CELTIC ADVANCED LIFE SCIENCE
INNOVATION NETWORK

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A Brief Guide to Biosensors

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Biosensors research overview

A biosensor is a powerful and innovative analytical tool, which integrates a biological recognition element to a physio-chemical transducer to detect biological substances. The International Union of Pure and Applied Chemistry (IUPAC) defines a biosensor as “a device that uses biochemical reactions mediated by isolated enzymes, organelles or whole cells to detect the effects of chemical compounds by electrical, thermal or optical signals”. The world first biosensor was invented in 1962 by Clark and Lyons to electrochemically measure glucose in biological samples. Since, its discovery in 1962 by Clark and Lyons, biosensors have gained prominence that is evident by their extensive use in various fields. Although Clark is considered as the father of the modern “Biosensor” concept, however the term biosensor was first coined by Karl Cammann in the year 1977.

Some of the important fields of biosensors applications include medical diagnosis, healthcare, biomedical, biomedicine, food safety, food quality, food processing, food monitoring, food authenticity, agricultural product monitoring, smart packaging, food packaging, forensic science, environmental monitoring, water characteristic test, sanitary surveillance, wastewater monitoring, defence and military, as well as security.

In the real-world settings, biosensors have replaced tedious, expensive and complex conventional analytical techniques. For example, the uses of biosensors in biomedical assays, immunoassays, PCR reactions, biochemical assays and in the area of biotechnology have prevented the need for tiresome and complicated processes. Further, hazardous reagents are no longer necessary, rigorous and time-consuming pre-treatment of samples has been eliminated and the use of enzymes and labelling of antibodies or antigens to amplify signal and sensitivity are no longer a requirement. Perhaps another reason for its popularity among researchers across the globe is that it creates a way to unite varying fields of biology, chemistry, physics, material sciences, nanosciences, electronics. optics and software engineering to allow for a multidisciplinary cooperation.

Importance of Biosensors?

Notable significance of the biosensors includes (i) sensitivity, (ii) specificity or selectivity, (iii) reproducibility or repeatability, (iv) stability, (v) possibility of miniaturization, (vi) portability, (vii) real-time analysis, (viii) minimal use of sample and reagents, (ix) ease of fabrication, (x) rapid analysis, (xi) mass-producible, (xii) inexpensive and (xiii) easy to use by untrained person.

Biosensor technology has advanced the research in the sector / benefitted science and innovation in broad range of application in different areas. One of the very much important area of the biosensor application include medical diagnostics for the early detection, diagnosis and prognosis of cancer using proteins cancer marker in the biological samples such as blood, serum, urine and saliva. Moreover, application of the biosensors in health diagnostics and analysis of the different clinical samples are currently growing rapidly. Some of the examples of the biosensors applications includes diagnosis of the infectious diseases such as tuberculosis, detection of stress hormone cortisol which may indicate number of medical conditions such as obesity, type 2 diabetes, hypertension, and strokes. Other important area of the biosensors applications in healthcare includes in early and sensitive detection of the cardiovascular biomarkers, artificially implantable medical and prosthetic devices.

However, biosensors application is not only limited to medical diagnostics whilst currently biosensors are considered as the “single shot” analysis tool for the food safety, food processing, food monitoring, food authenticity. Moreover, biosensors are being used as a potential monitoring device for the environmental pollution, wastewater, sewage epidemiology, detection of the toxic material of defence interest, and pathogens detection. Recently, wearable health monitoring biosensors have emerged as one of the most promising important strategies due to their various advantages and broad application. Such biosensors are integrated with the smartphones and smartwatches for signal readout, which is economical, easy to use and provide rapid result.

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Current research in Biosensors at Bangor University and how this could impact industry?

Currently biosensor is being developed for the sensitive, rapid, economical, and early detection of the acidosis in the horse. Biosensor is being fabricated on the gold electrode using thiol-modified capture probe to analyse the electrochemical impedance spectroscopy (EIS) signal corresponding to the target DNA specific for the bacteria species associated with diet induced acidosis in racehorses. Gut microsystem is highly sensitive to changes in diet. The bacterial population density adapts to cope with increased loads or changes to type of foods consumed. In most cases, this is reversible. Intensive high grain and starch feeding of managed racehorses can cause population shifts that take much longer to recover from with by-products that affect the general health of the horse. If starch load exceeds digestive capacity, it often moves through into the hindgut instead of being processed in the small intestine. This produces organic acids and alcohols due to fermentation as the gut bacteria break down and consume starch. This causes a decrease in gut pH which in turn results in a decrease in fibre-consuming bacteria, and an increase in bacteria tolerant of acidic-environments, namely, the lactic acid producing bacteria. It is diagnosed as acidosis if the gut pH decreases further to levels below six due to increased lactic acid concentration. Whilst some horses are able to recover, it can lead to laminitis which describes the detachment between tissues of the hoof wall and the distal phalanx, a condition that is both painful and causes lameness. A low pH gut environment may also impact the guts absorptive capacity which reduces the feed efficiency.

