Smart Biosensor for Monitoring Human Health- A Review

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Abstract: The importance of biosensor research is expanding, as it benefits from cutting-edge knowledge that enables innovative biosensing approaches. Biosensors are classified according to their biorecognition pathway, with the biocatalyst group consisting of enzymes, the bio-specific subset consisting of nucleic acids and antibodies as well as the microbiomes consisting of microbial species. The uniqueness, responsivity, and fast reaction of various electrochemical devices, combined with the specificity of bioreceptor molecules,gave advantage to electrochemical biosensors. The use of electrochemical sensors in diagnostic purposes also provide a precise and efficient response for biomarker assessment, with glucose sensors for diabetics being the most effective. This paper provides a review of biophotosensors for sample matrix such as lactate, glucose, Acetyl Choline Esterase (AChE), or protein kinase, collagenase, and others.

Keywords :*biosensors; photobiosensors; photoelectrochemical; nanocomposite; nanozyme*

Introduction Biosensors are diagonistic tools capable of converting a physiological reaction to an electronic impulse. The sensor system ought to be extremely specific, selfreliant of physicochemical characteristics (such as pH, temperature, and so on), and reusable. Numerous biosensors have been observed as time saver analytical approaches in identification of various analytical substances used in food, medicine and environment throughout the last six decades. Electrochemical transducers were being merged with metabolites, Deoxyribonucleic acid and antibodies, serving as physiochemical recognizers. These are now most common type of biosensor for sensing food, and environment. Generally genetic material, aptasensors and enzymes used as biocatalyst are examples of biomolecular constituents being used in biosensors. Physical signaling pathways are comparable to, magnetic, optical and electrochemical etc.

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By ensnaring Glucose oxidase enzyme inside a porous membrane over an oxygen electrode of the Clark-type, Prof. Clark in 1962 documented the very first instance of a biosensor based on enzymes [1]. According to recent research, electrochemical sensors are among the few ways to acquire uninterrupted display and information on biocompatible gadgets referring to particular cellular sites [2]. The primary benefit of wearable technologies is the detection of biomarkers on the skin which allows for remote monitoring of human health such as self-monitoring of glucose levels in diabetic patients on a continuous basis. The collection of samples in a hassle free manner necessitates the incorporation of microfluidic portable biosensor platforms. These allows transfer of sample data directly between the skin to the surface of the electrode [3,4]. Major percent of chemists dealing with bioelectrochemistry shifted their focus from feasible outcomes to problems with direct electron transfer (DET) for enzyme-based biosensors. These are critical for improving biosensor selectivity and sensitivity[5]. The case of glucose oxidase has received special attention (GOx). Alvarez-Malmagro et al. [6] addressed various biomimetic approaches for electrode surface modification to adapt enzymes that are bound by membrane. These includes the establishment of self-congregated hydrophobic uni and bi lipid layers, and deposition of liposome. Several enzymes had also combined with electrodes that are semiconductor in nature with a material that harvest light over the last two decades to produce photoelectrochemical embedded sensors. Del Barrio et al. [7] work was focused on improving device sensitivity by combining redox enzymes like glucose oxidase (GOx) and acetylcholinesterase (AChE) etc. with quantum dots nanomaterials and titanium oxide (TiO_2) nanoparticles.

Some impressive achievements has been gathered focusing on various concepts of the biosensing field, primarily showcasing latest improvements and upcoming constraints in detection of DNA, electrode surfaces modified by redox enzymes, photoelectrochemical reactions, biosensors based on field-effect transistors, etc.,. A short overview of every acknowledged achievements is presented below to motivate learners to know them and envision the advancements in biosensing.

