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WHAT IS A BIOSENSOR?

By

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A biosensor is an analytical device, applied for the detection of a target analyte of interest. Some people may think that they never encountered a biosensor before in their lives. One of the most common biosensors that are being used in our daily life is the glucose biosensor. The glucose strip is actually a biosensor and the device's component that shows the glucose reading is the data processor. A pregnancy test stick is another commonly used biosensor that involves the detection of pregnancy hormones. Recently, thanks to the COVID-19 pandemic, the whole wide world now knows of the antigen test kit; which is also, you guessed it, a biosensor!

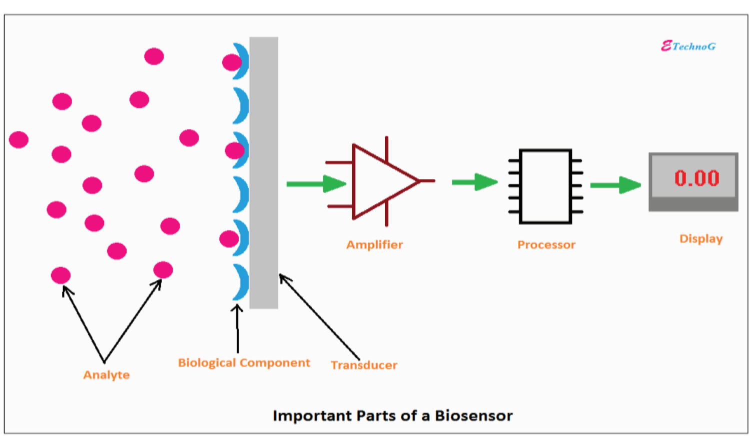

Figure 2. The major components of a biosensor. (*Source: ETechnoG, https://www.etechnog.com/2019/08/biosensor-applications-uses-examples.html*)

There are numerous types of biosensors currently developed for countless applications. However, the components will always be comprised of bioreceptor, transducer, and data processor, as shown in Figure 2. The target analyte can be of various components which include nucleic acids, whole cells, body tissues, peptides, proteins, enzymes, antibodies, microorganisms, and even chemical compounds (Askim and Suslick, 2017). The type of target analytes usually determines the type of bioreceptor that is being immobilized onto the transducer.

Figure 1. Commonly used biosensors. The top left is the glucose biosensor, the top right is the COVID-19 rapid test kit, and the bottom is the pregnancy test kit.

(*Sources: https://www.thequint.com/fit/3d-printed-biosensor-for-diabetic-patients; https://www.thestar.com.my/news/nation/2022/03/16/some-are-falsifying-test-results-to-skip-work; https://www.1mg.com/articles/home-pregnancy-test-kits-how-why-and-when-to-use-it/*)

The bioreceptor is the most crucial and sensitive part of the biosensor. Different types of bioreceptor produce different types of biosensors. The receptors responsible for sensitively detecting the target analyte can be chemical compounds or biological molecules which include proteins, enzymes, and single-stranded DNA (ssDNA).

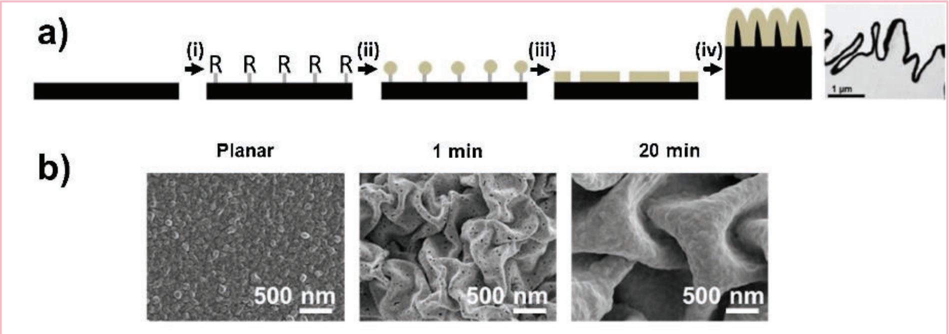

Figure 3. Wrinkled electrode prepared for a sensitive glucose biosensor. (Adams-McGavin et al., 2017)

This is the biocomponent that reacts with the target analyte from the environmental sample and produces a significant signal to be received by the transducer. The signal receives by the transducer will then be translated and displayed in a readable format to be analyzed.

The transducer of a biosensor is comprised of a substrate and a matrix on which the bioreceptors were immobilized onto. To date, numerous matrix bodies were designed to address multi-level sensitivities of the developed biosensor. In the preparation of biosensors, matrix fabrication plays a vital role in influencing the final performance of the produced biosensor. Some attributes that are being investigated in a fabricating material are the ability to increase electrode conductivity and effective surface area. The total effective surface area is a very important factor as it determines the loading capacity of bioreceptors on a sensor. A high total effective surface area should allow higher bioreceptor immobilization which influences the performance of the produced biosensor (Prakash et al., 2013; Shi et al., 2011; Y. Wang et al., 2017).

A study by Robert C. Adams-McGavin and colleagues (2017) describes the importance of the higher surface area in biosensors in influencing the efficiency of the device. A sensitive glucose biosensor has been developed with the application of a wrinkled electrode surface to increase the effective surface area (Figure 3). Compressive stress was applied onto the polymer substrate modified with stiff thin film, yielding a wrinkled surface while creating three-dimensional electrodes. This method successfully helped in increasing the sensitivity of the biosensor prepared.

As a component of the transducer, the substrate also plays an important role in contributing to the credibility of the biosensor. Electrochemical reactions take place on the surface of the electrode substrate.

