NANO BIOSENSORS : A SMART BOON IN HEALTHCARE

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ABSTRACT:

Basically, Nanotechnology is the study of extremely small things and can be used in all the other science fields, such as chemistry, biology, physics, materials science, healthcare and engineering. This technology is conducted at the nanoscale, which is about 1 to 100 nanometers. Recent advancements in nanotechnology and advanced fabrication technology in electronic led to the creation of a new set of biosensors known as Nanobiosensors. A Nano-biosensor may be stated as a biosensor with nanomaterials having dimensions of nanometre (1 nm = 10^{-9} m). Nano biosensors- based applications have an unprecedented role in Disease detection, retinal prostheses, contrast imaging during MRIs, medical mycology, health monitoring, heart diagnosis etc. Nano biosensors have great potential and capabilities to detect the outbreak of a virus and/or any disease like SARS, avian influenza, Nipah virus and the recent COVID-19 pandemic that greatly impact the globe. This short communication portrays the development of nanoscience and technology in healthcare. Furthermore, it also discusses the future perspectives of healthcare in a smarter way.

KEYWORDS:Nanotechnology, Nanobiosensors, Nanomaterials*

INTRODUCTION:

The utmost need for health and environmental monitoring results in the emergence of smart sensors to get accessible and improved healthcare for everyone. The factors like costs, quality, and production lead time etc. are influenced in a positive manner by digitization which is leading to the increased demand for modern smart sensors. For the fulfilment of the demands, sensors are used as an effective and essential analytical tool for diseaseprogression monitoring effective diagnostics, therapy efficacy assessment and targeted biomarkers detection for environment quality evaluation.The versatility of Advanced Sensor technologies has ameliorated the day-to-day lifestyle of humans and also enhanced the credentials of the entire globe. Effective delivery and more accessibility in all aspects are achieved due to these state-of-the-art instruments. Javaid et al. (2021); Kaushik, (2019). The term 'sensor' originated from the Latin word '*sentio',* which depicts '*to perceive or observe*'. Vikesland, (2018). "Pharmacy, biomedical, healthcare sectors and various healthcare systems and research sciences are exploiting the biosensors because of their cost-effective nature. " Haleem et al. (2021)

BIOSENSORS:

The International Union of Pure and Applied Chemistry (IUPAC) defines a biosensor as, "*a device that detects chemical compound by thermal, electrical, and optical signals generated by particular biochemical reactions channelized by isolated enzymes, immune systems, tissues, organelles or whole cells*". In 1962 Led and Clark developed the first ever oxygen-based bio sensor that gained tremendous popularity in past decades. Patel et al., (2016); Turner, (2013). Biosensors have three imperative components:

1. Bio-receptor that specifically binds to an analyte.
2. Transducer that generates a signal following the binding event.
3. Detector to quantify the signal and transform it into readable information. Pirzada & Altintas (2019); Mohanty, & Kougianos, (2006).
4. A bioreceptor is a biological recognition element that comprises of a non-motile bio-component for detecting the specific target analyte (e.g., enzyme substrate, complementary DNA, antigen). Secondly, the most imperative part of the biosensor is the transducer for converting a biochemical signal into an electrical signal, generated via the interaction of the analyte with the bioreceptor. The resultant intensity of the signal produced from the biochemical reaction is directly or inversely proportional to the concentration of the analyte. The signal may be in the form of heat (or absorbed) by the

reaction (calorimetric biosensors), a change in the distribution of charges which leads to the generation of an electrical potential (potentiometric biosensors).

