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REVIEW ARTICLE

Electrochemical sensors and its applications

Sahar S. M. Alabdullah[1], Ahmed Z. M. AL-Bassam[2], Noora Asaad[1]

[1]*Department of Chemistry, College of Science, Al-Nahrain University, Baghdad, Iraq*
[2]*Department of affairs of higher studies, University of Baghdad, Baghdad, Iraq*

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Abstract

The basic concept of this review is based on the performances of electrochemical sensors. All the main characteristics essential for this report are taken into account, consist of the fundamental quantifications of constructed materials applied as electrodes, the use of sensors and starting materials in the experimental work and their applied uses in verifying biological species, environmental issues and toxic metals, pharmaceutical compositions and progressive studies on different electrode fabrication methods, The last section is exhibited as a series of comprehensive reported an overall summarization methodologies of various studies. Then, recent trends and importance achievements are delineated along with future choices.

1. Introduction

Electrochemical sensors are type of instruments in which the electrode used as transducer element. Electrochemical sensors now a day became one of the most aspects in variety of fields for the research studies such in, monitoring, metal processing, hazardous ecological environmental analyses in manufacturing, treatment of plants, medical, biotechnological, quantitative analysis sensors and natural product applications [1-3]. Electrochemical sensors can provide many advantages of accurate reproducible data in linear responses and specific chemical species by an analytical signal and analytical devices [4]. The main types of electroanalytical sensors are commonly used such in conduct metric, potentiometric and amperometric sensors. Biosensors are also considered as one of the vital tools in different scientific applications for detection and quantifications in many biochemical reactions due to converting them into electrical signal. Recently, there have been new advancements on using electrochemical detections in environmental research which showed the importance of electrochemical sensors for identifying of toxic biomolecules and dangerous, radioactive, carcinogenic materials [3] This paper is an important advancement as it shows how both selectivity and performances of electrodes materials to applied as electrochemical sensors.

2. Methodology part

The electrochemical sensors ‘‘biosensors’’ was looked at in Science direct, google and all articles based on its applications were chosen.

2.1 Types of electrochemical biosensors

2.1.1 Based on enzymes

The initial enzyme-based electrochemical sensors were informed by Hicks and Updike in 1967 [5] Biosensors are

Corresponding author: Sahar S. M. Alabdullah
Email Address: sasahar1982@gmail.com
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created in immobilization procedures, i.e. adsorption of enzymes by covalent bonding or van der Waals forces and ionic bounding. Enzyme biosensors are conditional on specific enzyme to absorb in the surface of a sensitive electrochemical transducer [6]. The generally applied enzymes for this purpose are amino oxidases, oxidoreductases and peroxidases [7].

A typical biosensor contains highly selective and specific biologic discernment compounds, like in enzymes that connect reversibly and electrochemically active to a specific analytic, which in electrochemical bio catalytic sensors may include nanomaterials, resulting in a measurable signal for a given analyte [8]. SGlutamates are primary excitatory neurotransmitter in the mammalian brain and nervous system that are implicated in a variety of psychopharmacological and physiological processes. including Autism, Alzheimer's disease, depression, schizophrenia, and drug addiction. In addition, using enzyme-based electrochemical biosensors to detect glutamate for vitro and vivo is a hot topic of research. Different glutamate biosensors have been improved in measuring dynamic levels for extracellular glutamates in human brain tissues helping to medicinal understanding of these complex neurotransmitter systems and potentially influencing treatment plans. In addition to glutamate biosensors, a common flavor-enhancing food additive has been used in fermentation environmental monitoring, industry, and the food industry for monosodium glutamate evaluation (MSG) [9]. Nonetheless, several authors have been written on the use and production of glutamate biosensors are able to control of glutamates level in sufficient ways for free movement of mice and rats [10]. Glutamates biosensors have been improved in both vitro and vivo applications.

