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Nanobiosensor – A Modern Approach in the field of Biotechnology

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ABSTRACT

A biosensor is an analytical device containing an immobilized biological material (enzyme, antibody, nucleic acid, hormone, organelle or whole cell) which can specifically interacts with an analyte and produce physical, chemical or electrical signals that can be measured. Nanobiotechnology can have a combination of the classical micro-technology with a molecular biological approach. Biotechnology uses the knowledge and techniques of biology to manipulate molecular, genetic, and cellular processes to develop products and services, and is used in diverse fields from medicine to agriculture. Nanotechnology is playing an increasingly important role in the development of biosensors. The sensitivity and performance of biosensors is being improved by using nanomaterials for their construction. Nano sensors deliver real-time information about the antibodies to antigens, cell receptors to their glands, and DNA and RNA to nucleic acid with a complimentary sequence. Thus the aim of our study is to signify the importance of Nano-biosensor in our daily life and science.

Keywords: - Biosensor, nanotechnology, nanobiosensor, nanobiotechnology

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INTRODUCTION

Biosensors basically involve the quantitative analysis of various substances by converting their biological action into measurable signals. The most widespread example of a commercial biosensor is the blood glucose biosensor, which uses an enzyme to break blood glucose down. [1, 2, 3]

Features of ideal biosensor

- Accuracy/Precision - Our biosensors provide clinically acceptable accuracy and precision over relevant ranges of analyte measurement.
- Sensitivity - Small changes in sensed analyte levels are detectable within clinically meaningful limits
- Specificity - Uric acid, acetaminophen, and ascorbic acid, the most common interferons in blood, do not affect the accuracy or sensitivity of our biosensors.
- Simplicity - Lower cost, and less likely to be incorrectly made.
- Continuous - Close monitoring of patient analyte levels over time may be critical in some medical situations. Several of our biosensors are designed for such use.

General application of biosensor

In the beginning biosensor was applied in the field of medicine and industry. But in recent years, biosensors are becoming popular in many areas (pollution control, military etc) due to the small size, rapid and easy handling, low cost, and greater sensitivity & selectivity.

Some application of biosensor is as given below

- Environmental applications e.g. the detection of pesticides and river water contaminants
- Remote sensing of airborne bacteria e.g. in counter-bioterrorist activities
- Determining levels of toxic substances before and after bioremediation.
- Detection and determining of organophosphate.
- Routine analytical measurement of folic acid, biotin, vitamin B12 and pantothenic acid as an alternative to microbiological assay.
- Determination of drug residues in food, such as antibiotics and growth promoters, particularly meat and honey.
- Drug discovery and evaluation of biological activity of new compounds.
- Detection of toxic metabolites such as mycotoxins.
- Mutagenicity of several chemicals can be determined by using biosensors.
- Biosensors can be used for monitoring of fermentation products and estimation of various ions.
- Biosensors have been developed to detect the toxic gases and other chemical agents used during war.

- Immobilized cholesterol oxidase system for measurement of cholesterol concentration in food (e.g. butter).
- Ion- selective field effect transistors biosensors are used to monitor intramyocardial pH during open heart surgery.
- The whole cell biosensor developed by immobilizing Salmonella typhimurium and Bacillus subtilis in conjugation with oxygen electrode can be used to measure mutagenecity and carcinogenecity of several chemical compounds.

Limitation of conventional biosensor

- The major limitation of potentiometric biosensors is the sensitivity of enzymes to ionic concentrations such as H+ and NH+4.
- Piezoelectric biosensor is very difficult to use to determine substances in solution as because the crystals may cease to oscillate completely in viscous liquid.
- The whole cells, in general, require longer periods for catalysis and the specificity and sensitivity is also very low.
- The accuracy of the biosensor is doubtful with respect to monitor cell morphology, it may happen two cells can have almost similar pattern.
- Sometimes, it is not clear if the biosensor is useful for nonmammalian cell and plant cell.
- Time consuming.
- Cost-intensive & Non-portable.

