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Nanobiosensor

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Abstract

The nanobiosensor technology, an integral part of bioelectronics, is revolutionizing the health care industry, forensic medicine, home-land security, food and drink industries, environmental protection, genome analysis of organisms and communications. Through this paper we will discuss in detail the functions of biosensing electronics blocks such as biosensing, signal conversion and signal processing, and biosensing mechanisms. The use of smart nanomaterial's such as Zinc Oxide (ZnO) nanowire and carbon nanotubes (CNTs) in fabrication of biosensors will be described. A critical account on biological probe design, probe preparation and interfacing with signal transducer element of the biosensor will be given. Various transducer elements and biosensing methods will be enumerated. The applications of nanochemistry for biosensing packaging, with special reference to surface modification and biofunctionalization of sensor devices, and integration of biosensor system with system-on packaging (SOP) will be detailed. Finally, this concludes with future trends in biosensor technologies and a brief summary.

Keywords: Bioelectronics, nanobiosensor building blocks, nanochemistry, biofunctionalization, nanobiosensor packaging.

1. Introduction

Bioelectronics, including biosensors, is an emerging interdisciplinary field encompassing bioscience, chemistry, physics, material science, electronics, and engineering. A key factor of bioelectronics is in understanding the mechanisms of interfaces between biological materials and electronics. The miniaturization of electronic circuits laid the foundation for building microelectronic devices and modules. Typical bioelectronics devices are biosensors, biochips, electronic pills, electronic eye, electronic nose, genetic toggle switches, and biocomputing devices. Bioelectronics is revolutionizing the health care industry, forensic medicine, food and drink industries, environmental protection, genome analysis of organisms, and communications.

Biosensor is an analytical tool or a system comprising a biological material is immobilized, the type enzyme, antibodies, organelles. This biological material is in contact with a suitable transducer that converts the biochemical signal into an electrical signal can be quantified. The electrical signals produced may be continuous or discontinuous. A transducer is used because it is a device capable of transforming or converting one type of energy input in a different one to the exit. The choice of biological component also will depend on the substance commonly referred to as analyte, you want to analyze or quantify, and the transducer in turn also depend on the bio. Previously used electrochemical sensors and biosensors the emergences of different aspects were improved in the analysis. It thus improves the sensitivity and accuracy.

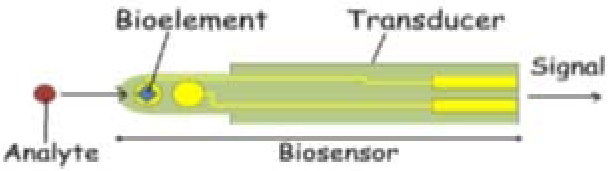

Figure 1: Basic scheme of biosensor.

2. Literature Review

Biosensor, like any other instrument, has evolved throughout history. Anecdotally we could say that the first biosensors were the canaries, as these birds were used in coal mines to detect toxic gases. The canaries are dying earlier than people in the presence of carbon monoxide and methane and are usually the most time singing that they did not became an audible alarm. But beyond this anecdotal fact, one can say that the father of these devices is Leland C. Clark Jnr., who in 1956 completed its work with the electrode of O_2, but not content with the idea of expanding its use to measure more analytes in the human body sensors in 1962 proposed making “smarter”. Subsequently, Guilbault and Montalvo detailed the first potentiometric enzyme electrode based on immobilization of urease on ammonium-selective electrode. In 1975 this became a commercial reality, putting on sale the first glucose analyzer based on amperometric detection of hydrogen peroxide in Ohio. This was the first biosensor for sale of many that would be marketed later. In 1987 through the use of electrochemical mediators immobilized enzyme are screen printed able to build the “pen” for personal monitoring of blood glucose. Currently there are many biosensors in which combine the wide diversity of biological components using various types of transducers.

3. Technical Activities

3.1. Transducers

Transducer is an analytical tool which provides an output quantity having a given relationship to the input quantity. Biosensors can be classified according the transduction method they utilize. Most forms of transduction can be categorized in four main classes: electrochemical, optical, piezoelectric and thermal detection.

3.1.1. Electrochemical

According to its type of operation, electrochemical sensors can be divided in two groups: amperometric and potentiometric. In the case of the former, the response is linear function of the concentration of the compound of interest. In the later, the response (a voltage) is a logarithmic function of the concentration. Currently available commercial electrodes basically belong to four types: those detecting cations, anions and gases, and platinum electrodes which measure the current in redox reactions. The ion selective electrodes, as well as those measuring pH, CO_2 and NH_4^+ use the potentiometric principle. Another important class of potentiometric transducers are semiconductor devices, such as field transistors (FETs), of which there are two main types: metal oxide (MOSFETs) and ion-selective (ISFETs). On the other hand, platinum electrodes, and those measuring O_2 and H_2O_2, use the ampreometric principle.

