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Use of Nanotechnology in Biosensor

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Abstract: Nanotechnology is a new technological revolution in the 21st century. It is the study and application of matter at dimensions less than 100 nm. With the advancement of nanotechnology, its creative and sharp application can be predicted to enhance the performance of electronic devices with high sensitivities and detection limits. Immobility of receptors is an important step to create biosensors. Nanomaterials are used as transducer material that is an important part for the development of biosensors. A variety of body elements like food samples, body fluids and the culture of cells can be determined for the analysis with the help of biosensors. Over the past decades, the development of biosensors in both research and product development was quite rapid. Undoubtedly, we can say that biosensors are not only interesting in academic field but also in industrial fields. The connections between the analyte and bioreceptors have become a suitable and easily readable result. This pathway has helped researchers from different zones of science to increase their skills. Recently, there has been a continuous increase in start-up companies based on biosensors in nanotechnology all over the world that gave a deep impact on the healthcare industrial sector. The main objective of this technology is to improve the quality of life in diverse areas.

Keywords: Nanotechnology, Immobilization, Bio receptors, Biosensors, Transducers, Analyte

I. INTRODUCTION

Nanotechnology is a new technological revolution in the 21st century. Nanotechnology is the study and application of matter at dimensions less than 100 nanometres, where unique phenomena enable novel applications. The exciting and absorbing properties of nanomaterials have attracted the world toward their application in various technology and industry sector such as - Information Technology, Medical Science, Transportation, Environmental Science, Textiles, Sports, Robotics, Molecular Engineering, and many more. Nowadays Nanotechnology is specially used in Nanoelectronics to produce biosensors. A biosensor is an analytical device that is used for the detection of biological and chemical reactions by making a measurable signal which is proportional to the concentration of the target analyte.

Nanotechnology's creative and sharp application is predicted to enhance the performance of electronic devices with high sensitivities and detection limits. Diagnostics is scientifically important both for the identification of disease and therapeutics. Earlier diagnostics play an important role to detect disease (prevention) or the outcome of disease (prognosis). Microfluidic biosensing devices provide important opportunities for research, especially for clinical diagnosis, due to their numerous advantages. These microscopic devices require minute volumes (10^{-9} to 10^{-18} L) in micron-sized channels and containers leading to the development of a “lab-on-a-chip”. A biosensor consists of five parts which are (1) an analyte (2)a bioreceptor, (3) a transducer, (4) a signal processor for converting electronic signal to a desired signal, and (5) an interface to display. A variety of body elements like food samples, body fluids and culture of cells can be determined for analysis with the help of biosensors. There are still many challenges such as automation, miniaturization, and integration of the nanostructured-based biosensors.

In 2004, a new type of carbon material has been introduced called “carbon dots”. Its size is below 10nm and it was discovered by Xu etc. all. During the purification of single-walled nanotubes.C-dots can also offer exciting opportunities for catalysis, photovoltaic devices, energy conversion, and Nanoprobes for sensitive ion detection. In 2004, after the discovery of “graphene”, carbon materials became the backbone of almost every field of engineering and medical.

With the progress of technology, at the beginning of the 21^{1st} century, nanoscience and nanotechnology brought a huge interest in the market of science. Currently, a number of studies highlighted the huge potential impact that nanotechnology has in the biomedicine field for the diagnosis and therapy of many human diseases. Nanoinformatics exclusively deals with the sharing, assembling, envisaging, modeling, and evaluation of significant nanoscale-level data and information [1,2]

II. MATERIALS AND METHODS

Nanomaterials are materials that have a particle of nanoscale dimensions which means 1-100 nanometers. In biosensor diagnostic devices, generally, nanomaterials (for example- nanowires, nanotubes, etc.) are used as a transducer material. In quantum mechanics, the Bohr exciton radius is defined by the characteristic radius of an electron. When the size of a particle is too small or comparable with the Bohr exciton radius, the electron mobility is confined.

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If a particle has nanoscale dimensions, the confining dimensions make the energy level discrete and increase the energy gap. When the particle size is comparable with Bohr exciton radius, the excitonic transition energy blue shift in the absorption, and due to the quantum confinement effect luminescence band gap energy increases [3,4].

Components

Analyte: An analyte is a chemical substance whose components are identified and estimated. Biosensor has the efficiency to find out the analyte with high specificity. The several analytes - Glucose, Lactate, Glutamate and Glutamine can be targeted by enzymatic biosensors.

