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A Study on Biosensors

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Abstract
Fast and authentic analyses is performed by analytic tools. Such analyses is required in different areas like medical and hospitality, security, food industry, environment monitoring. Biosensor is among one such analytic tool. During implementation in commercial sphere, there are imperfections which are needed to be mastered. In this study, we describe classification of biosensors, principles and recent technology development.

Keywords: Transducer, Nanoparticles, Biosensor, Bioreceptor

Introduction
Presently, to perform fast and exact analyses, reliable analytical devices are needed (Dzyadevych *et al.*, 2008) [10]. As such analysis is important in different areas like hygiene, food industry, environmental protection, drug development. Hence, monitoring and regulating various parameters as such area is increasing day-by-day. Use of the properly designed biosensors overcomes the traditional methods. Biosensors are still rarely used because of lack of useful practical applications for real samples. This is the major reason behind it. Therefore, scientists are now facing problems to develop some better existing concepts that new biosensors constructed will be applicable on real samples and also usable in commercial region. The first biosensor, an enzyme-based glucose sensor was developed by Clark and Lyons (1962) [9]. The main objective of this paper is to account the principle of biosensor and their applications in various food and agricultural industries and briefly discuss recent researches and future trends.
Recently, IUPAC has proposed a definition (Thevenot *et al.*, 1999) [21], "A biosensor is a self-contained integrated device which is efficient of providing certain quantitative analytical information with the help of a biological recognition component (biochemical receptor) which is in undeviating special contact with a transducer element. A biosensor must be clearly distinguished from a bioanalytical system as well as from a bioprobe. The former one requires more processing steps like addition of reagent while the latter one is disposable after single measurement i.e. not able to examine the analyte concentration continuously".

Biosensor is composed of 2 components:
(a) To convert (bio) chemical signals following from the interaction of the analyte with the bioreception into an electronic one, a transducer is used. There is a direct or indirect proportionality of the strength of generated signal to the analyte concentrate. To make biosensors, electrochemical transducers are oftenly used. There are many advantages like low cost, simple design that these systems offer. Biosensors can also be based on gravimetric, calorimetric or optical detection (Sassolas *et al.*, 2011) [20]. In accordance to basic principles of signal transduction and bio recognition elements, biosensors are classified. Biosensors can be categorized as electrochemical, optical, piezoelectric and thermal sensors (Thevenot *et al.*, 1999) [21] according to the transducing elements. Further classification of electrochemical biosensors includes amperometric, conductometric and potentio-metric sensors.
(b) A bioreceptor is an inactive sensitive biological element. For example DNA probe, antibody, enzyme identifying the analyte (e.g. antigen, enzyme substrate, complementary DNA). The most commonly used biosensing elements in biosensors are enzymes.

Principle:
The **b**asic principle of biosensor is made up of 3 elements:
1. First of all, production of biological recognition element takes place which is highly certain in the direction of biological material analytes.

2. After that due to the occurrence of reaction, transducers discover and transduces signal from biological target receptor molecule to electrical signal.
3. In the last, amplification of transduction signal from biological to electrical signal takes place which is necessary and then read out in detector after the processed values are displayed on monitor.

A contact is made between the inactive biological material and transducer. The analyte sticks to the biological material to form a bound analyte which as a result generates the electronic response that can be evaluated.

Occasionally, there is release of heat, gas, electrons or hydrogen ions takes place when analyte is converted. The transducer then transforms the product linked changes into electrical signal which can be measured after amplification.

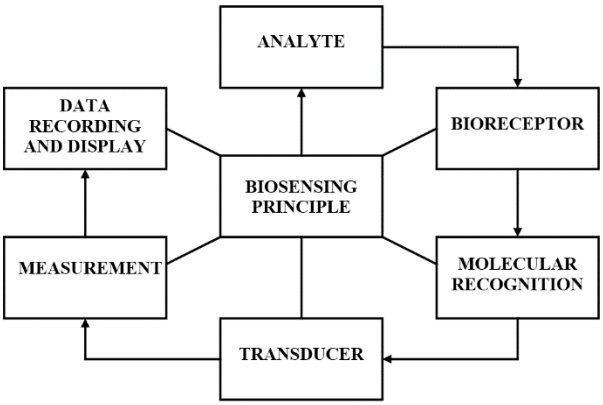

Fig 1: Basic principle of biosensor

Types of Biosensors:

