Rapid Detection of Tuberculosis without Pain and Blood: Biosensors Offer New Alternatives

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Varun Patel : I am interested in Drug Delivery Systems and a bit of Biotechnology too. I believe that Pharmacy is a truly noble field as it seeks to resurrect ill humans. Although new diseases crop up as our technology progresses, I wish to find a cure to all diseases that haunt our healthy world. The ultimate aim of my life is to infuse 'Godliness' in myself and the other members of the society. By this, I mean that I want to create medicines that will bestow the gift of immortality on the society.

Shobit Gogia : I wish to pursue my doctoral studies in Chemical Engineering. My primary research interests are Biochemical Engineering, Biomedical engineering, Environment and Energy. Chemical Engineering is an extremely potent and versatile discipline, and its advancement is one of the most desirable phenomena for society's betterment. I also want to contribute to this noble cause and wish to serve the society as an educationist-cum-researcher.

Abstract

Biosensors are chemical sensors that take advantage of the high selectivity and sensitivity of a biologically active material. The objective of the research described here is to use biosensor technology to develop a rapid method for the diagnosis of tuberculosis and other infections caused by mycobacteria. The work encompassed here describes the construction of antibody-based piezoelectric crystals capable of detecting mycobacterial antigens in diluted cultures of attenuated M. tuberculosis in an immunologically specific manner. The antigens were detected in either liquid or vapor phase.

Keywords: Biosensors, Tuberculosis, Piezoelectric, Immunosensing

1. Introduction

What is a Biosensor ?

A biosensor is an analytical tool consisting of biologically active material used in close conjunction with a device that will convert a biochemical signal into a quantifiable electrical signal. Biosensors have many advantages, such as simple and low-cost instrumentation, fast response times, minimum sample pretreatment and high sample throughput.

A biosensor has two components: a receptor and a detector. The receptor is responsible for the selectivity of the sensor. Examples include enzymes, antibodies and lipid layers. The detector, which plays the role of the transducer, translates the physical or chemical change by recognizing the analyte and relaying it through an electrical signal. The detector is not selective. For example, it can be a pH-electrode, an oxygen electrode or a piezoelectric crystal. Figure 1 describes a typical biosensor configuration that allows measurement of the target analyte without using reagents. The device incorporates a biological-sensing element with a traditional transducer. The biological-sensing element selectively recognizes a particular biological molecule through a reaction, specific adsorption, or other physical or chemical process and the transducer converts the result of this recognition into a usable signal, which can be quantified.

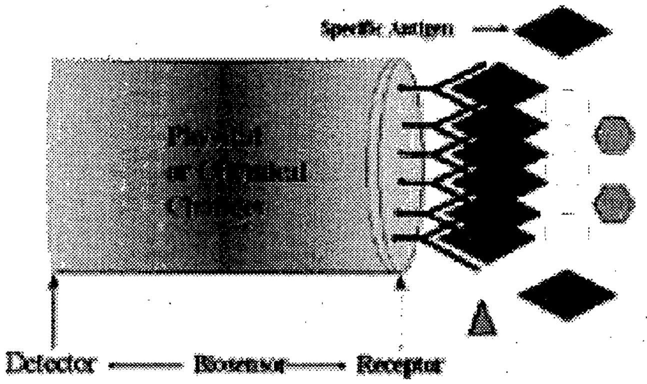

Figure 1 : Typical Biosensor Configuration

Almost all current methods of diagnosing tuberculosis (TB) have drawbacks. They tend to be either nonspecific or too time-consuming. In most cases of pulmonary and extrapulmonary TB, diagnosis depends upon culturing the mycobacterial organism, a process requiring 4-8 weeks. Significant attention has been devoted to developing more rapid diagnostic methods for TB, but some of them do not have the high specificity or sensitivity required for proper diagnosis.

A piezoelectric sensor that could reliably detect the mycobacterial antigen in biological fluids would be of enormous use. For instance, detection of the antigen in saliva could constitute a noninvasive method of screening high-risk populations. One tested piezoelectric crystal sensor gives results within a couple of hours after exposing the electrode to a liquid containing the antigen. The apparatus would be quite portable, so the immunological tests could be performed virtually anywhere and the results could be obtained very quickly. The feasibility of using piezoelectric immunosensors to diagnose TB based upon the detection of mycobacterial antigens in liquid depends upon the degree of sensitivity and specificity that can be achieved and upon overcoming any problems caused by potentially interfering substances in biological fluids. The feasibility of gas- or vapor-phase detection of antigen depends upon these same factors, plus any difficulties that may be unique to gas-phase antigen capture by antibodies.

2. Piezoelectric Biosensors: Background

The interaction of antibodies with their corresponding antigens is an attractive reason for attempting to develop antibody-based chemical biosensors, i.e. immunosensors. Theoretically, if an antibody can be raised against a particular analyte, an immunosensor could be developed to recognize it. Despite the high specificity and affinity of antibodies towards complementary ligand molecules, most antibody-antigen interactions do not cause an electronically measurable change. However, the remarkable selectivity of antibodies has fueled much research to overcome this intrinsic problem. The piezoelectric effect in various crystalline substances is a useful property that leads to the detection of analytes. Figure 2 shows a schematic diagram of an immunsensor device.

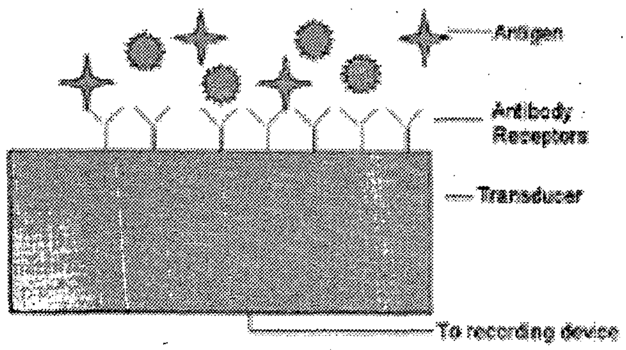

Figure 2. Schematic diagram of an immunosensor device. [Ref]

The piezoelectric immunosensor is thought to be one of the most sensitive analytical instruments developed to date, being capable of detecting antigens in the picogram range. Moreover, this type of device is believed to have the potential to detect antigens in the gas phase as well as in the liquid phase.

3. Theoretical Principles

The basic equations describing the relationship between the resonant frequency of an oscillating piezoelectric crystal and the mass deposited on the crystal surface have been derived, by Sauerbrey, he developed an empirical equation for AT-cut quartz crystals vibrating in the thickness shear mode that describes the relationship between the mass of thin metal films deposited on quartz crystals and the corresponding change in resonant frequency of the crystal:

$$\Delta F = -2.3 \times 10^{6} F^{2} \frac{\Delta M}{A}$$

where, ΔF = frequency change in oscillating crystal in Hz, F = frequency of piezoelectric quartz crystal in MHz, ΔM = mass of deposited film in g and A = area of electrode surface in cm^2.

The piezoelectric crystal detector can be a very powerful analytical tool because of the relationship between change in frequency to the analyte concentration with high sensitivity. The crystal detector indiscriminately changes frequency due to the deposition of mass of any material on its surface. Thus, it is the task of the researcher to choose a coating that will undergo a highly selective chemical or physical binding with the substance to be detected. Only then can a highly selective sensor be constructed that will be sensitive to the subject to be detected.

4. Conclusion

Biosensors for detection of tuberculosis have achieved prominence in the world diagnostics market and are now being joined by a diverse array of biosensors for detecting other analytes of clinical importance.

5. References

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