and linearity. Currently, newly developed nanobiosensors help in transduction and are employed to sense biomolecules bearing high sensitivity. Nanobiosensors also could be homogeneous or heterogeneous in nature and equally function in sensing mechanism of the biosensing technology. Thus, different nanobiosensors are greatly utilized to reduce poison in products, disease diagnostics and in many biomedical applications. Based on all these factors and the positive impact of using these devices; nanobiosensor types, applications, challenges and preferred solution in biomedical technology were considered and discussed in this work.

Keywords: Nanobiosensor, fabrication, challenges, application, biomedical technology

1. Introduction

Biosensor consists of three essential components such as transducer, bioreceptor and detector, which is used to detect some primary metabolites, immunological molecules and many more materials as shown in Figure 1 [1, 2]. The biosensor acts as a tool for the production of a form of signal from a biological response [1]. The two major high points of this device are the successful merging of biological and electronic components to generate signal during any analysis for utmost performance and the ability of the bioreceptor to remain stable in a non-biological environment. Biosensors are presented in different types because of their transduction and



biological recognition elements such as piezoelectric [3] and potentiometric for transduction, and antibodies, organelles and enzymes for biorecognition element [1, 4, 5]. Also, the characters of the biosensor required for its high efficiency may include sensitivity, response time, selectivity and linearity as highlighted in Table 1 [6].

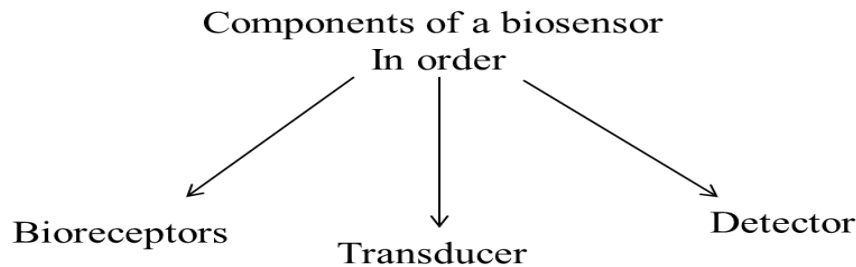


Figure 1. The basic components of a biosensor

Table 1. Characteristics of biosensor and their descriptions [6]

S/N	Characteristics	Description
1	Sensitivity	Electrode response per substrate concentration value
2	Response time	Time taken for about 95% response to be obtained
3	Selectivity	Proper reduction of chemicals interference is necessary
4	Linearity	Aid in high substrate concentration detection

The production of the premier oxygen biosensor by Lel and Clark in 1960s paved better opportunities for the development of many biosensors in Medicine, Biomedical Engineering and Technology (BMET) and Nanotechnology (NT) applications. Therefore, these devices pose potential benefits in fields of BMET, Medicine, Tissue Engineering (TE) and NT to enhance healthcare delivery and preserve human lives [7]. Specifically, some biosensors are applied in checking blood glucose level [8, 9] and *in vivo* studies, to detect disease-specific biomarkers. At cellular level, a biosensor of micro or nanoscale is required and the biosensors with nano-dimensions including nanowires and nanotubes have been introduced and produced for proper efficient diagnostic and Biosensing matters. This device may detect the pH level or other factors

[10]. Chan and Nie [11] and Tomasulo *et al.* [12] reported that “nanocantilevers had been employed to check the amount of serum protein markers and identify the parts of the specific DNA moieties”. A typical example of nanodevices, quantum dot is a unique nanocrystal that had been and could still be used to identify particular DNA or protein [13]. This is applied in an area of specialization termed as “nanotechnology”.

Nanotechnology is broadly referred to as the multidisciplinary study area that applies science, engineering and technology to efficiently manipulate and also manufacture materials and instruments on nanoscale ranging from 1 to 100 nm [14, 15]. It encompasses several technologies from various educational sectors including medicine, electronics, biomaterials, chemical engineering and biotechnology to synthesize well deserved materials for mankind. Advancement in this fast developing field has resulted to the introduction of biosensors at nanoscale for drug target, discovery and delivery, and many more biomedical applications bearing dynamic properties. Other application areas include the environment where nanotechnology is used to manufacture products for cleaning up environmental pollution. Most recently, biosensors best known to analyse the tiniest of biological interactions at an insignificant scale and with high precision, versatility and sensitivity have been reported [16, 2, 17]. A typical example is the nanobiosensor synthesized from the synergy of nanotechnology and biosensors.

A nanotechnology structured biosensor, consisting of a nanomaterial ranging from 1 to 100 nm becomes so unique, bearing several atomic constituents with are placed in or near the surface and have the important physical, chemical and physicochemical properties much more different from the same materials at the bulk level. Nanobiosensors may be homogeneous or heterogeneous in nature and they equally act in sensing mechanism of the biosensing technology [2, 18]. The former occurs in solution without a phase separation and later concentrates on a solid material such as capture material embedded with a chosen receptor including antigen that aids in the identification and capture of the analyte (antibody) to be detected.

A combination of electrical systems and the devices of the nanomaterials generate nanoelectromechanical system (NEMS) that are so active in the event of electrical transduction [2]. Most electronic and mechanical properties of some nanomaterials including nanotubes, nanorods, nanowires, nanoparticles and thin films consisting of crystalline matter are well known and utilized in improving transduction mechanisms and biological signalling [2]. Nanoparticles amongst other nanomaterials are well studied and analysed up to this moment. This review

focuses on nanobiosensor types, applications, challenges and preferred solution in Biomedical Technology.

2. Types of nanobiosensors

Nanobiosensors are grouped into different types with great considerations on the nanomaterials and biosensing operation. These nanomaterials possess properties that enhance the sensing mechanism. They include nanotubes-based sensors, nanoparticles-based biosensors, nanowire-based sensors, quantum dots-based sensors among others [2].

2.1. Nanotube-based sensors

Nanotube-based sensors (NTBSs) are a type of nanobiosensors with carbon nanotubes to improve the specificity of reaction. The NTBSs aid in monitoring glucose and detecting biomolecules. The development of glucose biosensors was concentrated on the utilization of nanotubes as immobilizing surfaces specifically for glucose oxidase which apparently quantifies glucose present in different bodily fluids including tears and saliva. Carbon nanotubes (CNTs) also known as hollow cylindrical tubes are sensing materials present in nanoelectromechanical sensors (NEMS) and are hollow cylinders-like that are produced in the rolled graphite sheet [19]. Its carbon atoms arrangement in the graphene sheet may be chiral, armchair or zigzag [20]. The different chirality, graphene wall number and tube diameter are points to consider for CNT conductivity [20, 21]. According to Bareket-Keren and Hanein [20], ‘They have special structures, are chemically inert, electrically and mechanically stable and have high tensile strength, high thermal conductivity, high surface to volume ratio and great electrocatalytic activity’[6]. Their structures are also special in their form.

The CNTs are produced using more than two (2) dynamic techniques including chemical vapour deposition (CVD). The later method most times yields CNTs in mass production and then purified for avoidance of structural damage and elimination of unwanted metals required as catalysts as CNT are produced [22]. The CNTs concentrate on monitoring glucose in urine and blood. They are clearly applied in material science and optoelectronics with unique properties including physical geometry, mechanical strength, asbestos-like characteristics and physicomechanical properties [2]. In recent past, CNTs have been extensively used in tissue engineering, biosensors, molecules as well as drug delivery and for diagnostics [6]. Based on the

number of layers of the concentric graphite covered by a type of hemispheres known as fullerene, CNTs are categorized into two namely; single walled CNTs (SWCNTs) and multi walled CNTs (MWCNTs).