One of the problems in using biosensors to test complex extracellular glutamate levels in human tissues are that glutamates are non-electroactive as compared to an electroactive analyst like dopamine. Consequently; voltammetry electroanalytical methods cannot directly have applied to quantify glutamate. While, in a biological recognition component, such in an enzymes are attached to a physical analyzer, glutamate levels can be indirectly determined by measuring one of the enzymatic generated yields in bio catalytic sensors [11]. The triple electrode was used to test L-glutamate levels in the rat brain, which averaged 6 M, whereas acetylcholine and dopamine levels were below the biosensor detection limits. The creation of appropriate biosensors for precise in vivo glutamate detection and monitoring is still ongoing, as some works have presented that the indication of glutamates by micro dialysimetry are not the same as the glutamates adjust by microdialysis are not only partially sourced from the synaptic transmission [12]. The concentration space of intracellular glutamate ranges from 2 to 20 micrograms [13]. Glutamate levels in plasma are usually about 150 micrograms, although they are around 10 micrograms in cerebrospinal fluid [10]. Monosodium glutamate ($C_5H_8NO_4Na$, MSG) was created in 1908 by Kikunae et al. and it is a popular taste enhancer originate in many Chinese restaurant pasta soups, processed meats, and some of packaged vegetables. Surprisingly, MSG's protection and effectiveness as a food additive have been a source of contention [14]. A broad range of biosensors has been improved systems by nanotechnology and microfabrication technology. Different biosensors enzymes consist of several of the more recent glutamate biosensors, have used nanoscale components with at slightest one dimension with range of size around (107-109) m [15]. Nanomaterials in these days have a lot of consideration in biosensors productions as a result of the trend toward smaller, more portable biosensor devices with improved performance.

The production of stable electrochemical and highly sensitive biosensors with significantly enhanced concert for several analgesics has recently resulted from combining the high bio selectivity and specificity of oxidoreductase enzymes with the various and beneficial chemical characterization of some organic or inorganic nanomaterials like graphene, nan Carbone materials, silver and gold [16].

2.1.2 Based on Graphene-Paper

Graphene paper has gotten a lot of attention since its first study in 2007, as an innovative type of graphene supporting nanomaterial.

Graphene paper has been found capable possibilities for different applications in energy technologies chemical sensors and one of the good recent advances in the scientific studies is two dimensional graphene papers 2D as significant raw materials in electrochemical sensors, because of their lightweight, high flexibility and electro conductive materials [17]. As a result of unique physicochemical characterization 2D papers construction are commonly tailored in many chemical applications such in purification of water, inventive electrodes, biomimetic, energy transfer, biomimetic, storage, and optical electronic products [18]. Graphene papers have huge potentials to be used in Nano electronic, optical electronic tools and electrochemical power equipment and solar systems, sensors, due to their high quality, low cost, and easy synthesis processes [19, 20]. Self-assembled 2D graphene usually used as main and attractive substances in the constructed of membranes, papers and films, these materials are also participated with nanostructured metals, food, environment researches, production of polymers, clinical applications and industrial applications [17,21].

Since glucose oxidase (GOx) enables catalytic oxidation of glucose with high sensitivity and selectivity, glucose oxidase adjusted electrodes are the most popular type of amperometric biosensors for glucose detection. Enzyme modification electrodes, however have a number of disadvantages, including electrode instability and poor reproducibility, high enzyme costs, and a difficult enzyme immobilization method. To address such problems, nonenzymatic glucose biosensors controlled by graphene sheets, which have a high nanostructured efficiency for the fabrication of electrochemical sensors, have been investigated [22].

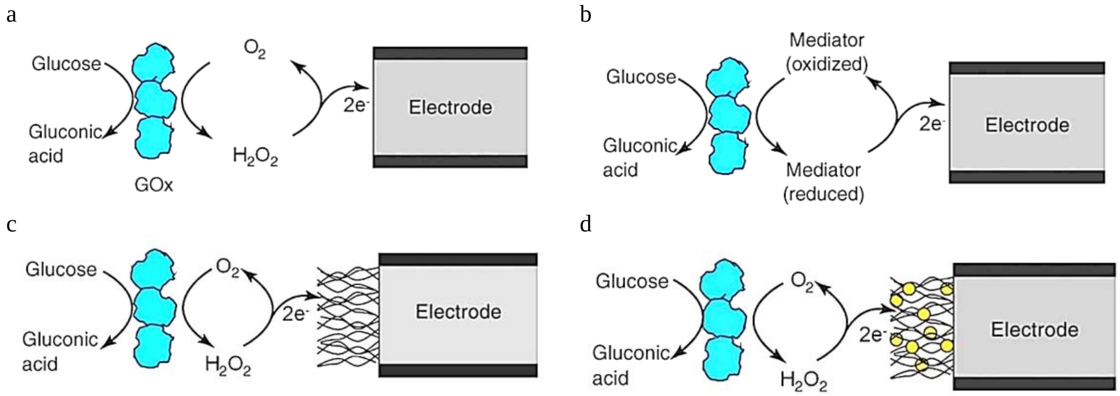

Figure 1: General GOx electrochemical biosensors (a,b). GOx layer (c,d). nanocomposites working together[22]

