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Recent Advances and Applications of Biosensors Technology In Diversified Fields

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***ABSTRACT*--Imperative utilization of biosensors has acquired paramount importance in the field of drug discovery, biomedicine, food safety standards, defense, security, and environmental monitoring. This has led to the invention of precise and powerful analytical tools using biological sensing element as biosensor They are specific and sensitive, and work in a cost-effective manner. Technically speaking biosensor is a probe that integrates biological components with an electronic component so that we can get a measurable signal. Biological components may include a whole bacterial cell or biological products such as antibody or an enzyme.**
The present work includes the application of Biosensors in following four fields
(1) Applications in Medicine and Health
(2) Applications in Industry
(3) Applications in Pollution Control and
(4) Applications in Military.

Keywords--Biosensors, electrochemical, nanomaterials, fluorescence-tag, bioelectronics, polymer, microbes, diseases, environmental monitoring

1. INTRODUCTION

Bio sensor is a device which converts the biological signal or response into electrical signal. A biosensor is a device that used to detect record and also transmit information regarding a physiological change or the presence of various biological or chemical materials present in the environment. Technically speaking biosensor is a probe that integrates biological components with an electronic component so that we can get a measurable signal. Biological components may include a whole bacterial cell or biological products such as antibody or an enzyme.

Characteristics of Biosensors

1.Biosensors are highly specific
2.Reaction are independent of physical parameters such as temperature, pH
3. Biosensors are biocompatible
4. Biosensors are economical
5. Biosensors should have market value
6. Biosensors should be precise and accurate

Carbon Nano Tubes

Carbon nanotubes are made up of carbon atoms which are rolled into sheet of 1 nanometer. In these nanotubes light is emitted after absorbing light in infrared region. As wavelength of infrared light are not blocked by body fluid, therefore this nanotubes are used to get information about the body. These carbon nanotubes are constructed in such a way that when they bind to target compounds, there is change in fluorescence dimension, this helps in identifying molecule present in the body.

2. Types of Biosensors:

1. Optical biosensors: Technique used in this biosensor is based on surface plasma resonance.

2. Electrochemical sensing biosensors: Technique used in this biosensor is based on amperometric sensing, conductimetric sensing.

In amperometric sensing, increasing potential is applied to the cell until oxidation of the substance to be analysed occurs. This in turn increases the cell current and gives a peak current. The height of this peak current will be directly proportional to the concentration of electroactive substances or molecules In conductive sensors substrate concentration is measured using relationship between conductance and concentration of ionic species.

3. Enzymatic biosensors: This type of sensors is widely used as they are easy to use. For example glucosebiosensors. In glucose biosensor enzyme acts as a biorecognition element and recognizes only the glucose molecule. These enzymes are present in the electrode surface. When enzyme recognizes the glucose molecule it act as biocatalyst and produces gluconic acid and hydrogen peroxide using glucose and oxygen from the air. This reaction leads to the flow of electrons from hydrogen peroxide/oxygen coupling. This flow of electron is directly proportional to the number of glucose, molecules present in the biological fluid such as blood.

3. Applications of Biosensors:

Biosensors are used in various fields such as food industry, environmental field, medical care both in clinical as well as laboratory use, and also in biotechnology fields.

3.1. Health Care

Measurement of Metabolites The initial impetus for advancing sensor technology came from health care area, where it is now generally recognized that measurements of blood gases, ions and metabolites are often essential and allow a better estimation of the metabolic state of a patient.

In intensive care units for example, patients frequently show rapid variations in biochemical levels that require an urgent remedial action. Also, in less severe patient handling, more successful treatment can be achieved by obtaining *instant* assays. At present, the list of the most commonly required *instant* analyses is not extensive. In practice, these assays are performed by analytical laboratories, where discrete samples are analyzed, frequently using the more traditional analytical techniques.

Market Potential. There is an increasing demand for inexpensive and reliable sensors to allow not only routine monitoring in the central or satellite laboratory, but also analysis with greater patient contact, such as in the hospital ward, emergency rooms, and operating rooms. Ultimately, patients themselves should be able to use biosensors in the monitoring and control of some treatable condition, such as diabetes. It is probably true to say that the major biosensor market may be found where an immediate assay is required**.** If the cost of laboratory maintenance are counted with the direct analytical costs, then low-cost biosensor devices can be desirable in the whole spectrum of analytical applications from hospital to home.