Bioreceptor: The bioreceptor is a biomolecule that particularly recognizes the analyte such as Glucose, Lactate, Glutamate, and Glutamine is known as a bioreceptor. The bioreceptor contains a layer of macromolecules such as enzymes, cells, antibodies, nucleic acids, and aptamers that have specific affinities to the analytes of interest. The process of signal generation in the form of light, heat, ph, charge or mass change, etc. upon the interaction of the bioreceptor with the analyte is termed bio-recognition.

Transducer: The transducer is a device that converts one form of energy into another, which is called signalization. In a biosensor, the transducer turns the bio-recognition event into a measurable signal. It changes various physical quantities such as pressure and brightness into an optical or electrical signal that is generally proportional to the amount of analyte-bioreceptor interaction.

Electronics: In biosensor, electronics processes the transduced signal and develop it for display. It comprises of complex electronics circuit that performs amplification and conversion of signals from analog into digital form. Then the processed signals are determined by the display unit of the biosensor.

Display: The display contains a combination of hardware and software that generates the result of the biosensor in a user-friendly manner. It comprises a user interpretation system that produces a number of curves comprehensible to the user. The output signal on the display can be numeric, graphic, tabular, or image form depending on the necessity of the end user.

Characteristics

Every biosensor possesses definite static and dynamic features. The optimization of this characteristic is reflected in the performance of the biosensor. The properties are Selectivity, Reproducibility, Stability, Sensitivity, Linearity and Selectivity. [5,6]

Probably, 'Selectivity' is the most important characteristic of a biosensor. Selectivity is the property for which the bioreceptor recognizes the specific analyte in a sample containing other impurities and mixtures. Selectivity is represented by the interaction between the antigen and antibody. Classically antibodies act as receptors and Buffer

Reproducibility

Reproducibility is the property of the biosensor to generate similar responses for a duplicated experimental setup. It is characterized by the precision and perfection of the transducer and electronics in a biosensor. When a sample is measured, the sensor can provide a result every time. The ability of the sensor is called precision. When the sample is measured more than one time, the sensor provides a mean value close to the true value. Accuracy indicates the sensor's capacity to provide this mean value [7,8].

Stability

Stability is the degree of susceptibility to surrounding disruption in and around the biosensing system. These disruptions which can cause an accumulation of the output signals of a biosensor make an error in the measured concentration. So it can affect the precision and accuracy of the biosensor. It is the most essential character in applications where the biosensor requires a long incubation period and uninterrupted monitoring. Due to the temperature sensitivity, the response of the transducer and electronics may influence its stability of it. Appropriate tuning of electronics is required to ensure the stability of the sensor. Degeneration of the bioreceptor over a time period also affects the stability of measurement.

Sensitivity

Biosensors can be detected a minimum quantity of analyte which is called limits of detection (LOD) or sensitivity. To confirm the existence of traces of analyte in a specimen, a biosensor is required to detect analyte congregation of as low as mg/ml or pg/ml in medical and environmental applications. For example, PSA = prostate-specific antigen concentration of 4 mg/ml in the blood is related to prostate cancer for which doctors suggest biopsy tests.

Linearity

The linearity of the biosensor can be related to the resolution of the biosensor and the range of analyte concentrations under test. It is the quality that exhibits the accuracy of the measured response (for a set of measurements with different concentrations of the analyte) to a straight line represented as $y=mc$, where **c** is the concentration of the analyte, **y** is the output signal, and m is the sensitivity of the biosensor. The resolution of the biosensor is described as the smallest change in the concentration of an analyte that is required to bring a change in the response of the biosensor [9].

Application

This technology can be used in electronics and IT applications. It can be helpful in making nano transistors that can help in storing the memory of entire computer in a single chip. It can help in studying both the diagnosis and treatment of arthrosclerosis, or the build-up of plaque in arteries. It is also used in Glucometer for the diagnosis of diabetes mellitus. It can be used for improving the efficiency of fuel production from raw petroleum materials through better catalysis. Nanotechnology could help meet the need for affordable, clean drinking water through rapid, low-cost detection and treatment of impurities in water. It can be used for monitoring food authenticity, quality and safety (Fig 1).