The SWCNTs are single objects between 0.4-2.5 nm in diameter and lengths usually up to a few millimeters, whereas MWCNTs are usually SWCNTs arranged in a coaxial manner, 2-100 nm in diameter and lengths ranging from 1-100 μm or more [20]. In addition, SWCNTs are sometimes metallic or semiconducting with MWCNTs bearing the metallic behavior [22]. Based on all these qualities, SWCNT and MWCNT have greatly been considered in developing biosensors for utmost functionality and output. Single walled (CNT) has been well known for enzymatic detection of glucose and its increment in enzymatic activity [23] and are also largely applied for recording and simulating neuronal activity [20]. Figures 2 and 3 depict the typical structures of SWCNT and MWCNT.

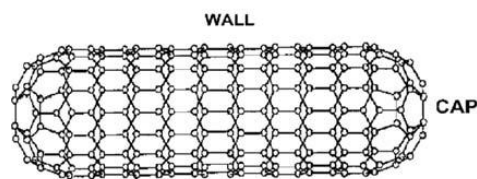


Figure 2. SWCNT structure displaying cap

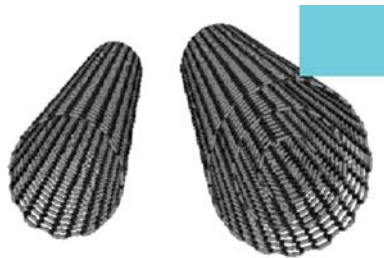


Figure 3. SWCNT and MWCNT structures and wall [6] with a difference [24]

2.1.1. CNTs in Biomedical Applications

More advances have been made in both fields of CNT-based technology and Biomedical Engineering Technology (BMET), where CNTs perform as biomaterials in the production of bionanosensors, vaccine and drug delivery vehicles, scaffolds, smart materials and biomolecule nano self-assembly carriers in an emerging and sophisticated subfield of BMET termed as Tissue Engineering (TE) (Figures 4-7). The CNTs help in some tissues' growth and proliferation [25], but have deficient solubility in aqueous media [22]. This deficiency can be corrected by increasing the chemical functional groups to parts of CNTs wall, including the tips [22]. According to Shi *et al.* [26], "CNTs are suitable materials for the synthesis of scaffolds in reproduction of bones bearing basic properties such as biocompatibility, biodegradability, cell proliferation and adhesion, absorption and many others".

A typical example is the ligation of the CNTs and a biomaterial, collagen which yielded high mechanical properties obtained from CNTs, thereby replacing the lost features of the already produced scaffolds [27, 22, 28-30]. Another example is the output realized from the ligation of CNTs and synthetic polymers resulting in a material so biocompatible for regeneration of tissues. Furthermore, the use of MWCNT and poly (L-lactide) together yielded high crystallization, direct-current conductivity and many other properties as studied by Zhang and colleagues [31] and electrospun nanocomposite scaffolds (ENSs) were produced from the encapsulation of MWCNTs in poly (lactic acid) (PLA) nanofibers by McCullen and partners [32]. The ENSs had fewer diameters and more conductivity than PLA only. Therefore, conductivity greatly seen as a physical property became more present as CNTs were added.

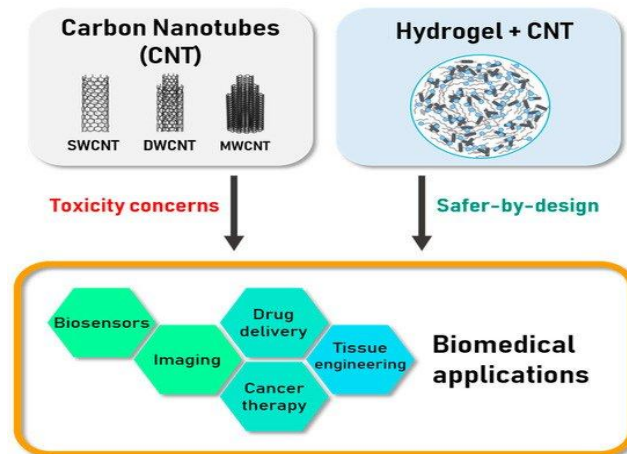


Figure 4. A schematic diagram displaying the application of CNT in biomedical engineering and technology [33]

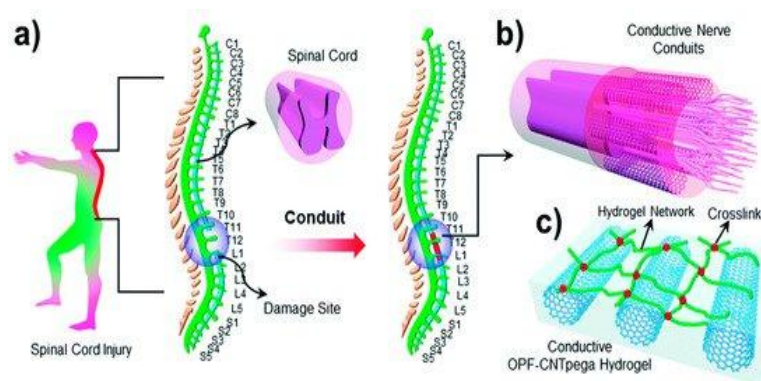


Figure 5. (a) A schematic representation of the human spinal cord. (b) Conductive nerve conduits for the treatment of spinal cord injury (c) Conductive oligo (poly (ethylene glycol) fumarate) (OPF)-CNT pega hydrogel construct [33]

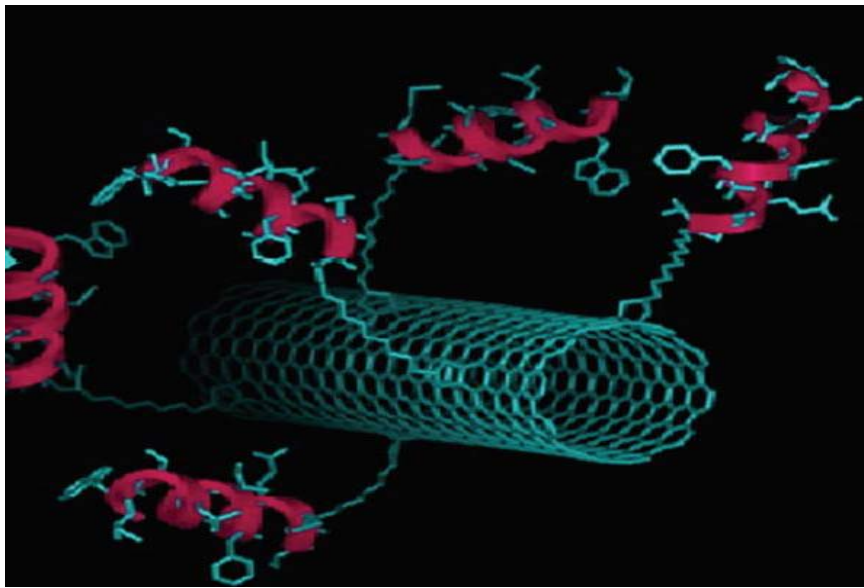


Figure 6. A pictorial diagram of drug loaded carbon nanotubes [24]