Diabetes. The 'classic' and most widely explored example of closed-loop drugcontrol is probably to be found in the development of an artificial pancreas. Diabetic patients have a relative or absolute lack of insulin, a polypeptide hormone produced by the beta-cells of the pancreas, which is essential to the metabolism of a number of carbon sources. This deficiency causes various metabolic abnormalities, including higher than normal blood glucose levels. For such patients, insulin must be supplied externally. This has usually been achieved by subcutaneous injection, but fine control is difficult and hyperglycaemia cannot be totally avoided, or even hypoglycaemia is sometimes induced, causing impaired consciousness and the serious long-term complications to tissue associated with this intermittent low glucose condition.

Insulin Therapy. Better methods for the treatment of insulin-dependent diabetes havebeen sought and infusion systems for continuous insulin delivery have been developed. However, regardless of the method of insulin therapy, its induction must be made in response to information on the current blood glucose levels in the patient. Three schemes are possible the first two dependent on discrete manual glucose measurement and the third a 'closed-loop' system, where insulin delivery is controlled by the output of a glucose sensor which is integrated with the insulin infuser. In the former case, glucose has been estimated on 'finger-prick' blood samples with a colorimetric test strip or more recently with an amperometric 'pen'-size biosensor device by the patient themselves. Obviously these diagnostic kits must be easily portable, very simple to use and require the minimum of expert interpretation. However, even with the ability to monitor current glucose levels, intensive conventional insulin therapy requires multiple daily injections and is unable to anticipate future states between each application, where diet and exercise may require modification of the insulin dose. For example, it was shown that administration of glucose by subcutaneous injection, 60 min before a meal provides the best glucose/insulin management.

Artificial Pancreas. The introduction of a closed-loop system, where integrated glucose measurements provide feedback control on a pre-programmed insulin administration based on habitual requirement, would therefore relieve the patient of frequent assay requirements and perhaps more desirably frequent injections. Ultimately, the closed-loop system becomes an artificial pancreas, where the glycaemic control is achieved through an

implantable glucose sensor. Obviously, the requirements for this sensor are very different to those for the discrete measurement kits. As summarized in Table 1.4, the prolonged life-time and biocompatibility represent the major requirements.

3.2. Industrial Process Control

Bioreactor Control. Real-time monitoring of carbon sources, dissolved gases,. in fermentation processes could lead to optimization of the procedure giving increased yields at decreased materials cost. While real-time monitoring with feedback control involving automated systems does exist, currently only a few common variables are measured on-line (e.g. pH, temperature, CO_2, O_2)) which are often only indirectly related with the process under control.
Three different methods of controlling a bioreactor are:
1. Off-line distant: central laboratory coarse control with significant time lapse
2. Off-line local: fine control with short time lapse
3. On-line: real-time monitoring and control

On-Line Control. Method 3 is most desirable, which allows the process to follow an ideal pre-programmed fermentation profile to give maximum output. However, many problems exist with on-line measurements including in situ sterilization, sensor life-time, sensor fouling, etc. Some of the problems can be overcome if the sensor is situated so that the sample is run to waste, but this causes a volume loss, which can be particularly critical with small volume fermentations.

Off-Line Control. Although Method 3 may be the ultimate aim, considerable advantage can be gained in moving from Method 1 to Method 2 giving a rapid analysis and thus enabling finer control of the fermentation. The demands of the sensor are perhaps not as stringent in Method 2 as in Method 3.

Benefits of Control. The benefits which are achievable with process-control technology are considerable:
Improved product quality; reduction in rejection rate following manufacture
Increased product yield; process tuned in real time to maintain optimum conditions throughout and not just for limited periods
Increased tolerance in quality variation of some raw materials. These variations can be compensated in the process-control management

Reduced reliance on human 'seventh sense' to control process
Improved plant performance-processing rate and line speed automated, so no unnecessary dead-time allocated to plant
Optimized energy efficiency
The use of biosensors in industrial process in general could facilitate plant automation, cut analysis costs and improve quality control of the product.

3.3. Environmental Monitoring

Air and Water Monitoring. Another assay situation which may involve a considerable degree of the unknown is that of environmental monitoring. The primary measurement media here will be water or air, but the variety of target analytes is vast. At sites of potential pollution, such as in factory effluent, it would be desirable to install on-line real-time monitoring and alarm, targeted at specific analytes, but in many cases random or discrete monitoring of both target species or general hazardous compounds would be sufficient. The possible analytes include biological oxygen demand (BOD) which provides a good indication of pollution, atmospheric acidity, and river water pH, detergent, herbicides, and fertilizers (organophosphates, nitrates, etc.). The survey of market potential has identified the increasing significance of this area and this is now substantiated by a strong interest from industry. The potential applications of biosensors are summarized.