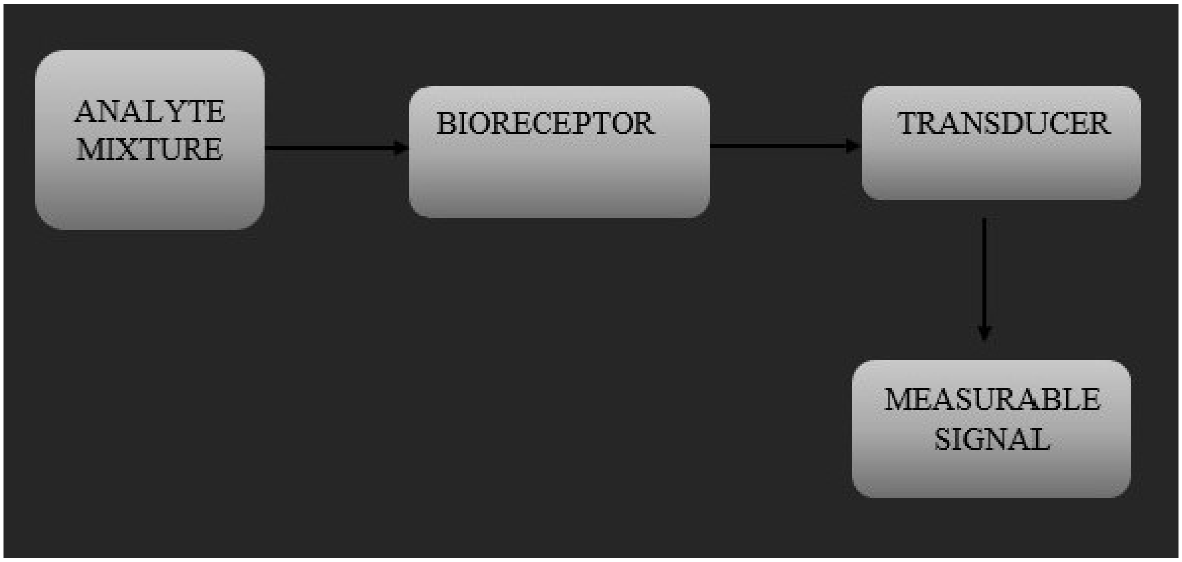

Fig.1. Components of Biosensors

Flow of electrons produced in a redox reaction (amperometric biosensors), photons during the reaction or the difference in the light absorbed between the reactants and products (optical biosensors) and change in mass of the reactants or products (piezo-electric biosensors) Atta et al. (2011). The third component is the detector which can be electrochemical, optical, or piezoelectric in nature Pirzada & Altintas (2019); Shoaie, (2020); Mohanty & Kougianos, (2006).

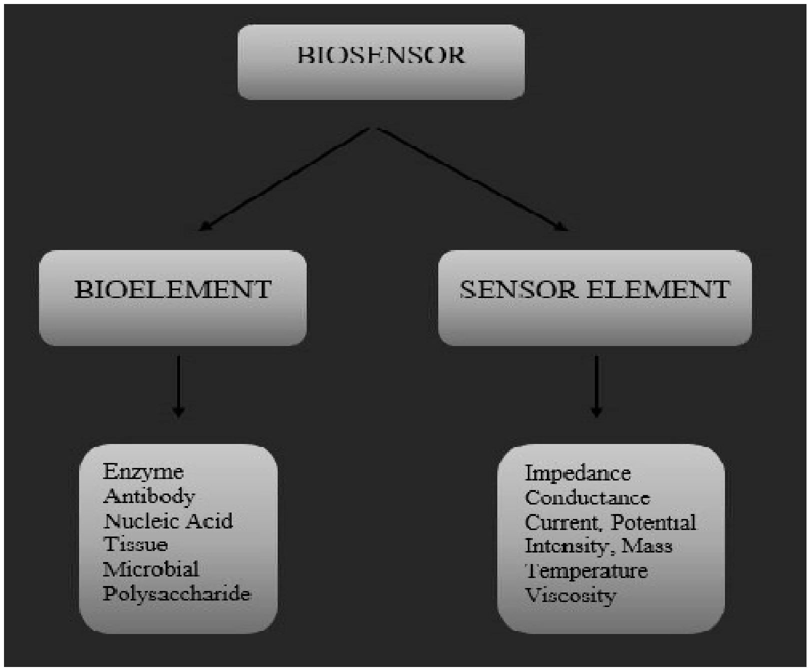

Fig.2. Elements of Biosensors

A biosensor must possess at least some of the properties mentioned here below to be a successful one:

i. The biocatalyst should be stable under normal storage conditions, have good stability over a large number of assays and have high specificity for the purpose of the analysis.
ii. The physical parameters as stirring, pH and temperature should not have any effect on the reaction.
iii. The accurate, precise, reproducible response should be observed without dilution or concentration and linear over the useful analytical range, without
iv. The electrical noise should not affect response.
v. The complete biosensor should be cost effective, easy to handle, portable and easy to operate Atta et al. (2011)

Over the last few years, biosensors are used as fast, reliable andspecific methods to detect, monitor and/or quantify an analyte into bio-medical markets around the globe forreal-time detection of biomarkers which play an important rolein several new healthcare programs likeroutine point-of-care (POC) clinical evaluation, on the spot detection of ailments in developing countries and quick genetic mapping for personalized care. Shoaie, (2020). There is an utmost requirement for continuous development of desired, cheap and portable biosensors with spontaneous response and detection sensitivities as compared to existing lab assay methods which are dated. These could perform a vital role in quick patient diagnosis and in some cases, declining overcrowding in the emergency room. In the case of biological and medical sensing applications, disease detection has been made possible by utilizing an ample number of techniques, including enzyme-linked immunosorbent assay (ELISA), particle-based flow cytometric assays and electrochemical techniques which rely on the measurement of capacitance, impedance and conductance measurement of semiconductor nanostructure.