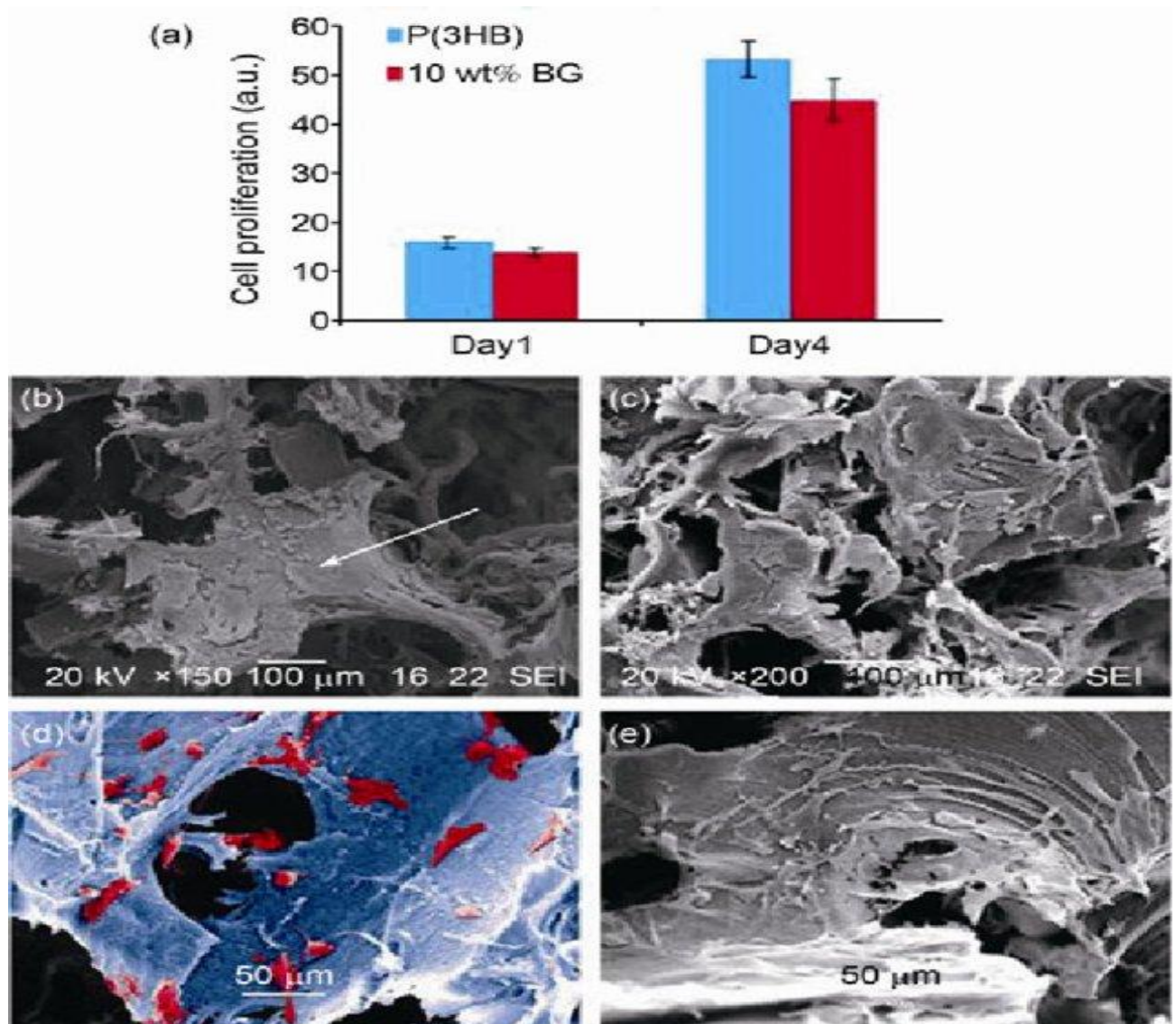


Figure 7. One CNT-based tissue engineering scaffold (a) cell proliferation for P(3HB) and P(3HB)/m-BG composite scaffolds on the first and fourth days (b) P(3HB) foams (c) P(3HB)/m-BG foams, (d) P(3HB) foams displaying the surrounding cells and bridging the pores and, (e) P(3HB)/m-BG foams having the properties of the cells to bridge the pores and also to consume the substrate contours [34]

2.2. Nanowire-based sensors (NWBSs)

Nanowire-based sensors are nanobiosensing devices specially made up of nanowires or fibres at nanoscopic scale covered by many macromolecules (bionanowires) including fibrin proteins and

DNA molecules [35]. According to Touhami [17], ‘A bionanowire resembles one dimensional (1D) fibril like nanomade structure bearing diameter ranging from 1 nm to tens of nanometers and appreciable length’. Based on the uniquely modified properties, nanowires become independently analyte. They may be applied in biomedical engineering, medicine, bionanotechnology, life sciences and other disciplines. Devices containing nanowires are best used for optical excitation, electrons transport and carriers, means to find species, including biological and chemical ones (proteins, viruses or drug molecules) through ultrasensitive and direct electrical methods [36]. The thin nature of the nanowires remains a major factor for developing the remote nanobiosensors to study the environment and also in-body sensing [17].

Nanowires, nanobelts and others are best used for biosensing research because of the special properties and ability to be made into high density nanoscale instruments. Nanowires also help in electron transport and excitation of optics. Based on these factors, they are involved in nanoscale device integration and performance. The NWBSs in Figure 8 bear special range of properties including semiconduction, metallic, biocompatibility, insulation and high surface to volume ratio [37, 38, 39], which enables the materials to function better. Also, the attached material supports nanowire detection of biomolecules while employing working mechanism in Figure 9. Nanotechnology methods applied in developing NWBSs effectively aid in the conversion of biological and chemical sources into signals electronically or digitally in Figure 9 [37]. For instance, nanowires were used to check for antibodies (proteins) in Figure 10.

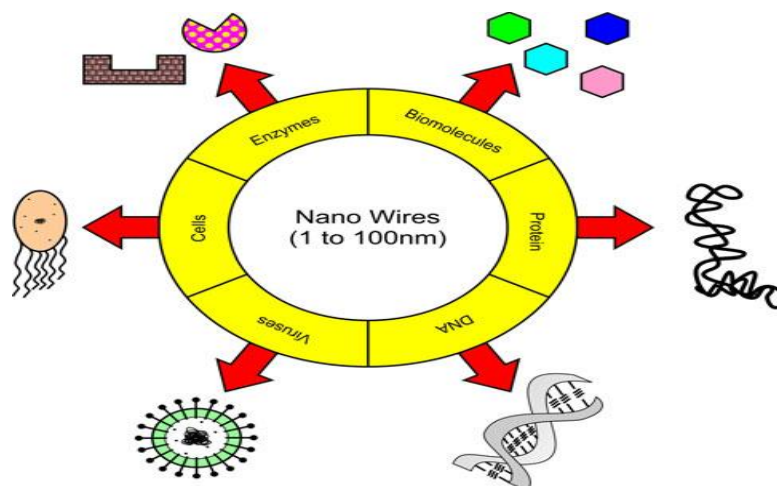


Figure 8. NWBSs required to check biomolecules [37]

