Biosensors EEL3050

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Commercially Available Biosensors

Commercially available biosensors are widely used in healthcare, environmental monitoring, food safety, and industrial applications. These biosensors combine biological recognition elements with transducers to convert biological interactions into measurable signals. Below are some commonly used biosensors, their functioning, and related industrial standards:

Glucose Biosensors (e.g., Continuous Glucose Monitors):

Functioning:

Glucose biosensors are crucial medical devices used predominantly for monitoring blood glucose levels in diabetic patients. Diabetes management relies on accurate and continuous tracking of glucose levels to maintain appropriate blood sugar levels, prevent complications, and ensure optimal health. These sensors play a key role in providing real-time glucose readings, enabling patients to make informed decisions regarding their insulin doses, dietary intake, and exercise routines.

In continuous glucose monitoring (CGM) systems, the glucose biosensor is typically inserted under the skin where it continuously measures the glucose levels in the interstitial fluid. These systems automatically track glucose levels throughout the day and night, sending data to a display device or smartphone application, which alerts the patient if the glucose levels rise too high (hyperglycemia) or drop too low (hypoglycemia).

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Glucose Biosensors (e.g., Continuous Glucose Monitors):

Working Principle:

The core component of a glucose biosensor is the **enzyme glucose oxidase (GOx)**, which catalyzes the oxidation of glucose ($C_6H_{12}O_6$) to gluconic acid. During this biochemical reaction, glucose is oxidized by oxygen (O_2), producing **hydrogen peroxide (H_2O_2)** and gluconic acid.

This hydrogen peroxide is then oxidized at the sensor's working electrode, generating an electrical current that is proportional to the glucose concentration in the interstitial fluid or blood. The transducer in the biosensor converts the biochemical reaction into a measurable electrical signal, which is processed by an onboard algorithm to calculate glucose concentration in real time.

Example: Abbott FreeStyle Libre, Dexcom G6

Industrial Standards:

- ISO 15197:2013: Requirements for blood-glucose monitoring systems for self-testing.
- FDA 510(k) for regulatory compliance in the U.S.
- ISO 13485:2016: Standard for medical devices' quality management systems

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Lactate Biosensors :

Functioning :

Lactate biosensors are essential tools used to measure lactate levels in biological fluids like blood and sweat. Lactate, a byproduct of anaerobic metabolism, is produced in muscles during intense physical activity when oxygen levels are insufficient to meet energy demands. Monitoring lactate levels helps assess physical performance, fatigue, and overall health, particularly in sports medicine, clinical diagnostics, and even in critical care settings for conditions like sepsis.

Working Principle :

The core of a lactate biosensor relies on the enzyme **lactate oxidase (LOx)**. Lactate oxidase catalyzes the oxidation of lactate to pyruvate, producing **hydrogen peroxide (H_2O_2)** as a byproduct.

When H_2O_2 is oxidized at the working electrode, it releases electrons, generating a current. The intensity of the current is directly proportional to the lactate concentration. The sensor then converts this current into a measurable signal, which is processed and displayed.

Example: Lactate Pro 2

Industrial Standards:

- CE Marking for Europe compliance.
- ISO 13485:2016 for quality management.

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Wearable Biosensors (e.g. Smartwatches):

Functioning :

Wearable biosensors are integrated into devices like smartwatches to measure physiological parameters such as heart rate, blood oxygen levels, and electrodermal activity.

Working Principle :

These sensors use optical, electrical, and mechanical transducers. For example, pulse oximeters use optical sensors to measure blood oxygen by analyzing light absorption.

Pulse oximeters rely on light absorption by oxygenated and deoxygenated hemoglobin in the blood. The device emits two types of light, **red light (around 660 nm)** and **infrared light (around 940 nm)**, through a body part, typically the fingertip or earlobe.

- **Oxygenated Hemoglobin** absorbs more infrared light and allows more red light to pass through.
- **Deoxygenated Hemoglobin** absorbs more red light and allows more infrared light to pass through.

The sensor on the opposite side of the body part detects the amount of transmitted light, and the difference between red and infrared absorption provides a measure of the percentage of oxygen in the blood.

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Wearable Biosensors (e.g. Smartwatches):

Example : Apple Watch, Fitbit

Industrial Standards: ISO 80601-2-61:2017: Standards for pulse oximeters.
•FDA regulations for medical-grade wearables.
•IEC 60601 for medical electrical equipment.

DNA Biosensors :

Functioning :
DNA biosensors detect specific nucleic acid sequences, widely used in genetic testing, infectious disease diagnostics, and forensics.

Working Principle:
DNA biosensors function based on the interaction between a **probe DNA** immobilized on the sensor surface and a **target DNA** present in the sample. When these complementary DNA strands hybridize, a specific signal is generated, which is then detected by various transducer types (electrochemical, optical, or mechanical).

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DNA Biosensors :

Example :
GeneChip (Affymetrix)

Industrial Standards:

- ISO 18385:2016: Minimizing contamination in forensic DNA analysis.
- ISO/IEC 17025:2017 for laboratory testing standards.

pH and Ion Sensors (e.g. pH Meters :

Functioning: These biosensors measure the pH or ion concentration in solutions and are extensively used in food, environmental monitoring, and healthcare (e.g., blood gas analyzers).
Working Principle: These sensors rely on ion-selective electrodes (ISE) to detect specific ions, with changes in ion concentration causing changes in the electrical potential that is measured.
Example: Hanna Instruments pH meters

Industrial Standards:
•ISO 10523:2008: Determination of pH.
•FDA standards for IVD devices in healthcare.

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Cholestrol Biosensors :

Functioning: Cholesterol biosensors are used to monitor cholesterol levels in blood, crucial for managing cardiovascular diseases.

Working Principle: Enzymes like cholesterol oxidase and esterase are used to catalyze reactions involving cholesterol, generating a measurable electrochemical signal.

Example: CardioChek

Industrial Standards:

•ISO 15197:2013 for glucose and cholesterol monitoring systems.

•CE and FDA standards for medical devices.

Food and Safety Biosensors :

Functioning: These biosensors are used to detect pathogens, toxins, and allergens in food products, ensuring food safety and quality.

Working Principle: They rely on immunoassay-based methods (e.g., ELISA) or aptamer-based detection, where the binding of the target molecule triggers a signal from an optical or electrochemical transducer.

Example: iQ-Check for pathogen detection in blood

Industrial Standards: ISO 22000:2018: Food safety management systems; HACCP (Hazard Analysis and Critical Control Point) standards

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Environmental Biosensors (e.g. Water Quality Sensors):

Functioning: These biosensors detect pollutants, heavy metals, and other harmful substances in water or air.
Working Principle: Enzyme-based or microbial biosensors convert the interaction with pollutants into a measurable electrical or optical signal.
Example: Aquasensors for water quality monitoring
Industrial Standards:
•ISO 14001:2015 for Environmental Management Systems
•EPA (Environmental Protection Agency) standards

Pregnancy Test Kits:

Functioning: These biosensors detect the presence of human chorionic gonadotropin (hCG) hormone in urine to determine pregnancy.
Working Principle: Lateral flow assays detect hCG through antigen-antibody interactions, producing a color change visible on the test strip.
Example: Clearblue Pregnancy Test.
Industrial Standards:
•FDA regulations for In-Vitro Diagnostic Devices.
•CE marking for compliance in Europe.