These assay techniques have some drawbacks which are mentioned here below:

One analyte measurement at a time is possible by ELISA. Particle-based assays are long and tedious though these allow multiple detections by making use of multiple beads. Electrochemical devices are economic, but there is scope for improvements in sensitivities yet. Yang (2020 [8] These diagnostic methods havelimitations like improper sensitivity and specificity, and slow pace.The development of nanotechnologies in diagnostic tools has turned out to be revolutionary because of the increased sensitivity, and specificity of the tools Nagraik,et.al. (2021)

NANOTECHNOLOGY:

The word Nanotechnology stems from the Greek word 'nano' which implies 'dwarf', and implemented to the manipulation, observation and measurement at a scale of less than 100 nanometres. Nanotechnology is a self-ordered and self-assembled system, interiorly multidisciplinary, based on pure science, analytical techniques and a number of disciplines like chemistry, physics, electrical engineering, material science, molecular biology etc. It is one of the emerging and most disruptive techniques and has significantly converted the sensor sector. The main objective in the field of nanotech is the development of nanoparticles for artificial receptors, DNA sequencing, manufacturing of unique drug delivery systems and diagnostic and screening purposes. Kubik,et.al. (2005); Fayaz & Qazi (2021); Javaid & Haleem (2021).

NANOBIOSENSORS

Recent advancements in nanotechnology and advanced fabrication technology in electronics lead to the creation of a new set of biosensors known as Nanobiosensors. Jianrong, et.al. (2004). A

Nano-biosensor is defined as a biosensor with nano-materials having dimensions of nanometre (1 nm = 10^{-9} m). The implication of nanomaterials in biosensors has gained attention due to their peculiar optical, catalytic, electrochemical, mechanical, biological, magnetic and surface properties. Nanobiosensors and biosensors work on a similar principle, though in the former, the transducers are devised by combining with nanomaterials.

Nanobiosensors are advantageous over traditional methods in the following ways:

i. Due to presence large surface area to volume ratio many of them are located near their surface thus enhancing the transducing and signalling capabilities.
ii. Better accuracy in data recording.
iii. Irritation-free fitting in the person.
iv. Perfect for mass production with low power consumption
v. Cost-effective and handy
vi. High sensitivity
vii. Reusable and spontaneous
viii. Low sample volume
ix. Less detection times
x. High pace and real-time analysis
xi. Multi-analyte detection
xii. Detection atmuch lower levelas compared to their macroscale analogues. Evans et. al. (2016); Prasad, (2014); Sharma, et.al (2021); Mishra & Sushmith, (2022).

These large advantages of nanobiosensors make them an efficient technology for the advancement in various fields like disease diagnosis, medicine, healthcare etc. A variety of nanomaterials is available for exploration, with particular sets of properties that help to increase the performance of biosensors of sensitivity and precision. The main three classes of nanomaterials are

1. Nanoparticles or zero-dimensional (0D) nanomaterials, for example, clusters of atoms having particle diameter less than100 nm
2. One-dimensional (1D) nanomaterials like nanotubes, nanowires and nano-cables with a width below 100 nm

3. Two-dimensional (2D) nanomaterials such as nanofilms and superlattices with a layer thickness in the nano-range. Crapnell & Banks, 2021; Jeevanandam, (2022) On the grounds of chemical composition, nanomaterials mostly are categorized into:

1. Carbon allotrope-based nanomaterials constituting only carbon atoms
2. Inorganic metallic or non-metallic based nanomaterials constituting Au, Ag, SiO_2
3. Organic polymer-based nanomaterials.