3.1.2. Optical

Conventional optical transducers were originally used for the measurement of dissolved O_2, CO_2, and pH. Several types of photometric behavior are useful for the construction of biosensors, namely:Visible/Ultraviolet absorption, Fluorescence, Chemi or bioluminescence, Reflection spectroscopy and laser light scattering. The principle of measurement is an immobilized reagent, able to interact with the analyte, forms a complex with distinctive optical properties which can hence be monitored by the sensor. Usually, the biological element is immobilized at one end of an optical fiber, with both the excitation and detection components located at the other end. For absorption-fluorescence-based transducers, the most widely used system has been $NAD(P)^+$/NAD(P)H-dependent dehydrogenases because NAD(P)H is known to absorb light strongly at 340 nm and fluoresce at 460 nm. Luminescence and reflection spectroscopy have been particularly useful in immunoassays. The main principle involves the labeling of an antigen with a substance (like luminol or its derivatives) which, when oxidized, produces visible light, and the labeling of the antibody with a fluorescence compound such that emission from the luminol will excite fluorescence. A similar approach can be used with firefly luciferins.

3.1.3. Thermal

As most biologically-catalyzed reactions generate heat, the accurate measurement of this heat generation, together with the specifically of the biological element, can be used to construct a biosensor. Basically, this device is a small calorimeter, instrumented with highly sensitive thermometers, usually able to detect temperature changes in the range of 0.0001-0.05^{0}C. This technique can detect analyte concentrations as low as 10^{-5}M.

3.1.4. Piezoelectric

Piezoelectric transducers are the smallest of balances. Crystals, such of those of quartz have no center of symmetry and produce an electrical signal when stressed mechanically (i.e. by applying some pressure on them). A crystal oscillates at a certain frequency, which can be modulated by its environment. When the crystal is coated with some material, the actual frequency depends on the mass of the crystal and the coating. The resonant frequency can be measured with great accuracy hence making it possible to calculate the mass of analyte adsorbed onto the crystal surface. This means, that with these devices, detection limits are down to the pictogram level. Antibodies, enzymes and antigens have been used as biological elements in these devices.

3.2. Biological elements

In the case of biosensor, a biological element is, on the one hand, any biological entity capable of causing a specific reaction or a binding with the compound or parameter that one wishes to analyze, and on the other hand, is able to generate a signal detectable by a conventional sensor. Figure 2 shows the basic types of biological elements used in biosensor construction. The most common biological elements are enzymes, antibodies, tissues and microorganisms, but nucleic acids and receptors have also been used.

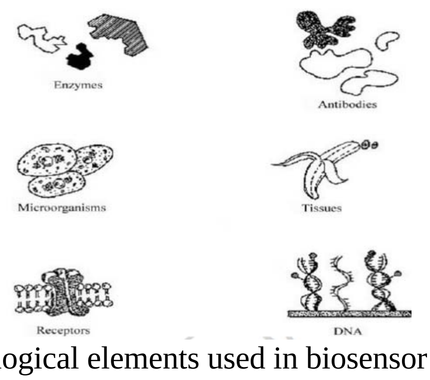

Figure 2: Biological elements used in biosensor construction.

The conventional transducer will measure any one of a number of possible variables, including the product of an enzymatic reaction, the consumption of a substrate, the use of a cofactor, the respiration or growth of microorganisms, the production of a certain metabolite, the binding of an antigen, the response of a receptor.

3.3. Biosensor packaging

The highly miniaturized electronics system technology mostly relies on integrated circuits (IC) integration for performance improvement and cost reduction. System-on-package (SOP) technology paradigm pioneered by Georgia Tech Packaging Research Center, since the early 1990s provides system-level miniaturization in a package size that makes today's hand-held devices into megafuntional systems, with applications ranging from computing, wireless communications, health care, and personal security. The SOP is a system miniaturization technology that ultimately integrated nanoscale thin film components for batteries, thermal structures, active and passive components in low cost organic packaging substrates, leading to micro-scale to nanoscale modules and systems. True miniaturization of products should take place not only at IC but also at system level, the latter made possible by thin film batteries, thermal structures, and embedded actives and passives in package- size boards. This is the fundamental basis for the SOP concept.

4. Applications

1. Health care
    - Measurement of metabolites
    - Drug discovery
    - Diabetes
    - Insulin therapy
    - Artificial pancreas
2. Industrial process control
    - Industrial bioprocess control and monitoring
    - Bioreactor control
    - On-Line control
    - Off-Line control
1. Military applications
2. Environmental monitoring
    - Air and water monitoring
    - Tuning to application.

5. Advantages

- In a biosensor, no involvement of exogenous molecules of labels such as conjugation with enzyme, radioactive fluorescence, or chemiluminescence molecules.

- It is a detection of the target molecules, a key factor in early detection of diseases such as breast cancer and AIDS.
- Rapid and high-throughput detection
- Detection processes are simple, user friendly, fast, and cost effective
- Reduced material requirement to fabricate, and easier recycling
- Novel properties and new capabilities
- Repetitive, portability, and stability.

6. Future Trends

The tremendous advancement in the sensor technologies are due to the great technological demand for rapid, sensitive, and cost-effective biosensor systems in vital areas of human activity such as health care, genome analysis, food and drink, the process industries, environmental monitoring, defense, and security. At present, the nanotechnology-based biosensors are at the early stage of development. The vast applications of nanotechnology in such diverse fields such as semiconductors, biological and medical devices, polymer composites, optical devices, dispersions, and coatings are amazing.

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