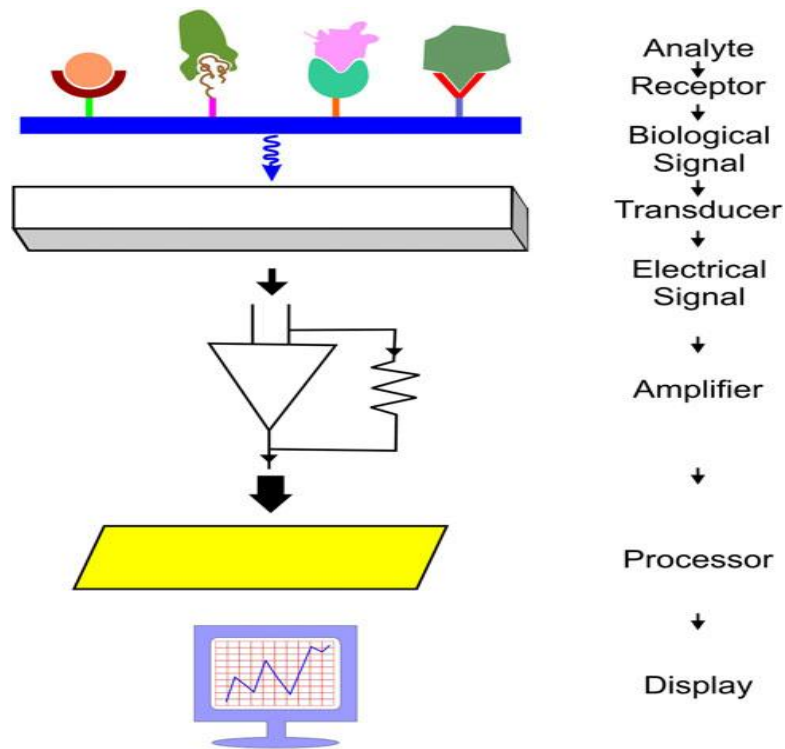


Figure 9. Detection of nanowire working procedure in a descending order [37]

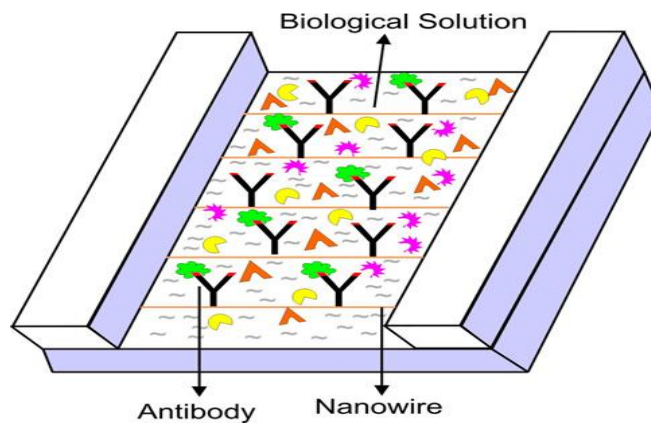


Figure 10. Nanowires used to identify antibodies. The antibody (Y) was glued to the nanowire in orange colour and the active sites in red colour ligate to the molecule in green colour due to specificity [37]

2.3. Quantum dots nanobased sensors (QDNSs)

Quantum dots (QDs) are types of nanoparticles that are inorganic fluorescent semiconductor in nature and are made up of 9 or more to less than 51 atoms bearing a diameter between 3-9 nm [40,41]. There is a size and a particular shape controlling ability that help some important features. They hardly degrade or alter in any form but apparently functions in terms of light imaging in human systems [40]. The QDs are said to be useful vehicles popularly used for delivering genes for prevention of any harm that could affect the cell membrane [24]. They can also be used as self-trafficking transfection tool for Multiple Drug Resistant (ABCB1) siRNA [42] and as radio sensitizers or near-infrared (NIR) optical imaging devices for viewing and treatment of cancer and other tumours [24]. Sequence variations including point mutation, deletions and single nucleotide substitutions can act as point of identification in diagnosis of cancer. The QDNSs have widely been used to diagnose point mutation when it comes in synergy with oligonucleotide ligation reaction assay (OLA) as reported by some researchers [43, 44]. For instance, the quantum dot based mutation detection assay has gracefully been employed to diagnose two types of point mutation (Kras and Braf) in victims having a special type of tumor [43, 44].

Semiconductor quantum dots have been considered to be extensively used as the beginning tools for the synthesis of good sensitive, simple, selective and rapid growing biosensors for macromolecules (DNA, proteins and RNA) and human cells detection. These nanobiosensors possess various dynamic optical and electronic properties including distinctive photo electrochemical features, broad absorption spectrum and others [45]. Unfortunately, they are quite toxic in nature when applied in the presence of deadly heavy metals harmful to human. Therefore, it is of utmost importance to run toxicity and many other tests before they are made available for human application [24].

3. Biosensor/bioelectrode materials/materials for nanobiosensors

Several materials are considered suitable for the production of nanobiosensors. The biosensing materials should be biocompatible, affordable, and reproducible for them to be developed in large quantity. Most of the recently produced materials exhibit and enhance the stability, sensitivity, mechanical and chemical strength of the sensor for any practical application [46].

These include but are not limited to carbon based materials (graphene-based materials, carbon nanotubes and carbon nanoparticles) in Figure 11, polymers (conductive and insulating) in Figures 12 and 13, hybrids in Figure 14, and organic and inorganic nanomaterials including magnetic and metal nanoparticles. The characteristics of conducting polymeric nanobiosensors (CPNBSs) such as morphology, size, shape and many others determine their activities and CPNBSs are widely used in biomedical, food, agricultural, nuclear and nuclear applications. For instance, cationic polymers are deemed worthy to be used as a tool for non-viral vectors for delivering genes because of their unique properties including flexibility and facile synthesis in Figure 15. When in contact with macromolecules such as DNA through electrostatic force attraction at physiological pH, there tends to be quick gene delivery and their molecular weight, structure and other aspects are well needed for the efficiency of gene transfection. Some examples of the polymers used in this process are poly (L-ornithine), poly (amidoamine) dendrimers and poly (L-lysine) as synthetic and dextran, chitosan and gelatin as natural ones [47].

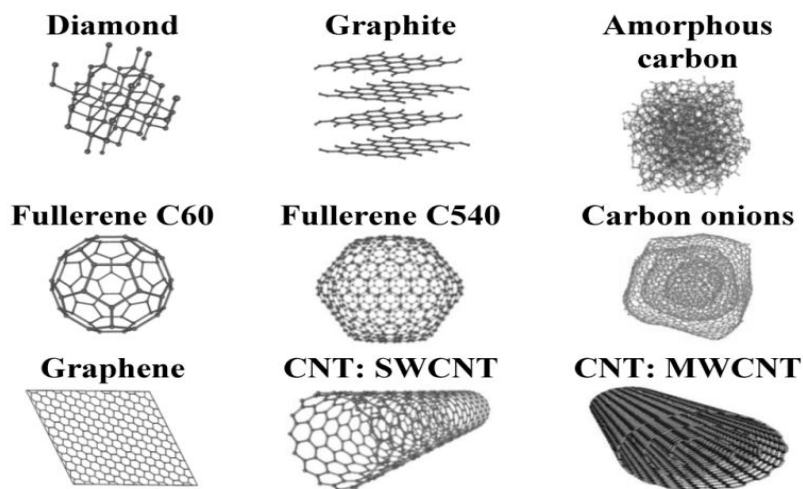


Figure 11. Carbon based nanomaterials [48]