Structured materials for biosensor

Neumann et al. [8] explored the feasibility of blending heme peroxidases both artificial and natural with semiconductor electrodes to provide options to detect the presence of hydrogen peroxide and phenolic compounds. Extensive exploration has been done about the utilization of structured materials for biosensor applications like nanoporous metal, carbon nanotubes, and graphene [9]. Nanomaterials containing sulphur, as well as their derivatives have recently seen widespread use in the creation of innovative biosensing devices. The recent studies and current prospects of using modified electrodes by metallic sulphide nanomaterial, revealing their special characteristics in particular like outstanding catalytic activity, photoluminescence quenching abilities, interesting optical properties.[10] Nanozymes are nanomaterials with enzyme-biomimicking properties. Stasyuk et al. [11] highlighted the most recent nanozyme research. This study provides an overall idea of nanozyme classification, advantages over natural enzymes, with a focus on the various methods of synthesis established as yet. Additionally, immunosensors are utilised to develop point-of-care medical equipment. Sharafeldin et al. [12] focused on the latest research on 3D-printed immunosensing devices for detection of cancer. Santhanam et al. [13] documented one of most latest findings regarding DNA/RNA-based biosensors, taking into account traditional detection method disadvantages, which are time-consuming and necessitate the use of skilled experts and equipment. In microbiology, immunosensors, DNA/RNA biosensors, and aptasensors are presently regarded as effective tools for detecting microbial cells at the subcellular level. They are also active even amidst high concentrations of other bacterial species[14]. Another most notable studies on non-carbon two dimensional biosensors were revealed by Sedki et al. [15]. They explored the influence of variety of transition metal dichalcogenides , as well as hexagonal boron nitride and black phosphorus in order to develop biosensors based on field-effect transistor .

Glucose Biosensor Glucose biosensors have now become significant medical devices and has become a major contributor to the treatment of diabetes mellitus. Because of their biocompatibility and good electron transfer capability, ZnO nanoparticles bind to glucose oxidase [16]. The greater surface area of nanoparticles of ZnO significantly increases the electrode's current action due to improved GOx adsorption. The other glucose biosensor incorporating GOx, ITO, and ZnS nanoparticles was designed [17]. CdS, which was previously used as the major semiconductor in the sensor, is toxic and environmentally harmful. So Cd was replaced by electrodeposition of ZnS on the ITO electrode surface. When exposed to light, the photovoltaic activity of ZnS nanoparticles contributed to increased sensitivity and a lower detection limit. Additionally,the sensor has proven to be reliable and consistent in its output over the course of testing. A bidimensional nanosheet composite of g-C_3N_4 and TiO_2 was created by Liu et al. [18]. The biosensor was constructed by combining the composite with GOx and Naffion serving as binders for ITO electrodes. These

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combination shifted the photoelectrochemical efficiency compared to the constituent alone. The photocurrent switching phenomenon of $BiVO_4$ semiconductors enabled the development of a PEC glucose sensor [19]. The drop of photocurrent of H_2O_2 produced throughout GOx-catalyzed glucoseoxidation was measured using an FTO/$BiVO_4$/GOx photoelectrode. As a hydrolase, Acetylcholine Esterase (AChE) is responsible for converting acetylcholine into acetate and choline. The reaction is inhibited by a variety of inhibitors. Pesticides that contain organophosphorus or carbamate may also be included. BiOINFs (bismuth oxyiodide nanoflake arrays) were combined with AChE to create an amazing biosensor that can identify pesticide containing organophosphate [20].

Kinase activity Monitoring Generally the phosphotransfer from ATP to biomolecules including amino acids found in peptides and nucleotides etc. are catalysed by enzymes called Kinase. Activity of protein kinase (PK) and phosphorylation procedure are linked to cancer, diabetes like variety of disorders. [21]. Numerous photochemical biosensors were thus designed to monitor kinase activities in an easy to use way, as well as to select the appropriate inhibitors. The photosensitive material used in the majority of PEC biosensors detecting PK activity were composed of g-C_3N_4 (graphitized carbon nitride). [22] For signal enhancement, Yin et al. established an g-C3N4-based PEC biosensor that is triggered by visible light, the selective binding molecule Biotin and streptavidin alkaline phosphatase (Phos-tag-biotin)[23]. Zhou et al. [24] used a system of PEC biosensing for immobilised on Bismuthsulphide (Bi_2S_3) and gold nanoparticles (AuNPs) electrodeposited indium tin oxide (ITO) electrode for Kinase-induced phosphopeptides. In the existence of Zn^{2+}, this might fasten to a Phos-tag biotin. The photocurrent may then be reduced if streptavidin was captured on the surface of the electrode. The response was proportional to the extent of phosphorylation, and thus to PK activity. A type of organic-inorganic blended material Metal-organic frameworks (MOFs), also were employed to boost the responsivity of the biosensors. To create a biosensor, metal-organic frameworks based on Zr (UiO-66) with $[Ru(bipy)_3]^{2+}$ were chosen for the pores.[25] The UiO-66's high surface and pore size distribution increased the $[Ru(bipy)_3]^{2+}$ proportion, that further elevated electrons in the semiconductor TiO_2. This enhanced the biosensor's specificity and photocurrent.

