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Acoustic biosensor: A brief review

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Abstract

Recently, the need for the rapid and accurate detection of different biological substances has led to the rapid development of a wide variety of biosensors. This has resulted to the development of biosensors and their applications across several domains, such as biotechnology, disease diagnosis, drug detection and food control. The technological progress of integrated reading circuits has led to the creation of small-scale bioremediation devices with high accuracy, fast response time and the ability to control real-time biomolecular interactions. Therefore, the heyday of electronic circuits and the design of detection devices contributes to the progress and the study of applications of interdisciplinary interest.

Key words: *Biosensor; Acoustic physics*

INTRODUCTION

A biosensor is a complete device that is independent and capable of displaying specific quantitative or semi-quantitative analytical information, using a biochemical receptor, i.e., a biological identifier that is in direct contact with a converter element. In 1969 the first potentiometric biosensor was built by Guilbault and Montalvo. Subsequently in 1980, the optical biosensors revolution began with the construction of the first fiber optic sensor for the in vivo detection of gases in the blood (Peterson). In 1983 the first surface plasmon resonance (SPR) immunosensor was produced and, in 1984 the first ammeter-mediated biosensor: ferrocene is used with glucose oxidase to detect glucose [1].

Analyzing the functional parts of a biosensor, we first encounter the bio-receptor which is integrated into a converter element, which converts the measured element into an output signal. A bio-receptor is a biological or biologically derived sensory element that typically uses certain types of molecules to identify biochemicals, such as enzymes, antibodies, nucleic acids, proteins, or a biological system (cells, tissues).

Thus, biosensors are divided based on the type of bio-receptor, into biogenic, where the bio-receptors have either antibodies or nucleic acid samples, and into biocatalysts, where the bio-receptors have a cell, enzyme, or tissue. Most transmission mechanisms are either optical or electrochemical based on mass, i.e., piezoelectric. In addition, electrochemical detection is based on the chemical properties of the specific substances which are present in a solution (analyzers) and are measured compared to a reference electrode. By selecting the mass-based detection method, the change in the frequency of the piezoelectric crystal, which depends on the mass of the crystal and the frequency of the applied electrical signal, provides useful information.

Biosensors are categorized based on the type of inverter in: electrochemical (ammeter, potentiometric, conductivity), optical (fiber optic, surface plasmon tuning, fluorescent), calorimetric (heat-conducting, isothermal, iso-environmental) and acoustic (surface acoustic wave, piezoelectric).

Acoustic Biosensors: Definition & Function

Electroacoustic biosensors function by detecting a change in mass density, due to the elastic, electrical or

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dielectric properties of a membrane. This membrane consists of chemically interacting materials which are in contact with a piezoelectric material. In 1880 the Curie brothers discovered the piezoelectric effect, named after Henkel in 1881 and used in 1921 by Cady [2]. In piezoelectric sensors, when alternating voltage is applied, mechanical waves will be generated which will propagate through the substrate and will be converted back into an electric field which will be recorded as an electrical signal.

Exploiting elastic or acoustic waves is a modern challenge that could offer great opportunities for evolving technological applications [3]. Acoustic waves are longitudinal or transverse in the direction of their propagation and are characterized by surface or volume according to the dimensions of the instrument in which they propagate [4]. Acoustic sensors are divided into two categories depending on the type of wave they are operating. These are the BAW (volume wave based) acoustic sensors and the SAW surface acoustic sensors.

In acoustic volume sensors, the energy of the wave is diffused throughout the volume of the material to which it propagates, which is why these sensors are characterized by lower sensitivity. In contrast, in acoustic surface sensors, surface waves limit all their energy to the surface of the material to which they propagate, resulting in a higher sensitivity [4,5]. As the wave propagates, the surface of the sensor and any mass on it will oscillate simultaneously and thus an acoustic wave will be generated simultaneously. These changes depend on both the frequency at which the sensor oscillates and the type of the sensor. As a rule, increasing the operating frequency produces greater acoustic changes. When operating in an aquatic environment, the liquid in contact with the surface will oscillate following its movement, thus creating a damping acoustic field on the surface between liquid and solid (Figure 1) [6].

Applications

The need to study the interactions with other biological boundaries led to the creation of applications that involve the development of membrane bilayer models on surfaces. Other applications provide information on the kinetics of the interactions [7]. Recently, a class of Love type sensors was constructed which were designed to immobilize on their surface [8]. Tangibles specifically recognize a protein that is associated with blood clotting, thrombin and is a target for therapeutic agents.

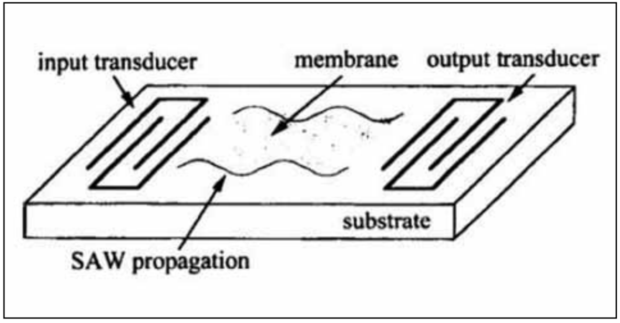

Figure 1. The propagation of sound waves on the surface of a sensor [6].

Over the last decade, significant applications of piezoelectric biosensors have emerged, such as the reliable and rapid detection of the hepatitis B^9 virus. At the same time, there were cases of coupling of biosensors with other techniques such as atomic force microscopy, surface plasma tuning, and fluorescence microscopy in an attempt to increase their sensitivity and resolution [9].

In general, the number of commercially available instruments has increased significantly with the aim of developing sensors to study virtually any type of receptor-analyte interaction. The great challenge lies in the development of methods that combine biotechnology with the science of chemistry, biology, and physics for the simultaneous, multiple and needless labeling analysis of various bio-critical interactions in each area of modern research.

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