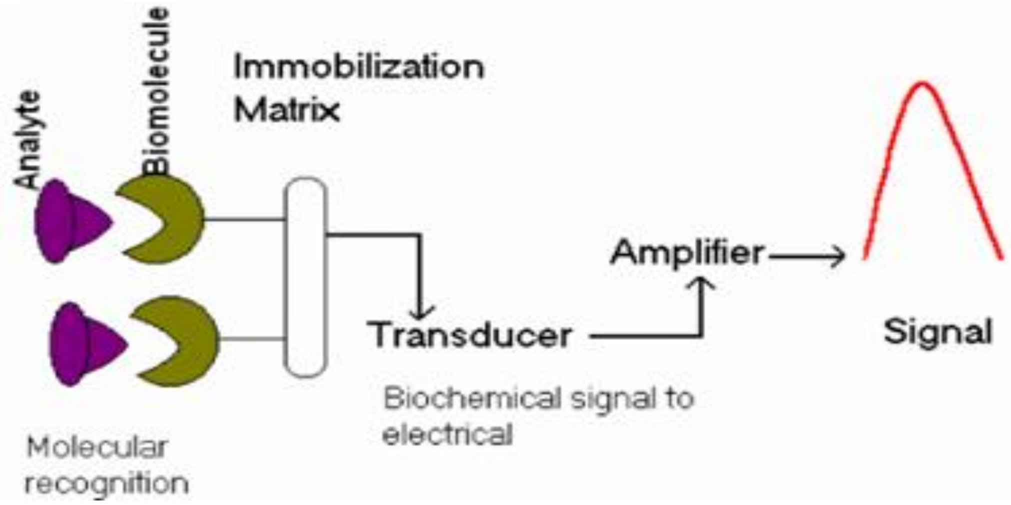

Fig. 1 Molecular recognition process at the sensor-analyte interface functioning of biosensor

III. DISCUSSION

Case Studies

IIT ROORKEE develops biosensors to accurately detect environmental pollutants
(https://www.eetindia.co.in/scientists-develop-biosensor-for-accurate-detection-of-environmental-pollutants)
A team of researchers at the Indian Institute of Technology Roorkee (IIT-R) claimed to have developed the world's first specific reliable bacterial biosensor to detect the presence of SDS. According to the researchers, they genetically redesigned the DNA of a specified bacterium (Pseudomonas aeruginosa) for their research. SDS, Sodium Dodecyl Sulphate or Sodium Lauryl Sulphate, is widely used in soaps, toothpaste, creams and shampoos. These things are the causes of harmful effects on aquatic organisms, environmental microcosms, and associated living organisms. It also deteriorates the quality of drinking water. So, there have no specific biosensors to detect the SDS with high precision.

IIT HYDERABAD develop an efficient sensor device to detect heart diseases quickly (https://www.indiatoday.in/education-today/news/story/iit-hyderabad-researchers-develop-efficient-sensor-device-to-detect-heart-diseases-quickly-1582297-2019-08-19).

It is collaborating research of IIT Hyderabad with research institutions across the worldto develop a device to detect heart disease with high speed, sensitivity, and reliability. Prof Renu John, Head, Department of Biomedical Engineering, IIT Hyderabad, is the head of the research team. Their research not only detects the diagnosis or prediction of heart disorders but also be extended to detect other diseases.

Microfluidics-based biosensors work

Nano-sized materials that are a hundred thousand times smaller than the thickness of a single human hair - are often used in microfluidics-based biosensors as the transducer to convert the biochemical reaction into an optical or electrical signal.Researchers used hollow nickel vanadate nanospheres, modified with chitosan and loaded with antibodies of cTns in a microfluidic setup.

When blood containing the CVD biomarker cTns was passed through the biofluidic setup loaded with the biosensing nanospheres, cTns binds with the antibody and induces an electrical signal in the nanosphere, which is then detected.

IV. CONCLUSION

Nowadays in vitro molecular biosensors are omnipresent in biomedical diagnosis. Besides this biosensor are used in the observation of treatment and disease progression, environmental observation, food control, and drug exploration. Over the past decades, the development of biosensors in both research and product development are very fast. The reasons are:

(i) Developments in miniaturization and microfabrication technologies,

(ii) Utilization of novel bio-recognition molecules,
(iii) Novel nanomaterials and nanostructured devices,
(iv) Better interaction between life scientists and engineering or physical scientists, forensics, and biomedical research.

Biosensor devices need the interaction of different regulations and depend on very distinct perspectives such as the study of interactions of a bio-recognition constituent with bimolecular analytes, immobilization of biomolecules on solid surfaces, development of anti-fouling surface chemistry, device design, and manufacture. Undoubtedly, we can say that biosensors are not only interesting in academia but also interesting in the industry

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