Uric acid, dopamine and ascorbic acid are the most important small biomolecules and could be main factor for human health. Electrochemical sensing of such small biomolecules has considered a crucial tool in health monitoring. Building electrochemical sensitive systems for recognition of small biomolecules depends on graphene supported nanomaterials has recently become a priority [23, 24].

2.1.3 Electrochemical sensors in air pollution monitoring

Electrochemical gas sensors are now essential for monitoring the quality of the atmosphere and health life especially due to controlling of contaminations. Most of these gases influence the environment systems such as metal oxides, toxic gases, propane and some of volatile organic substances. The greatest common issues from gases and metal oxides like acid rain, soil erosion, water pollution, and other direct health effects [23]. The most advancement has been made in transportation, communications, manufacturing of various human items such as cosmetics, hygiene, care goods and drugs. These processes have originated a significant cost in terms of overall environmental quality, including air, soil, and water emissions, human-caused climate change, deforestation, and contribution to global warming. The sensed molecules undergo oxidation reduction reactions on an appropriate electrode on an electrochemical gas sensor surface, producing an electrical current that is proportional to the gas concentration. The sensitive layer of the gas sensing surface forms a receptor. Particular operational surface groups allow for adsorption or chemisorption of the detected species, which is often followed by combustion or other chemical reactions involving electron transfer.[24]

2.1.4 Clinic analyzers with electrochemical sensors

Since clinical studies in a clinical chemistry laboratory are costly and time-consuming, one of the most pressing issues today is the creation of methods for performing these rapid "in situ" analyses. These methods must be sensitive and accurate, as well as able to identify a wide variety of substances with different properties. Electrochemical sensors for the measurement of analytes of interest in clinical chemistry are ideally suited for these new applications due to their high sensitivity and selectivity, compact field-based size, quick response time, and low cost [25]. Since 1962, when Clark and Lyons developed the first electrochemical biosensor, known as the enzyme electrode, using the enzyme glucose oxidase, the modern concept of using electrochemical sensors to determine the level of substances and other biological parameters has reflected a rapidly expanding area of electrochemical sensors instrument design (GOx), The main principles of the GOx layer in an electrochemical signal are that the signal is transmitted from the enzyme through O_2 reduction to generate H_2O_2 or the reduction can take place to another chemical mediator as shown in figure 1. The types of GOx are determined through the use of single types of nanomaterials or multiple nanocompounds working together, as in nanocomposites [25].

Another important electrochemical sensor is founded to determine enzymes including cholesterol levels such in cholesterol oxidase (ChOx) and cholesterol esterase in human blood. Nanostructures have been used as intelligent building blocks in the creation of new electronic and sensing devices. Using a combination of molecular imprinting and thick film electrochemical sensor techniques, researchers created a new sensing method for the detection of cholesterol [25, 26].

The detection of uric acid (UA) also has been used by electrochemical sensors in several research groups as it's an important concept in detection of many diseases such in obesity, diabetes, high blood pressure, high cholesterol, renal disease, cardiac disease, and kidney disease [27-29]. The electrochemical sensors for determination of nitrogenous compound contained in urine Gout is help to measure levels of UA in the blood. In some cases, the electrochemical interferences, such as ascorbic acid (AA), which has a similar oxidation potential, cause problems in biological UA determinations. The calculation of UA can be done in two methods: enzymatic and non-enzymatic [4]. UA analysis applied surface-modified electrodes, and various non-enzymatic electrochemical methods, such as redox mediator, have been published. To aid in the improved UA detection signal, miniaturized electrodes and special electrochemical methods were used [30]. Electrochemical sensors have opened new promising opportunities for deoxyribonucleic acid (DNA) analysis. DNA is an important biomolecule function that plays a key role in testing of genetic and infectious diseases. Electrochemical sensors have been improved towards the asses of rapid, simple recognition methods.