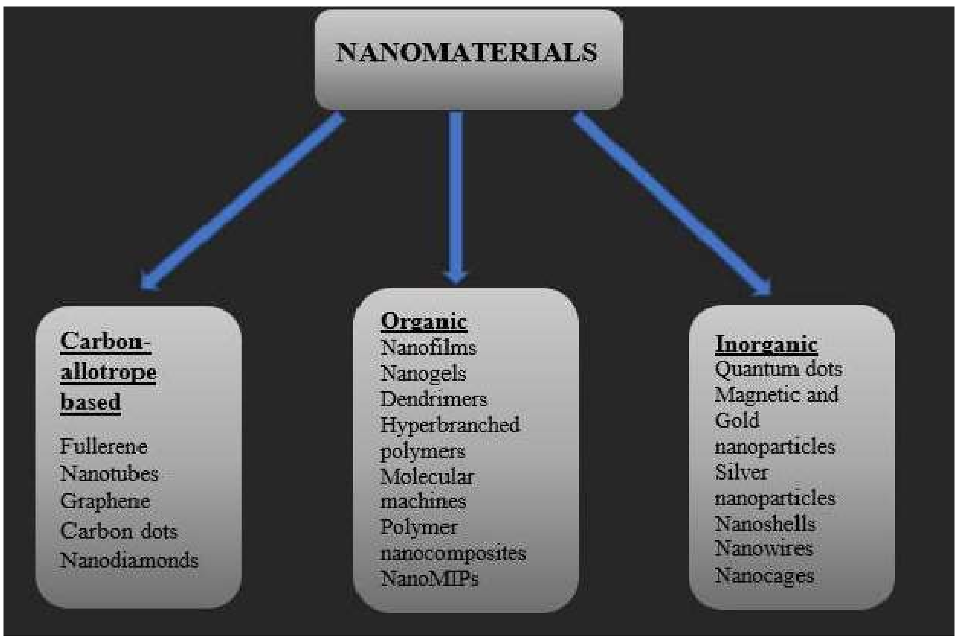

Fig.3. Classification of Nanomaterials on the basis of their structural differences

Different types of nanobiosensors have been developed by incorporating the nanomaterials of different types.

Table 1: Nanobiosensors and their applications

NANO BIOSENSOR	APPLICATIONS
Optical Nanobiosensor	Diagnosis of cancer, Direct glucose level detection in blood
Electrical Nanobiosensor	Diagnosis of different diseases, Label free DNA detection
Electrochemical Nanobiosensor	Electrochemical detection of blood glucose level, determination of DNA and its effectors
DNA Nanobiosensor	Detection of genes and mutant genes related to inherited human diseases
Viral Nanobiosensor	Used in place of ELISA-Based methods, Improvement over PCR based detection, Cheaper, Fast method
NanoshellNanobiosensor	Used for immunoassay, Diagnosis and therapy of cancer, Diagnosis of Alzheimer's disease
Nanowire Nanobiosensor	Diagnosis of cancer, Drug recovery, treatment of diseases, Kinetic studies of fundamental biochemical reactions
Nanotube based Nanobiosensor	Used in immunoassays, nucleic acid probe assays, clinical chemical assays

Large-scale nanomaterials are incorporated into biosensors in recent years to enhance their selectivity and accuracy. Development of single-molecule biosensors, high-throughput biosensor arrays and enhanced mechanical, optical,electrochemical and magnetic properties of biosensors is achieved by the amalgamation of nanomaterials and biosensors Vigneshva et.al., (2016); Pandey & Malhotra (2019); Kokardekar et.al. (n.d).

On the basis of nanomaterials used,nanobiosensors are classified as follows:

A. Carbon-based nanobiosensors constituting CNT (Carbon nanotube), Graphene etc. as nanoparticles

B. Metal based nanobiosensors having Gold (Au), Silver (Ag), Platinum (Pt) and Palladium (Pd) as nanoparticles
C. Nanobiosensors based on Semiconductors (Quantum Dots)
D. Electrospun nanofibers
E. Paper‐based (optical) nanobiosensors
F. Plasmonic nanobiosensors
G. Microfluidic nanobiosensors
H. Lab-on-a-chip
I. RT‐LAMP mediated nanoparticles‐based nanobiosensor Patel, et.al. (2016); Mishra, & Sushmith, (2022).

ROLE IN HEALTHCARE

The main goals in health carepromotion, delivery and research are to assess health status, disease onset and progression, and monitor treatmentoutcomes through a non-invasive method. The main three conditions to reach these aims are:

- ❖ Particular biomarkers that specify a healthy or diseased state
- ❖ A non-invasive approach to detect and monitor the biomarkers
- ❖ The technologies to differentiate the biomarkers

The utilization of nano biosensors in healthcare is tremendous and mainly used in day-to-day activities. The enhanced monitoring of glucose levels and enabling the user to know the triggers easily and report to the doctors reinforce efficiency in treatment and care plans. Nano biosensors allow people to be monitored in various environments in order to avoid injuries from overwork, falling, heavy machinery, etc. In association with advanced cognitive capacities and extra venous sources such as environment and weather, nano biosensors turn out to have great potential for better good health, management, and security to change our way of life and work. Javaid & Haleem (2021); Nikolelis, D.P. & Nikoleli, G.P., Eds. (2018).