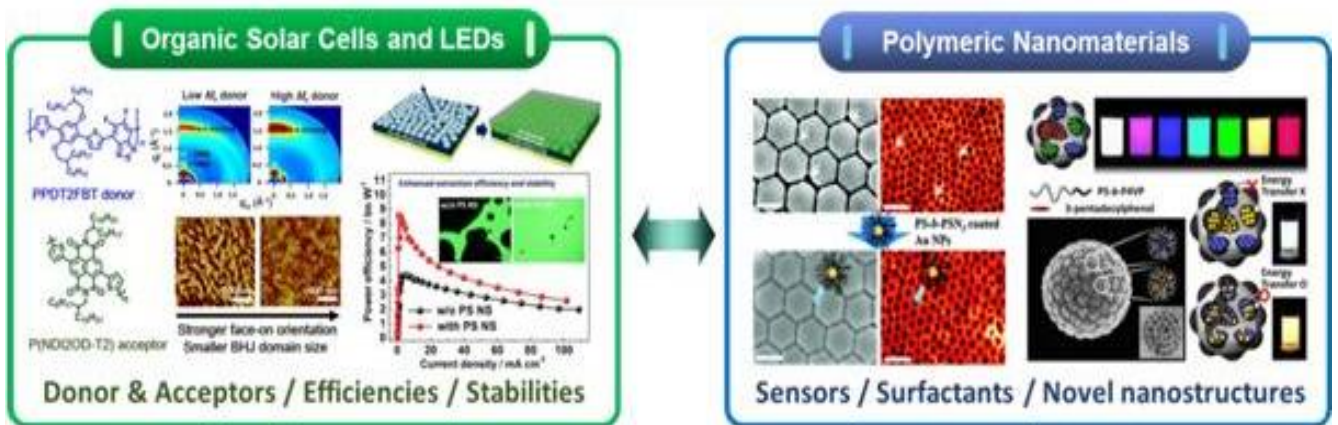


Figure 12. Polymer based nanomaterials [49]

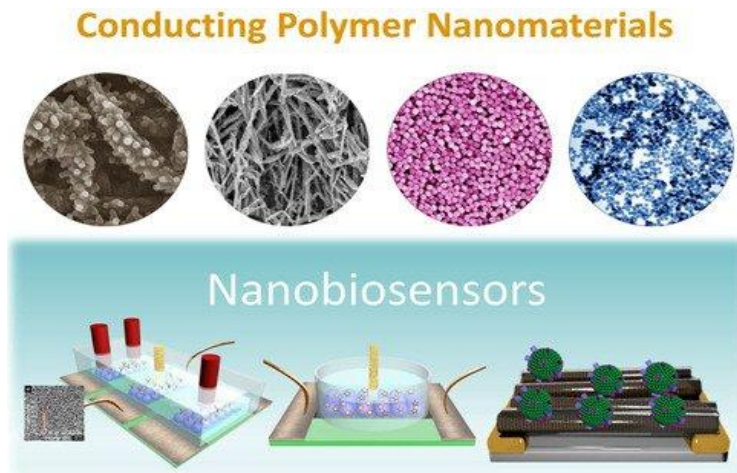


Figure 13. Conducting polymeric nanomaterials [50]

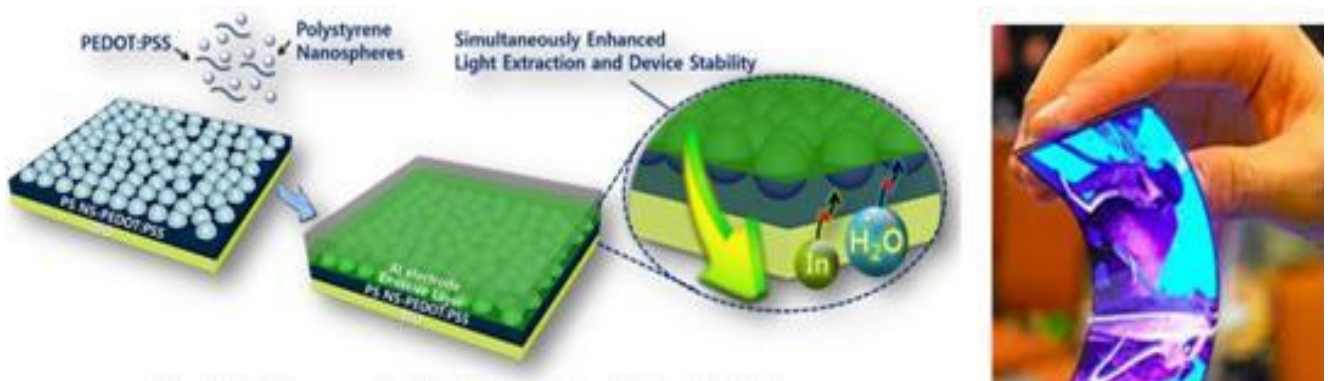


Figure 14. Hybrid nanoparticles with much efficiency and stability [49]

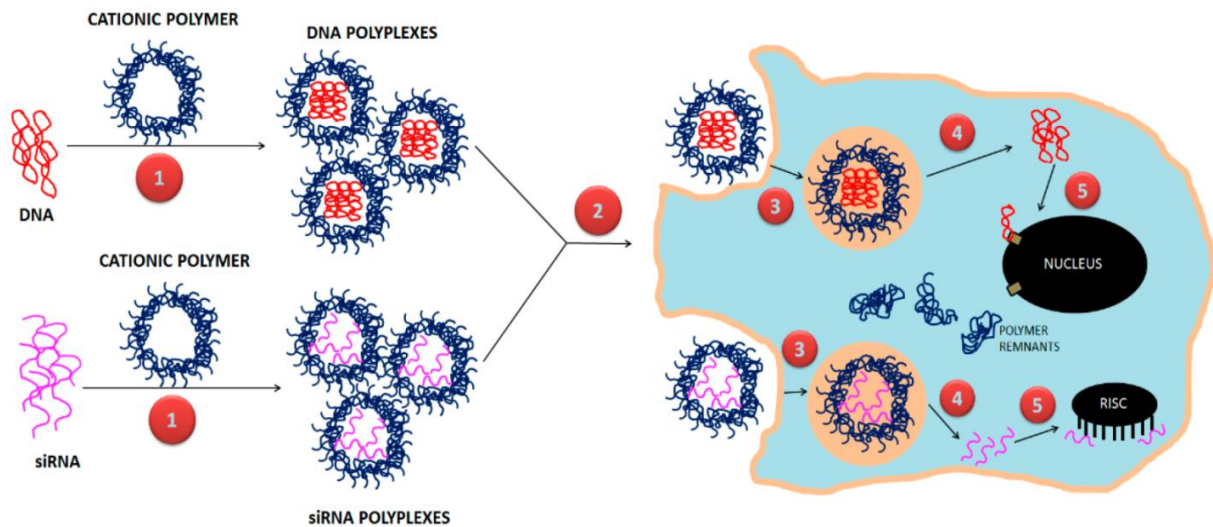


Figure 15. The intracellular delivery of DNA and siRNA using polymeric nanoparticles; A) The cationic polymers and anionic DNA and siRNA in a complex situation to form polyplexes; B) The cells absorb the polyplexes through several endocytic routes C) Proper releasing of polyplexes from some endo-lysosomal areas; D) Removal of DNA and siRNA from polyplexes and keeping behind polymer material; E) DNA transfer to nucleus for expression by a type of protein and ligation of siRNA by RNA-induced silencing complex [47]