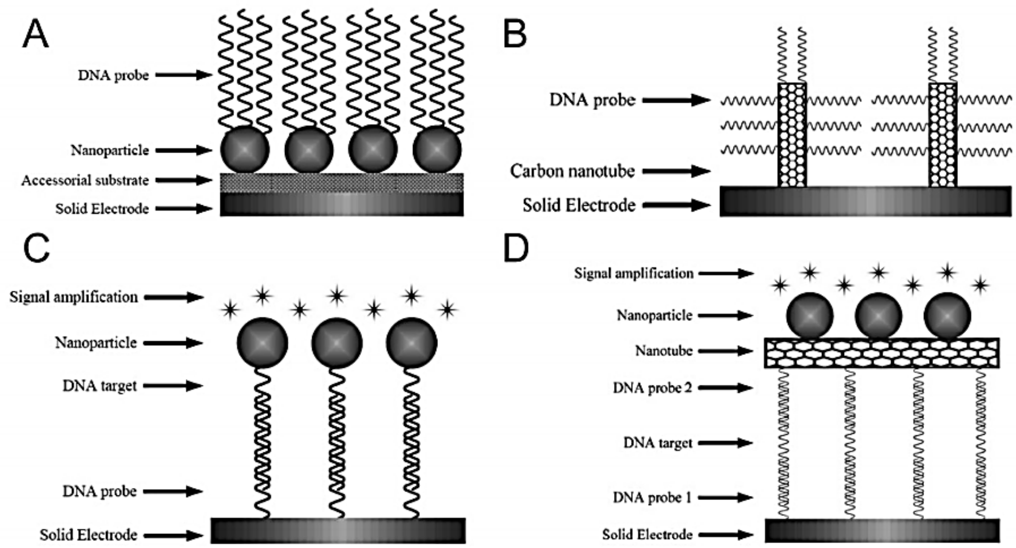

Figure 2: Principles for nanometrial sensor in DNA probs (a). electrode coated(b). probe labeling(c). target labeling (d). signal reported [31]

Electrochemical sensor for DNA is generally an electrode or a capture probe constitutes a DNA sensor. A capture probe is an element that is immobilized into a solid substrate, such as the electrode surface, and is used to detect the target DNA. They can, however, be immobilized on nanomaterials or biomolecules. Some of sensors are improved by addition of electrode coated and intermediate nanomaterials to increase the efficiency and the performances of the sensor.[31] A comprehensive analysis of nanomaterial based for DNA biosensors can be found in the literature [31-34].

2.2 Other electrochemical sensors in detection studies

Electrochemical detection technologies represent a large proportion of research into toxic gas measurement such as micro fuel cells are designed to be low-maintenance and long-lasting devices. The sensors of these types have three and four electrodes for detecting toxic gases. Cross-sensitivity to other gases can be avoided by using the fourth auxiliary electrode. For example, the sensing reactions in carbon monoxide sensors are similar to those in hydrogen gas sensing in terms of electrical changes in the sensing field [35].

3. Conclusions and Future Prospects

The research and future direction of electrochemical sensors is focused on the improvement of low cost, integrated sample handling, rapid and high specific systems. The improvement of probe sensors is a significant research field that will continue to be pursued in the future. Despite the fact that advancement in this area is fast and furious, the end objective of achieving long-term success remains the same. Bio sensors have been widely reported for UA, DNA, glucose, detection because the response can easily be documented and the sensitivity is very high [36]. Nanomaterial sensor is more sensitive to low concentration than is normal bio sensors. However, these sensors are much more difficult to reverse than the effects of the same sensors in monitoring gases detection. Gas sensing has good reproducibility and detection of the air pollutant, While, the controlling systems in these sensors are not easy to control [37]. Some of air quality management devices are attractive for chemical microsensor applications because of their small size, low cost, high sensitivity and good controlling systems, but they are less sensitive than the optical Nano-sensor of nitrogen dioxide in the air as an example [38]. Nanosensors are important tools that can be applied extensive applications [39-41]. However, Future work should focus on testing in practical, clinical samples, also for proof of function sensor designs, to help achieve this aim. These sensors should also be compared to commercially available sensors in order to better demonstrate the nanosensors' benefits and drawbacks. These direct comparisons will help explain the increased expense and effort required to overcome the manufacturing challenges of nanosensors versus standard sensors.

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