Nano biosensors-based applications have an unprecedented role in Disease detection, retinal prostheses, contrast imaging during MRIs, medical mycology, health monitoring, heart diagnosis, etc. Nano biosensors have great potential and capabilities to detect the outbreak of a virus and/or any disease like SARS, avian influenza, Nipha and the recent COVID-19pandemic thathas a great impact around the globe. The amalgamation of surface chemistries and the nanomaterials has led to the development of highly sensitive and specific nano biosensors that play an important role in the detection of various cardiovascular disorders. Handy and portable electronic point-of-care monitoring technologies play a vital part in the overall healthcare system, with great capability for surveillance, treatment, diagnosis, fitness, and well-being. Biosensors are also used in devices which predict addiction in pregnancy, and monitor the glucose levels. These biosensor-based systems help patients to control thems lves resulting in declining length of hospital stay and effective tracking.

Nano biosensors are utilized to measure, diagnose and treat various ailments. The tracking of the vital signs of a patient and identification of biological abnormalities and accurate results can be achieved by biosensors when incorporated into health care systems. Nano biosensors provide prevention of early intervention drive treatment costs, the identification and surveillance of risk factors to reduce healthcare costs, and effective time to enhance results by the patient's treatment and care stakeholder. Vikesland, (2018); Patel et al., (2016).

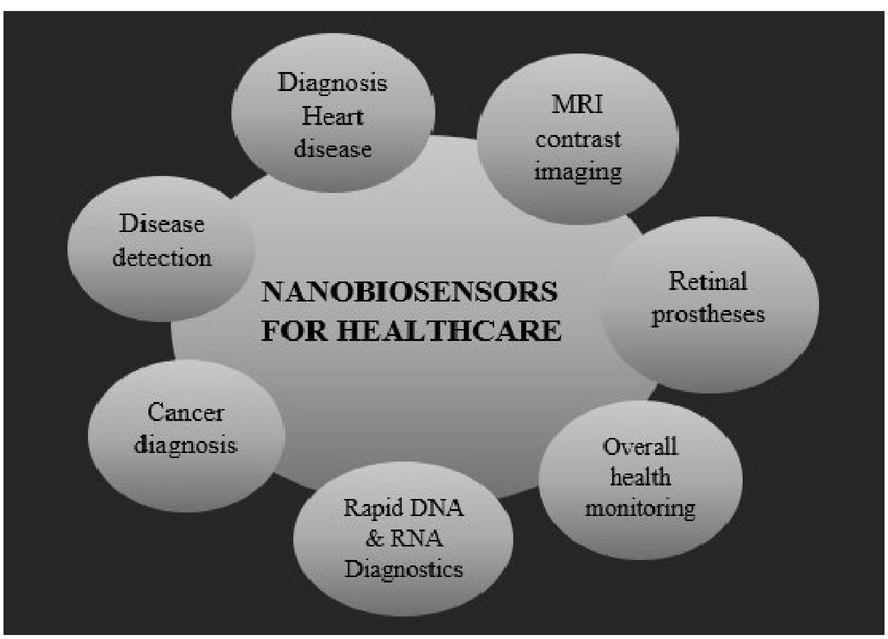

Fig.4. Applications of Nanobiosensors in Healthcare

At the molecular level, nanoparticle based nano biosensors can help doctors in the detection of any health issues in advance. Mainly gold and silver nanoparticles are used for this purpose. Nanotechnologies have an avid role in care diagnostics, the combination of therapeutics with medical specialty and the development of personalisedmedicine. The macroscopic changes from outside the body are observed by Nan biosensors and they exchange these changes to alternative nano-products operating inside the body. To detect the tumors at intervals the body selenide-based quantum dots nanosensors are used. Fayaz & Qazi, (2021). Advanced Nanotechnology on a chip is the emerging platform for designing diagnostic assays for disease. Molecular diagnostics and health care are influenced by thecapability to extract analytical quantification of chemical and biological information in a quick and relatively cost-effective way. Nanofluidic arrays and protein nano biochips are the devices that incorporate nanotechnology-based biochips and microarrays which can be adapted for point-of-care use.Studies have shown that healthcare systems will be the most important area for the applicability of nano biosensors. One of the greatest challenges of science and technology is the maintenance of health and early diagnosis, prevention and treatment of diagnosis. Prasad, (2014).

CONCLUSION:

The use of sensors in medicine is an emerging area that holds huge potential in efficient and effective healthcare delivery from diagnosis to the monitoring of therapy. However, there is still some work to be done in standardization and optimizing nanotechnology for widespread use in medicine with necessary regulatory framework.

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