1) **Potentiometric Biosensors:** To convert the biological reaction into electronic signal, these biosensors use ion-selective electrodes. The electrodes used are mainly PH meter electrodes coated with a gas selective layer (for NH or H_2S, CO_2) or electrodes of solid. Biosensor usually detects and measures the H^+ ion which is generated during reactions. In such cases, very weak buffered solutions are taken. To detect and measure the content of gas produced sensing electrodes are required. An illustration of potentiometric electrodes is based on urease which catalyzes the following reaction:-

$$CO(NH_2)_2 + 2H_2O + H^+ \rightarrow 2NH_4^+ + HCO^-_3$$

A PH sensitive, ammonium ion sensitive, NH_3 sensitive or CO_2 sensitive electrode can be used to measure this reaction. Now-a-days, the Biosensors which are extremely small are prepared by placing enzyme coated layers on the ion – selective gates of ion – selective field effect transistors (FET's)

2) **Optical Biosensors:** When both catalytic and affinity reactions are to be measured then optical biosensor are used. When products are produced by catalytic reactions, these biosensors evaluate a change in fluorescence or in absorbance. Secondly, some measurable changes are induced in the intrinsic optical properties of the biosensor surface due to assimilation of the dielectric molecules like protein (in case of affinity reactions). A firefly enzyme luciferase is used by the most promising biosensor (involving luminescence) to detect the presence of bacteria in food or clinical samples. The bacteria are particularly destructed to liberate ATP which in turn used by luciferase in presence of oxygen so as to produce electromagnetic wave having range 400 nm – 700 nm which is actually measured by the biosensor.
3) **Calorimetric Biosensors:** They measure the change in temperature of the solution having the analyte following enzyme action and result it in form of the analyte concentration in the solution. The analyte solution is moved through a compact packed bed column having inactive enzyme; just before the entry of the solution into the column takes place and just as it leaves the column using different thermistors, the temperature of the solution is measured.

   This sensor can be used for murky and powerfully coloured solutions. Hence, this is the most commonly applicable type of biosensor. The major disadvantage of such sensors is the sensitivity and quite low range for most of the applications i.e. one has to keep the temperature of the sample stream, say $\pm 0.01^0$C. This sensitivity can be enhanced by using two or more enzymes of the passage to join various reactions to increase the output of heat.
4) **Amperometric Biosensors:** When potential is applied between two electrodes, production of a current takes place. Such biosensors have electrodes which functions by the production of current; the current and substrate concentration are being proportional to each other. The fundamental ampeometric biosensors use the clark oxygen electrode which measures the decrease in amount of O_2 present in the analyte solution.

   A main disadvantage of such biosensors is their dependence on the dissolved O_2 congregation in the analyte solution. This problem may be overcomed by the use of mediators; these molecules transfer the electrons produced by the reaction directly to electrode instead of reducing the O_2 dissolved in analyte solution. They are also known as second generation biosensors. Without any help of mediators, electrodes remove the electrons directly from the reduced enzymes and are painted with electrically non-insulating organic salts.
5) **Acoustic Wave Biosensors:** Piezoelectric devices is the another name of such biosensors. The surface is generally coated by antibodies which stick to the commendatory antigen present in the sample solution. Consequently, mass is enhanced which in turn decreases their vibrations per second; to know the content of antigen in the sample solution, this change is measured.

Features of Biosensors:

1) **Linearity:** For the measurement of high substrate content, linearity of the sensor should be high.
2) **Sensitivity:** Utility of the electrode response per substrate concentration.
3) **Selectivity:** To have accurate results, chemical interference must be diminished.
4) **Response Time:** Time required having 95% of the response.

Applications of Biosensors:

1) **Agricultural Industries:** Enzyme biosensors constructed on retardation of cholinesterases have been used to measure traces of organophosphates and carbonates from pesticides. For the evaluation of ammonia and methane, selective and sensitive microbial sensors have been studied. BOD (Biological Oxygen Demand) analysers

based on micro-organisms such as Bacteria Rhodococcus erythopolis inactive in collagen is commercially available biosensors for wastewater quality control.