4. Design and optimization of nanobiosensors

The use of nanobiosensors for detection of biomaterials, biological and chemical products (such as drugs, cholesterol, enzymes, blood glucose, RNA, DNA, protein to mention a few) involves transformation of chemical or biological response to electrical signal. This indicates concentration or composition, pH, rheological properties, energy, polarization, amplitude, decay time, and many more based on sensitivity and stability within a shortest time or seconds [6, 51, 52]. Silver, gold, platinum, and palladium nanoparticles are used in design and fabrication of biosensors because of their versatile specific behaviours. The design of nanobiosensors is in line with the chart presented in Figure 16. It requires: (1) recognition element that can identify biological and chemical products; (2) suitable and sensitive materials called transducers that sense information from recognition element from those products and transmit signals including wavelength, wave propagation, time and distribution of the spectrum. The transducers may be solid articles, ceramics, metals, glasses or plastics that transform substrate into measurable

signals like electrochemical, piezoelectric, thermal, opto-electronic and mass type; (3) contact surface technique or binding specificity and transducer contact surface probe which should be governed by thin film model; (4) detector for transfer of electrical signal from transducer to amplifier typed microprocessor for a specific task.

The optimization parameters include the sensitivity and dynamic range of concentration, quantity of the substrate or sensory materials, pH, temperature, sensing time and wave phase, rheological parameters and many more [53, 54]. In glucose nanobiosensor design as reported by Ridhuan *et al.* [54], the optimization was also based on selectivity as a feature of high performance, which can be influenced by reaction and measurement of substrate, specificity, effectiveness and cost implication. ZnO is a good electrode used to fabricate electrochemical glucose biosensors. It possesses high isoelectric point (IEP) with large surface area which makes it an effective and reliable surface for immobilisation of Glucose oxidase (GOx) enzyme because of its biocompatibility and other unique properties like low toxicity, high degree of electron mobility and easy to construct at low cost. ZnO nanorods grow on a seeded substrate by hydrothermal method which make them useful to modify electrode to detect glucose level. Sol-gel technique is used to produce seeded substrates in which ITO (indium tin oxide) substrates is coated by seed layer. This method is simple, economical, effective and suitable for producing a high-quality ZnO seed layer for growing nanostructures by the above mentioned method. The use of ITO glass substrate is attributed to low cost and resistivity compared with gold (Au) and carbon glass electrodes and electron mediator.

GOx immobilisation step increased the reliability and performance of glucose detection. In transcription factor (TF) based nanobiosensor, sensory proteins that regulate the physiology of cell gene expression are known as transcription factors, which have been reported to be used for sensing antibiotics, amino acids, vitamins, succinate, sugars, butanol, triacetic acid lactone and malonyl-CoA by Liu *et al.* [53]. The ChnR was controlled by constitutive promoter called *Acinetobacter* sp. Chnb promoter (Pb) with reduction in metabolic burden of replicated and produced plasmid by low copy number of plasmid.

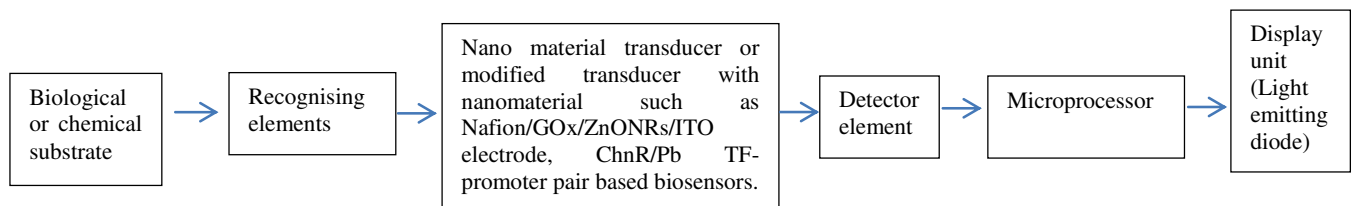


Figure 16. Design flow chart of nanobiosensors

The developmental procedures usually focus on the principle and application of the sensing devices including printing techniques for many purposes [52], heat and pull method, and chemical etching for optical nanobiosensors [17]. The use of printing techniques may be attributed to high resolution, large-area devices, roll-to-roll compatibility, energy utilization, temperature requirement, stress and impact on substrate or biomolecules, crystallization, carrier mobility fastness efficiency and damage to the substrate which are needed for design and optimization of non-biosensors development [55, 56]. Printing techniques employ image carrying medium (ICM) that stores information based on deposition of substrate or analyte from recognition element to be printed in ink and show on display unit. Printing techniques are of two (2) classes: Convectional or master technique uses screen printing technology, and non-impact printing technology which operates on drop-on-demand mode [48].

4.1 Heat and pull method

Heat pulling devices like laser-based micropipette puller are usually employed to fabricate nanobiosensor where in an optical fibre is placed in the micropipette puller and heated by carbon VI oxide (CO_2) laser. The fibre is stretched along tension axis in Figure 17. When optical fibre is pulled, tapering of heated region occurred and the fibre pulled into two, each tapered optical fibre have one large end and one end with nanometer dimensions. It was reported that temperature varies with applied tension for pulling process with change in tip diameters of fibre of a range of less than 20 nm and greater than 1000 nm [2, 51] which was determined by scanning electron microscopy (SEM).

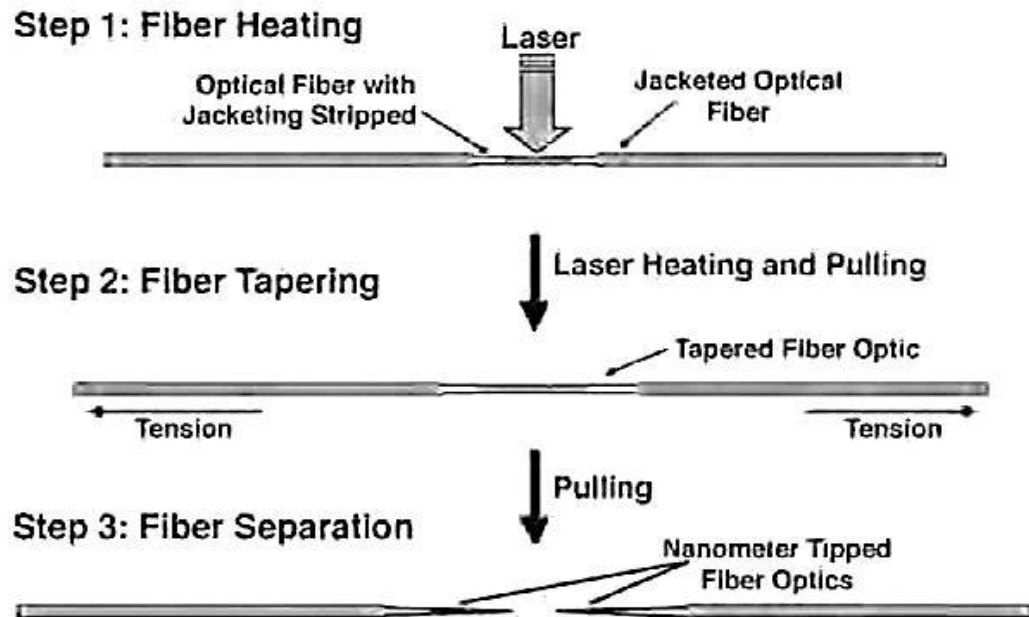


Figure 17. Cartoon depicting the heated pulling process used for nanofiber fabrication [31]

4.2 Chemical etching

This is of two types, namely; Turner etching and tube etching [6]. Hydrofluoric acid (HF) is used in chemical etching process for removal of silica core of an optical fibre into a smooth tip at a large taper angle after removal of polymer cladding. In the Turner method, the fibre is placed in the meniscus between HF and an organic over layer, causing the HF to etch the silica and the organic layer formed to protect it. This process creates fibres with larger taper angles than those produced via the heated pulling method. These larger taper angles allow excitation light to travel closer to the edge of the fibre before being trapped, providing a better excitation process.