Therefore, proposed portable and field deployable biosensor will have great potential to impact the industry and business. For example, biosensor will be highly useful for the sensitive and rapid detection, diagnosis and monitoring treatment of the acidosis in racehorses.

Application of research into Biosensors?

Biosensors are being applied all sectors of life sciences including medical diagnostics, medical engineering, health diagnostic, analysis of clinical samples, food industry, agriculture industry, forensic analysis, environmental and wastewater monitoring, defence and security. Moreover, with the recent progress in the artificial intelligence (AI) applying machine learning, biosensor technologies are also being integrated for their effective applications. Therefore, such device fabricated with the integration of the AI, biosensors and the medical engineering could overcome the limitations of proof and will act as an effective in controlling medical malpractice. Additionally, laser ranging and scanning with high accuracy technologies are being integrated with biosensors for remote sensing. Basically, a remote biosensor is a type of optical biosensors which are gaining attention by the researchers interested in remote sensing due to their rapid responses, high sensitivity, anti-interference abilities, and robust adaptability features. Few examples of remote biosensing comprises satellites and aerial sensors for disaster controls, urban surveillance and monitoring of cardiac patients.

One of the important examples of the biosensor application in life sciences involves detection of the Botulinum neurotoxins (BoNTs). For this purpose, a biosensor for the detection of BoNTs has been developed and patented at the Bangor University. In the developed biosensors botulinum type, A, C and E specific protein SNAP-25 are attaches to a gold surface which produce electrochemical impedance spectroscopy (EIS) and UV-visible spectroscopy signal corresponding to the concentrations of BoNTs. As the practice method for the detection of the toxins is using the mouse bioassay which involves injecting live mice with samples and observing them for symptoms of the disease botulism over several days. Therefore, focus of this biosensor fabrication was to replace this assay not only due to the suffering of the animals but due to the length of the assay and the costs associated with it.

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Summary

(a) Biosensor is a modern electroanalytical device which integrate biorecognition elements with transducers for the sensitive and reliable detection of the target or analytes. Depending upon the target to be detected biorecognitions elements could be antibodies, nanobodies, affibodies, DNA, RNA, aptamer, enzymes, synthetic receptors, cell receptors or organelle, microorganism, tissues, and organs. Whilst examples of the targets or analytes includes, pathogens, microorganisms, peptides, proteins, viruses, biomarkers in biological and real samples, adulterant in foods and food products, explosives, heavy metals, illicit drugs, toxins, samples from crime scenes, toxins, metabolites and pollutants.

(b) Glucose biosensor was the first successful achievement in the field of biosensing, since than researchers across the globes are continuously employing novel strategies for developing more sensitive, rapid and reliable biosensors to detect different analytes or targets of interests. The international markets value of the biosensors was reported USD 19.6 billion in 2019 and it is anticipated to be market value of USD 36.0 billion by 2027.

(c) Due to the huge potential of the biosensors in medical diagnostics, medical engineering, health diagnostic, analysis of clinical samples, food industry, agriculture industry, forensic analysis, environmental and wastewater monitoring, defence and security innovative approaches and advance biosensing technologies are being developed. Current focus of the biosensor researches involve development of highly sensitive, rapid, real-time, coeffective, mass producible, eco-friendly and user-friendly biosensors. To achieves this eco-friendly electrode are being tested to fabricates biosensors using nanomaterials for signal-readout on the personal devices such as smart phone. Such developed biosensor to be used with personal device will be highly useful in different sectors, particularly to be used as bed-side modern diagnostic device in compliance of WHO “ASSURED” criteria: (i) Affordable, (ii) Sensitive, (ii) Specific, (iii) User-friendly (iv) Rapid and Robust, (v) Equipment-free and (vi) Deliverable to end-use.

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