2) **Food Industry:** Biosensors are commercially available for the evaluation of carbohydrates, acids and alcohols. In quality assurance labs, such devices are generally used in on-line coupled to the processing line by a flow injection analysis system. The execution in-line is restricted by the requirement of analyte dilution, sterility, frequent calibration etc.
3) **Environmental screening:** During environmental pollution observation, chemical analysis by itself may not give data upto mark to evaluate the ecological risk of contaminated water and wastewaters (Castillo *et al.*, 2001). As a result, lots of biosensors for toxicity measurement were developed in the current years. For instance, the toxicity assays Microtox® (UK, Azure, Bucks) is based on the use of vibrio fischeri, lumnicent bacteria to measure toxicity from the surroundings.

Recent Technology in Biosensors:

1) **MEMS/NEMS Based Biosensors:** The interests in micro electromechanical systems (MEMS), nano electromechanical system (NEMS) and microfluidic systems have increased due to the growing need of biosensors. Such systems which are miniaturized give more sensitive, high performance, specific, accurate, cost-effective biosensor devices. Several methods are used in MEMS which includes magnetic, electrochemical, optical and mechanical detections. Semiconductor quantum dots, organic dyes and other optical fluorescence probes are used in optical detection methods. In magnetic MEMS biosensors conjugation of magnetic, paramagnetic or ferromagnetic nanoparticles have been used. The changes in mass and in surface stress are the factors which are responsible for designing of mechanical MEMS. The electrochemical MEMS based biosensors use potentiometric, amperometric or conductometric detection.
2) **Carbon Nanotube Based Biosensors:** Early cancer detection *in vitro* systems is one of the most modern discoveries from carbon nanotube based biosensors. The unique chemical and physical properties have made it possible. The particular coated surface of nanotubes could be used for measuring proteins and viruses of interests. The major reason of this invention are observable changes in the electrical conductivity of the nanotubes when distance between the antibody and protein changes. An electrical meter is used to measure this change of distance. These nanotubes have been largely used in DNA, glucose, dehydrogenase, peroxidase and catalase sensors.
3) **Graphene Quantum Dots Based Biosensors:** Graphene Quantum Dots (GD) have zero dimension. GD is one of the grapheme derivatives; are photo-luminescent materials obtained from grapheme or carbon fibers. GD have very unique properties in combination of quantum confinement and zig-zag edge effects. The ultra nanosized GD with large area of emission spectrum are a pipe dream for applications in photoluminescence, electrochemical and electrochemical luminescence and electronic sensors fabrication for several biological and chemical analyses.
4) **Quantum Dots Based Optical Biosensors:** Due to the ultra-stability and excellent quantum confinement effects, semiconductor quantum dots (QD) are one of the most promising optical imaging agents for *in vivo* (noninvasive imaging of deep tissues) and *in vitro* (biosensors and chemical sensors) diagnosis of diseases. QD have narrow size (5-10 nm in diameter) and a broad excitation tunable emission spectrum with narrow emission bandwidth. Due to these unique properties, QD are used in a wide range of fields like biosensor, electronics, biomolecules (protein, nucleic acids and enzymes), biology and solar cells. The decoration of QD and modification of surface have inspired the development of biosensors which are based on novel multimodel probes through linking with nuclei acids, peptides or targeting ligands. The fluorescence transduction based on physical or chemical interaction occurs on the surface either through quenching or direct photo luminescent activation since the fluorescence intensity of QD is highly sensitive and stable. The recent advancements in application of QD in tissue engineering are essential achievements of biosensing research to detect the biomolecules and enzymes.

Merits of Biosensors:

Some of the advantages of biosensors are listed as:

1) Continuous and rapid control is possible with them.
2) They can even detect non-polar molecules which don't give response to many other measurement devices.
3) They are practically applicable.
4) Response time is very short (generally less than a minute)

Conclusion:

In this paper the classification of the biosensors and techniques to implement them are discussed alongwith the working principles, advantages and application of many biosensors. Some biosensors were successfully implemented, yet a large number of them need to be improved so as to destroy irregularities. The coming generation of biosensors based on nanostructures could result into a formation of devices which are able to perform noticeably challenge with other analytical methods used today and can bring an useful change.