5. Application of nanobiosensors to biomedical technology

Nanobiosensors, small and smart technology are widely used in broad fields of biomedical technology such as tissue engineering, 3D printing, biotechnology, biomaterials, sport, medical technology and many more. They are employed for several purposes including diagnosing, preventing, clinical testing, treating, monitoring of human diseases as illustrated in Figures 18-20

[57, 58]. A typical example is the transistor-based biosensor bearing nanowire characteristics and protein-nanoparticles biosensors aimed at detecting the ultra sensitivity of DNA and proteins respectively without performing PCR or curing with bisulfite in the case of DNA. These sensors may further serve to check plant diseases and some unparallel issues associated with biomarkers and lack of minerals. Also, the SPR biosensors plays a significant role in vitamin analysis, while other types could check for the availability and efficiency of antibiotics and then, immunobiosensors with other factors find a particular type of *E. coli*.

According to Cavalcanti *et al.* [59], 'Nanorobot sensor device (NRSD) has potential in medicine. These medical NRSDs are produced to solve the common inconvenient procedure of collecting blood samples from diabetic patients to manage and control glucose level by activating the proteomic-based result to check the biochemical alterations related to hyperglycemia'. The outer part of NRSD contains carbon metal nanocomposites with properties including hardness and atomic smoothness [58]. The NRSD with radiofrequency identification device (RFID) CMOS transponder machine help *in vivo* positioning. The NRSD decreases the patients lost time from hyperglycemia mishap and also give a unique medical attention and type of medication of the client [58].

Localized surface plasmon resonance (LSPR) nanobiosensor, an optical type, has a potential of carrying out prototypical immunoassay on biotin (B) and anti-biotin (AB). Rai *et al.* [58] reported that 'this type of sensor checks for any form of difference in local refractive index (LRI) by proper monitoring of the sensor extinction maximum and UV-visible spectroscopy. According to Nagrath *et al.* [60], a microfluidic nanobiosensor could be designed and fabricated to identify and isolate peripheral blood tumor cells in most cancer patients. Also, an optical fiber nanobiosensor (OFNBS) was developed for cancer marker check-up, telomerase at the level of one cell having a nanoscale tip [61]. Some other nanobiosensors are produced to detect harmful bacteria, its metabolic work and its reproduction in an antibiotic environment. A typical example is the superparamagnetic iron oxide nanoparticles which have been applied in the diagnosis of *Mycobacterium avium* spp. *paratuberculosis* (MAP) via magnetic resting [62]. In a nutshell, these nanobiosensors are applied extensively in monitoring glucose, sense pH, identify asthma, DNA, proteins or microorganisms, diagnose cancer, and facilitate drug delivery [63].

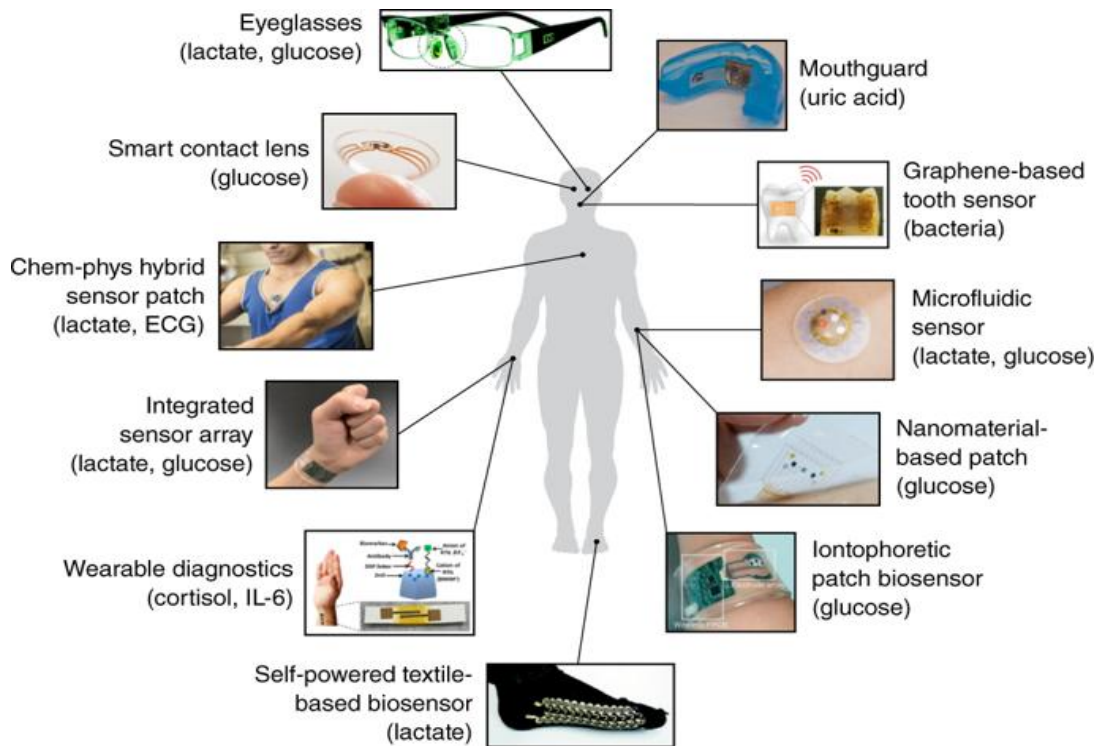


Figure 18. Utilization of nanobiosensors in biomedical technology [64]