Nanobiotechnology – A general approach

Nanotechnology refers to a field of applied science and technology whose theme is the control of matter on the atomic and molecular scale, generally 100 nanometers or smaller, and the fabrication of devices or materials that lie within that size range. Nanobiotechnology is the unification of biotechnology and nanotechnology. This hybrid discipline can also mean making atomic-scale machines by imitating or incorporating biological systems at the molecular level, or building tiny tools to study or change natural structure properties atom by atom. Convergence is an activity or trend that occurs based on common materials and capabilities-in this case the discipline that enables convergence is nanotechnology. The potential opportunities offered by this interface are truly outstanding; the overlap of biotech, nanotech and information technology is bringing to fruition many important applications in life sciences. [4, 5]

Nanotechnology and biosensors

Nanotechnology is playing an increasingly important role in the development of biosensors.

- The sensitivity and performance of biosensors is being improved by using nanomaterials for their construction.

- The use of these nanomaterials has allowed the introduction of many new signal transduction technologies in biosensors.
- Because of their submicron dimensions, nanosensors, nanoprobes and other nanosystems have allowed simple and rapid analyses in vivo.
- Portable instruments capable of analyzing multiple components are becoming available.

Advantages of nanobiosensor

- Particles that are smaller than the characteristic lengths associated with the specific phenomena often display new chemistry and new physics that lead to new properties that depend on size.
- When the size of the structure is decreased, surface to volume ratio increases considerably and the surface phenomena predominate over the chemistry and physics in the bulk.
- The reduction in the size of the sensing part and/or the transducer in a sensor is important in order to better miniaturist the devices.
- Science of nano materials deals with new phenomena, and new sensor devices are being built that take advantage of these phenomenon.
- Nano sensors deliver real-time information about the antibodies to antigens, cell receptors to their glands, and DNA and RNA to nucleic acid with a complimentary sequence.
- Reduction in time than conventional biosensors.
- Sensitivity of the conventional biosensors is in the range between 103 and 104 colony forming units (CFU)/ml. The dimensional compatibility of nanostructures materials renders nanotechnology as an obvious choice derived from its ability to detect ~ 1 CFU/ml sensitivity.

Application of nanobiosensor

Glucose biosensors for diabetic patients

Diabetics have to test their blood sugar levels as often as four times a day by pricking their fingertips to obtain a drop of blood (two microlitres), which is transferred to a test strip. This is then inserted into an electronic reader. IBN's glucose biosensor, which is a disposable test strip made up of a nanoparticulate regulating membrane, only requires 0.2 to 0.3 microlitres of blood to generate a reading - the smallest sample volume needed amongst all glucose biosensors available in the market. The membrane contains sensing elements and regulates the glucose flux. After the blood sample is introduced to the biosensor, the porous membrane will retard the diffusion process and prolong the reaction time, levelling off the signal over a wide-time window. Using this technology, patients will no longer need to draw blood from their fingertips - an area of the body that is rich in capillaries, but also highly sensitive to pain. Instead, a very small amount of blood can be obtained from any other part of the body, like a person's arm. The high sensitivity of the biosensor allows readings of very minute amounts of glucose, and it can generate accurate results within seconds. [6, 7, 8, 9]

Using multiwalled carbon nanotubes (MWNTs) biosensor in medical diagnostics

In the medical diagnostics arena, nanotechnology-based biosensors could be used, for example, to replace more costly and tedious laboratory methods for monitoring a patient's blood for proteins, chemicals, and pathogens. Our goal is to build an interdisciplinary team based on the expertise developed on carbon nanotubes, to develop novel, rapid-response biochemical sensors selective for targeted chemical and biological molecules. Multi Walled Nanotubes (MWNT) can be considered as a collection of concentric SWNTs with different diameters. The length and diameter of these structures differ a lot from those of SWNTs and, of course, their properties are also very different. Using of Multi-Walled Carbon Nanotubes (MWNTs) in Biosensors has various advantages. Firstly, these MWNTs have a high electrochemically accessible surface area, high electrical conductivity, and useful mechanical properties for developing electrochemical sensors in selectively detecting uric acid (UA) in the presence of L-ascorbic acid (L-AA). Secondly, MWNTs can be used as a nonenzymatic sensor to detect glucose with high sensitivity and stability in alkaline medium. Thirdly, we have successfully constructed a hemin-modified MWNT electrode in the development of a novel oxygen sensor for working at a relatively low potential. [10, 11]