Tuning to Application. The potential for biosensor technology is enormous and is likely to revolutionize analysis and control of biological systems. It is possible therefore to identify very different analytical requirements and biosensor developments must be viewed under this constraint. It is often tempting to expect a single sensor targeted at a particular analyse, to be equally applicable to on-line closed-loop operation in a fermenter and pin-prick blood samples. In practice, however, the parallel development of several types of sensor, frequently employing very different measurement parameters is a more realistic.

3.4. Military Applications

Dip Stick Test. The requirement for rapid analysis can also be anticipated in military applications. The US army, for example, have looked at dipstick tests

Clinical diagnosis and biomedicine Farm, garden and veterinary analysis

Process control: fermentation control and analysis food and drink production and analysis

Microbiology: bacterial and viral analysis Pharmaceutical and drug analysis Industrial effluent control Pollution control and monitoring o Mining, industrial and toxic gases Military applications based on monoclonal antibodies. While these dipsticks are stable and highly specific (to Q-fever, nerve agents, yellow rain fungus, soman, etc.) they are frequently two-step analyses taking up to 20 min to run. Such a time lapse is not always suited to battlefield diagnostics; the resulting consequences are suggested.

A particularly promising approach to this unknown hazard detection seems to be via acetylcholine receptor systems. It has been calculated that with this biorecognition system, a matrix of 13-20 proteins are required to give 95% certainty of all toxin detection.

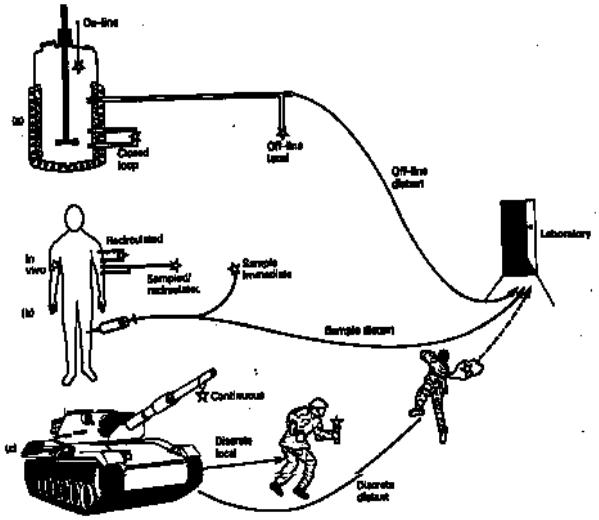

Fig. 1. Comparison of sensing modes: (a) bioreactor; (b) clinical applications; (c) military or environmental monitoring.

4. Future Prospects

Data Processing and Pattern Recognition. If we compare the present biosensors with the natural ones (of, for example, the nose or the eye), they are very crude and simplistic. The recognition molecules in the 'natural sensors' are not necessarily highly specific but the signal transduction via the biomolecules is sophisticated. The specificity often comes from processing of the data collected and recognizing the pattern via a continuous learning process. This mode of operation using the data collected from multiple biosensors is expected to be exploited in the future because the ever increasing capability of microprocessors will provide fast computation.

Micro Instrument. As shown in Fig 1, the third generation biosensors have built-in signal processing circuitry. When such sensors are combined with the micro scale valves and actuators currently under development (utilizing micromachining technology), a whole analytical instrument can be built on a silicon wafer. Such an instrument can be mass produced and used in a variety of applications including homes, hospitals, automobiles, toxic dump sites, etc.

Molecular Electronics. The effort to continuously increase the density of electronic components to obtain ever smaller 'packages' will be limited eventually, not by the microlithographic technique employed but by the minimum size allowable for a transistor (note that 'transistor' is the building block of microprocessors and memory chips).

Many biological molecules are able to synthesize complex self-organizing molecules with apparently just the required electronic properties. This suggests that the solution to this problem may be found in replacing silicon with biomolecular components. This idea has led to the proposition of many *molecular electronic* systems. In the past, materials and processing methods developed for microelectronic applications have been exploited in sensor developments. Therefore, any future developments in molecular electronics are expected to be imported into biosensor technology.

Multi-Disciplinary Nature. The arena of expertise required for biosensor development can be sustained by collaboration from many areas of academia and industry. The resulting output of this collaboration is likely in many cases to be a slow process, but is probably the only realistic route to successful future advances.

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