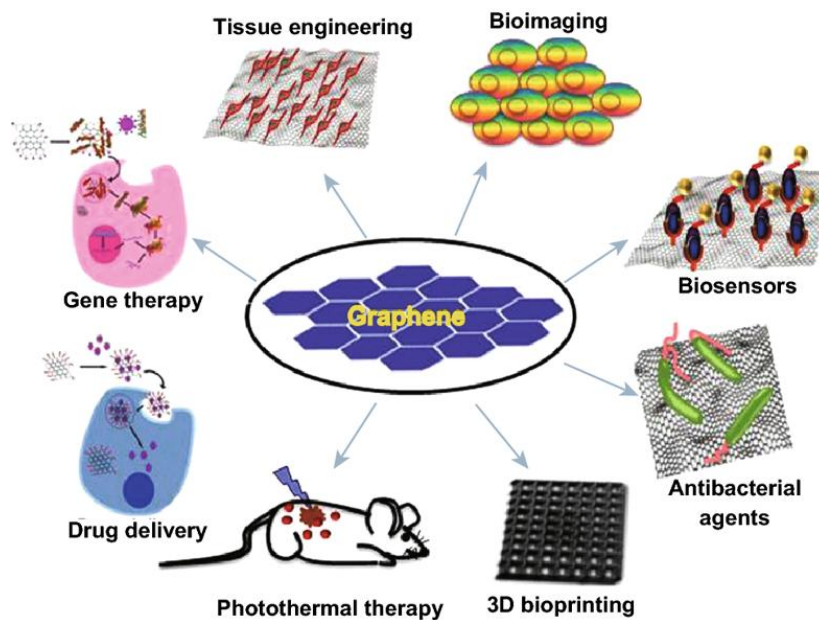


Figure 19. The application of graphene in different subdisciplines of biomedical technology [65]

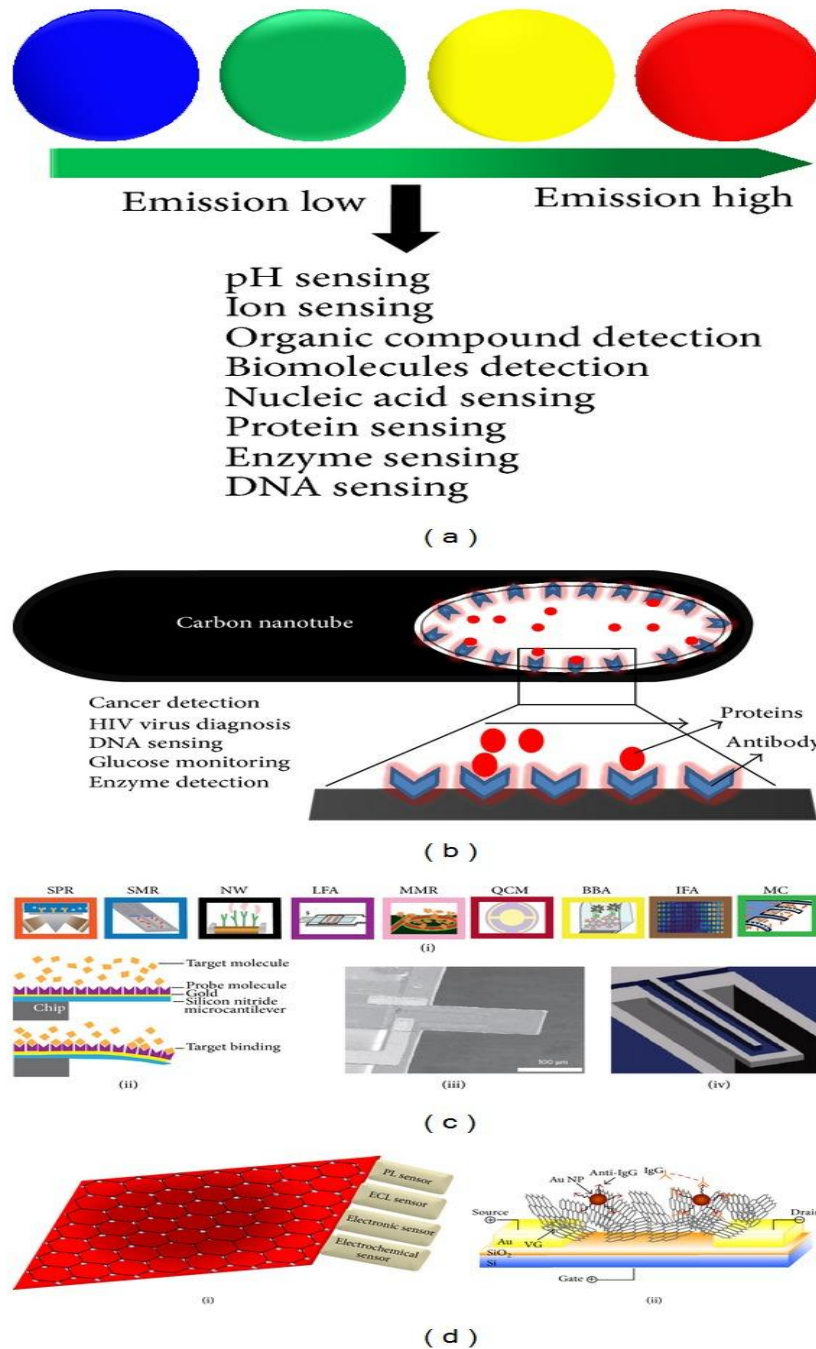


Figure 20. Application of nanobiosensors in tissue engineering (a) Change in colour of quantum dots may occur based on their emission wavelength; (b) CNT based biosensor is used for the identification biomolecules produced by the cell; (c) MEMS based biosensors (surface plasmon resonance, lateral flow assay, microring resonator, microcantilever etc.); d) Graphene and its derivatives and vertically-oriented graphene based field effect transistor-sensor [7].

6. Challenges and future research

The possible challenges that might occur with technology of nanobiosensing includes, but not limited to scalability emanating from the nanowire or nanoparticles synthesis bearing specific properties including shape or size (using bottom-up procedures), reproducible fabrication and failure to quantify analytically, both biological and chemical information in a quick and cheap manner [66]. Therefore, modified fabrication methods mainly applied for multiplexing and to fabricate reproducible devices could ultimately assist in the synergy of technology and diagnostic tools, thus increasing the amount of different analytes with specific sensors on one platform as well as creating great impact on disease identification, and also introducing more reliable and efficient tools such as the nanotechnology on a chip meant for molecular diagnosis which will eventually improve healthcare delivery. A typical example of nanotechnology biochips is the nanofluidic type developed for DNA and protein isolation and analysis [66]. Others may include presence of high level of toxicity of nanomaterials; miniaturization and integration of microfluidic systems; lack of security and futuristic effect of nanobiosensors in terms of risks; less biocompatible and biostable.

These problems may pose potential risks on the lives of the end users, patients or even the laboratory research analysts. Therefore, more effective and efficient therapeutic solutions with little or no adverse toxic effect, enhanced durability and biocompatibility could greatly influence and improve healthcare delivery. These may thereby make the technology to gain more weight in biomedical as well as clinical applications and industrial productions in the area of nanobiosensors [24]. Nanotechnology as a multidisciplinary field has come to stay and cause positive impact globally. Nanobiosensors with magnetic nanoparticles might serve as a significant tool for telomerase activity screening in living experiments. Nanorobot sensor, a unique type, can diagnose as well monitor diabetes by producing a form of proteomic-based output for diagnosis and apply its increased sensitivity for optimum performance, thus diagnose and treat different types of cancer. They could also identify some microbial pathogens and its toxins in clients too. In the nearest future, the production of wearable biosensors for real-time sensing of most physiological features and development of more biosensors for other aspects of medicine will be used for proper understanding of human diseases. Development of these novel nanobiosensor tools and solutions will ultimately be used to positively change the medical conditions in the world.

7. Conclusion

Many nanobiosensors have been and are still being produced in the world, and yet the likes of multiplexed, affordable and high throughput devices have not been fully developed. More works should be done to achieve this goal and many others in the healthcare system as future nanobiosensors will aid in accurate as well as precise medical diagnosis and treatment than the old and current nanobiosensors.

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