A nanobiosensor for Salmonella detection

Salmonella is the most common cause of food borne illness in a year. Sources are raw and undercooked eggs, undercooked poultry and meat, dairy products, seafood, fruits and vegetables- so basically more or less everything you eat. Early detection of Salmonella is therefore an important task to control food safety. Several methods have been developed in order to detect this pathogen; however, the biggest challenges remain detection speed and sensitivity. [12, 13, 14]

Nanobiosensor to spot the right smell

An electronic biosensor using nanotechnology techniques could help companies to develop the right smells for their foods, or to sniff out rotting ingredients in the receiving area. The accuracy was achieved by using proteins corresponding to olfactory receptors in animal noses. A layer of the proteins is placed on a microelectrode; Data is then measured by determining the reaction when the proteins come into contact with different odors. The Spot-Nosed researchers copied the genes from several hundred different proteins from rats, which they claim is enough to determine almost any type of smell due to the number of reactions the proteins produce. The human nose uses 1,000 different proteins to allow the brain to recognize 10,000 different smells. [15, 16]

Ultrasensitive DNA/RNA nanobiosensor for early breast cancer diagnosis

Early detection will certainly improve a patient's chances of recovery, and much work is currently being done to improve breast cancer diagnostics. Joining this effort is IBN, which has developed a sensitive tool that deciphers the cancer's genetic code (DNA/RNA). An ultrasensitive DNA/RNA biosensor is a nanofilm containing capture probes on its surface is used. A catalytic current is generated after DNA/RNA a sample hybridizes with these probes. This electrical signal correlates directly to the amount of diseased DNA/RNA. Conventional biosensors used for this purpose generally employ fluorescent techniques. Few of these have sufficient sensitivities for the detection of genetic material at subpicomolar levels. (A picomole is 10-12 of a mole, which is the SI base unit of an amount of substance) In fact, this biosensor is so responsive that it can recognize breast cancer susceptibility genes in messenger RNA extracted from human breast tissues without involving a PCR (polymerase chain reaction) step, which is typically used to amplify the gene expression. [17]

Nanobiosensor probes single living cells

The size of nano-needle is about 50nm in diameter by silver-coated optical fiber that carries a helium-cadmium laser beam. Attached to the optical fiber tip are monoclonal antibodies that recognize and bind to BPT. The laser light, which has a wavelength of 325 nm, excites the antibody-BPT complex at the fiber tip, causing the complex to fluoresce. The newly generated light travels up the fiber into an optical detector. The layer of silver is deposited on the fiber wall to prevent the laser excitation light and the fluorescence emitted by the antibody-BPT complex from escaping through the fiber. The ben-zo[a]pyrene (carcinogen) metabolite reacts with the cell's DNA, forming a DNA adduct, which can be hydrolyzed into a product called benzo(a)pyrene tetrol (BPT). A nanosensor probe carrying a laser beam (blue) penetrates a living cell to detect the presence of a product indicating that the cell has been exposed to a cancer-causing substance. [18]

Future Scope of nanobiosensor study

- Application of biosensors for diagnosis and treatment of disease - The present invention uses biosensors that mimic naturally occurring cellular mechanisms, including RNA oligonucleotide chains or “aptamers,” in combination with molecular beacons or nanotechnology to provide an effective and efficient method for diagnosing a condition and/or disease within a patient.
- Anti-body based piezoelectric nanobiosensor to be used for anthrax,HIV hepatitis detection.
- Nanobiosensor for drug discovery – The work is based on Illustration of tyrosine kinase function, where ATP binds to the kinase active site and then phosphate is transferred to a tyrosine (Tyr) residue of the substrate protein.
- A fiberoptic nanobiosensor - This a nanoscale probe that consists of a biologically or chemically sensitive layer that is covalently attached to an optical transducer. Biological

sensing elements can be either a biological molecular species or a living biological system that uses a biochemical mechanism for recognition.

- Nano-transducer will help to advance the capabilities of currently designed nano-biosensors for higher sensitivity and speed of detection. These nanomaterials will also contribute to the knowledge base in nanoscale science and engineering for the prevention and protection of our food supply and agricultural operations, and facilitate the improvement of nano-biosensor architectures.

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