Each individual substrate contributes to a different reaction and measurement of a target analyte. The substrate offers the opportunity to be fabricated with materials that enhance biosensor performance. The most frequently used electrodes as the substrate in other research studies are glassy carbon electrodes (GCE), gold electrodes (AuE), and indium-tin-oxide-coated glass electrodes (ITO) as portrayed in Figure 4.

Figure 4. Frequently used electrode substrates. The top left is the GCE, the top right is the AuE, and the bottom is the ITO. (*Sources:* *https://www.x2lab.com.sg/productdetail/?Glassy-Carbon-Electrodes; https://www.metrohm.com/en_nl/products/i/deau/ideau200.html; https://www.sigmaaldrich.com/MY/en/product/aldrich/636908*)

The working principle of biosensors depends on the different types of signal transducers being utilized; optical, optoelectronic, electrochemical, thermometric, magnetic, and piezoelectric biosensors (Farré and Barceló, 2007).

Let's have a look at an optical biosensor. For example, the bioreceptor of a biosensor is an enzyme. This enzyme catalyzes the metabolism of a target substrate which produces a blue-colored product. So regularly, without the presence of the target substrate, the absorbance (signal transducer) will be different as compared to when the substrate is available as the color of the reaction would change. The fluctuation of the absorbance will be the significant signal for the detector that will be visualized as a measurable result. The whole reaction is depicted in Figure 5.

In a nutshell, the basic principle of a biosensor is the effect of the analyte-bioreceptor interaction towards the transducer. The analyte-bioreceptor interaction causes a significant fluctuation of reading, by comparing the before and after of the reaction which will be then translated by the data processor into a quantifiable measurement.

The high sensitivity, selectivity, and accuracy make the biosensor a promising device to be applied in many fields. This is why research on biosensor development is still active as the potential of this technology has yet to reach its limit.

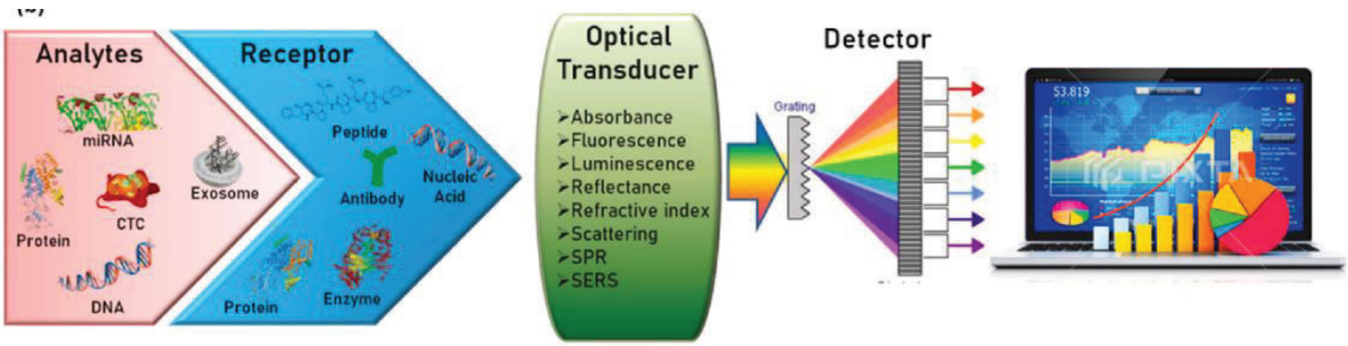

Figure 5. The components for optical biosensors. (Soni et al., 2022)

A different mechanism is being applied in an electrochemical biosensor. For example, a DNA-based electrochemical biosensor depends on the hybridization state of the bioreceptor. The biosensor will have the ssDNA as a bioreceptor immobilized onto a chosen transducer. The initial impedance and electroconductivity will be measured to identify the base measurement without the presence of a target analyte. After exposure to the environmental sample, if the target ssDNA is present, hybridization of the analyte and bioreceptor will occur. This reaction influences a significant change in the impedance and conductivity measurement. The fluctuation of the parameters will be recorded as the biosensor detection input. An example of an existing electrochemical study is depicted in Figure 6 that shows the different voltammetry measurements between non-hybridized and hybridized biosensors. The difference in measurement can be further calculated for a quantitative study.

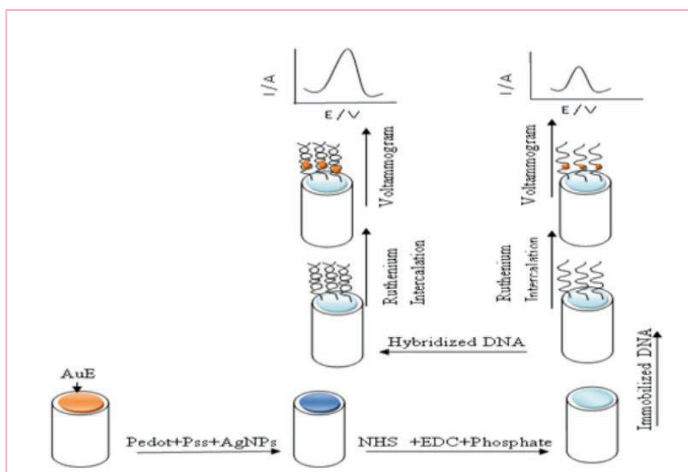

Figure 6: The differential pulse voltammetry measurement for non-hybridized vs hybridized DNA-based electrochemical biosensors. (Dutse et al., 2013)