References

1. Alvarez-Gonzalez MI, Saidman SB, Lobo-Castanon MJ, Miranda-Ordieres AJ, Tunon-Blanco P. *Anal. Chem*. 2000; 72:520-527.
2. Antonelli ML, Spadaro C, Tornelli RF. *Talanta* 2008; 74:1450-1454.
3. Banerjee P, Bhunia AK. *Biosens. Bioelectron*. 2010; 26:99-106.
4. Bhand SG, Soundararajan S, Surugiu-Warnmark I, Milea JS, Dey ES, Yakovleva M, Danielsson B. *Anal. Chim. Acta*. 2010; 668:13-18.
5. Britto PJ, Santhanam KSV, Ajayan PM. *Bioelectrochem. Bioenerg* 1996; 41:121-125.
6. Bučkova M, Labuda J, Šandula J, Križkova L, Štepanek I, Duračkova Z. *Talanta* 2002; 56:939-947.
7. Castillo M, Alonso MC, Riu J. *et al.* Anal. Chim. Acta 426: 265-277. 24. Cevik E, Şenel M, Abasıyanık MF (2010) *Curr. Appl. Phys*. 2001; 10:1313-1316.
8. Chaubey A, Malhotra BD. *Biosens. Bioelectron*. 2002; 17:441-456.
9. Clark LC, Lyons C. Electrode systems for continuous monitoring cardiovascular surgery. *Ann. N. Y. Acad. Sci*. 1962; 102:29-45.

10. Dzyadevych SV, Arkhypova VN, Soldatkin AP, Elskaya AV, Martelet C, Jaffrezic-Renault N. 2008; 29:171-180.
11. Hasan A, Nurunnabi M, Morshed M, Paul A, Polini A, Kuila T *et al.* Review Article Recent Advances in Application of Biosensors in Tissue Engineering. *Bio Med Research International*, 2014, 1-18.
12. Karl H, Willig A. A Short Survey of Wireless Sensor Networks, Technical University Berlin, Telecommunication Networks Group, 2003.
13. Kim K, Cheng J, Liu Q, Wu XY, Sun Y. MEMS capacitive force sensors for micro-scale compression testing of biomaterials, in Proceedings of the 21st IEEE International Conference on Micro Electro Mechanical Systems (MEMS '08), pp. 888–891, Tucson, Ariz, USA, 2008.
14. Kim K, Cheng J, Liu Q, Wu XY, Sun Y. Investigation of mechanical properties of soft hydrogel microcapsules in relation to protein delivery using a MEMS force sensor. *Journal of Biomedical Materials Research A*, 2010; 92(1):103-113.
15. Mao S, Yu K, Chang J, Steeber DA, Ocola LE, Chen J. Direct growth of vertically-oriented graphene for field-effect transistor biosensor. Scientific Reports 2013; 3:1696.
16. Monošik R, Streďansky M, Greif G, Šturdik E. Cent. Eur. J Chem. 2012; 10:157-184.
17. Monošik R, Streďansky M, Lušpai K, Magdolen P, Šturdik E. *Enzyme Microb. Tech* 2012; 50:227-232.
18. Nidhi uppangala. Charscteristics and applications of biosensors. *Biotech articles,* 2010
19. Prasad NR, Alam M. Security Framework for Wireless Sensor Networks. Wireless Personal Communications 2006; 37:455-469.
20. Sassolas A, Blum LJ, Leca-Bouvier BD. Immobilization Strategies to Develop Enzymatic Biosensors Biotechnology Advances 2011; 30(3):489-571.
21. Thevenot DR, Toth K, Durst RA, Wilson GS. Electrochemical Biosensors: Recommended Definitions and Classification. *Pure Appl. Chem.*, 1999; 7:2333-2348.
22. Timurdogan E, Alaca BE, Kavakli IH, Urey H. MEMS biosensor for detection of Hepatitis A and C viruses in serum. Biosensors and Bioelectronics 2011; 28(1):189-194.
23. Wittman C, Riedel K, Schmid RD. Microbial and Enzyme Sensors for Environmental Monitoring. In Handbook of Biosensors and Electronic Noses. Medicine, Food and the Environment; Kress-Rogers, E., Ed.; CRC Press: New York, 1997, 305-306.
24. Xu Y, Heidemann J, Estrin D. Geography-Informed Energy Conservation for Ad Hoc Routing, Proceedings of the 7th Annual International Conference on Mobile Computing and Networking. *Mobi Com* 2001; 1:70-84.