Monitoring of Lactate and Collagenase Monitoring of Lactate is very much essencial for both in sports medicine as well as medical diagnosis. Lactate is a predictor of brain damage [26,27], and its levels provide information about players' training condition. As an immobilisation template for lactatedehydrogenase (LDH), the first PEC LDH biosensor that illustrated possible application for real cases have used nano TiO_2 and carbon nanotube matrix [28]. A TiO_2 nanotubes ternary composite and AuNPs, LDH, nicotinamide adenine dinucleotide (NAD^+), were immobilised on ITO (Indium Tin Oxide) electrodes to create the PEC biosensor which outperformed other electrochemical lactate biosensors [29]. Collagenase, is another enzyme acting as cancer marker. An ITO electrode was designed with CdTe quantumdots and an artificial peptide comprising the collagenase cleavage target sequence Gly-Pro-Ala [30]. Arginine amino acids were added to other end of the sequence and modified with silver nanoparticles. The sensing was accomplished through an increase in photoelectrochemical current triggered by peptide cleavage.

PhotoBiosensor Photo-biosensors have also been interested in the activity of nucleic acids. The enzyme DNA methyltransferase was detected using ITO electrodes modified with Bi_2S_3 and methylated DNA specific antibodies. [31], which is being connected to a variety of ailments, such as malignancies. Applying ITO electrodes modified with WS_2 and gold nanoparticles, the photo-biosensor was demonstrated to detect DNA with hydroxymethyl group [32]. It was possible to use an electrode modified with DNA to recognize activity of glycosyl transferase according to the researchers. Such a DNA hydroxymethyl derivative can also be used by enzymes to substitute sugar derivative and Boronic acid-terminated quantum dots can easily detect this. Also N-methylglycine, a naturally occurring amino acid widely recognized by sarcosine, is found in several living beings that participates for certain metabolic activities such as glycine synthesis or decomposition. It could be used as a diagnostic markers for prostate cancer [33]. A photosensitive biosensor was studied, which was developed on ITO electrodes and then enclosed Sarcosine oxidase and NiO layers followed by $CuInS_2$. Because of the activation of enzymatic processes of sarcosine oxidase, pathway was followed by reducing photocurrent. A recent study developed a Photoelectrochemical and electrochromic dual biosensors cell to power and sense the device [34]. The photoanode was made of a nanocomposite of Ni:FeOOH/$BiVO_4$. The anodic chamber was loaded with glucose. The glucose oxidase enzymatic reaction produced H_2O_2. When illuminated, electrons were donated to the photoelectrode and oxidized in order to raise the current.

Conclusion

Photoelectrochemical biosensors are a relatively new development, arriving fairly late compared to the other two biosensors due to their greater sophistication and impossibility in realising. Subsequent work concentrates on novel interfaces such as electrode-semiconductor as well as semiconducting-macrobiomolecule improvement where is sufficient to conduct when boosting the sensor's selectivity and sensitivity. The PEC biosensors described here too detected activities of PKA in lysates cell, which is gaining interest about drug discovery systems, medical diagnostics, with pharmacologic efficacy assesment. All attempts might also be important in the context of bioelectrochemical sensors for practical applications.

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