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Utilization of Nanomaterials in Electrochemical Sensor: A Review

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Abstract: *Nanomaterials (NMs) have been proven feasibly applied in different sectors. Sensing is such an application. Due to some special properties, several NMs such as metal oxide nanoparticles (MONPs), metal organic frameworks (MOFs), carbon nanotubes (CNTs) have electrochemical sensing applications. These materials can identify a wide range of harmful compounds, biological compounds, heavy metals, pesticides, organic pollutants, and inorganic anions etc. Electrochemical methods such as potentiometric, conductometric, amperometric etc. are employed in sensing these things. This article will focus primarily on the potential uses of electrochemical sensors utilizing NMs for sensing of various substances in the environment.*

Keywords: Sensing; Electrochemical; Biosensing; Toxin sensing.

1. INTRODUCTION

Electrochemistry is one of the techniques that are favored in biological and environmental assessment due to its versatility, easiness, consistency, quick processing times, low energy consumption, incredibly cheap devices, and outstanding response rate. However, a wide range of electrochemical sensors have been applied for the detection purposes [1]. Electrochemical analysis is direct, sensitive, and dependable. It can be used to determine nitro-phenolic substances [2]. MONPs, nanorods, nanoflowers, nanospheres, nanowires, nanotubes, etc has been proven in detection of various items. High stability of ZnO nanoparticles (NPs) at high isoelectric points and efficient charge association make it a good electrochemical material [3,4]. NPs have catalytic, optical, electrochemical, magnetic, etc. characteristics. Nanoscale size changes nanoparticle surface area. Researchers selected ZnO nanoaggregates because of their huge active surface area and strong binding feature. ZnO's quicker fabrication ideal for low-cost sensor fabrication [5]. ZnO can detect harmful compounds such as acetone, ethanol, 4-aminophenol, and bisphenol A in freshwater [6]. Hierarchically micro/mesoporous hybrid structures and large specific surface areas can be identified in FeOx/TiO₂@mC nanocomposites, which further lead to the materials' high electron transfer rate. Electrochemical detection of contaminants is one possible potential for it [7]. Exceptional electrocatalytic activity has made it the perfect electrode for nonenzymatic nitrite sensors. It has excellent electrocatalytic properties, is affordable, simple, environmentally safe, and stable [8]. Carbon based NMs including CNTs are expected to play vital role in electrochemical sensors due to its remarkable physiochemical properties. CNTs and graphene-based electrochemical transducers may improve immunosensors, enzyme electrodes, and nucleic-acid sensors [9]. CNTs and other NMs are promising for electrode modification. Thus these can support in biosensor applications with low electrical resistance, and superior charge-transport characteristics. CNTs can immobilize ZnO nanostructures on electrode surfaces. CNTs helped strengthen and adhere ZnO nanoflowers to the electrode surface, ensuring a vast surface area and

swift mass transport [10]. MOFs are extremely important due to their enormous specific surface areas, ease of adjusting their structures, thin thicknesses, high porosities, and numerous exposed active sides [11]. MOFs are a relatively new class of crystalline inorganic-organic hybrid materials that have been rapidly developed in recent years. The benzene-1,4-dicarboxylate (BDC) and tetrahedral zinc oxide (ZnO₂) units that make up MOF-5 are the building blocks of one of the most well-known and well researched examples of porous MOFs. It is expected that the catalytically active sites will be provided by the transition metal ions. These ions are embedded within the framework structure. The enormous size of these particles, on the other hand, makes it more likely that they will dislodge themselves readily from the electrode surface, which will lead to an unstable catalytic performance [12]. In this study we will give an overview of electrochemical sensing of various compounds by several nanomaterials. Our objective was to give an overview of the potential of these materials in sensing. We explained about the importance of these materials briefly to the upcoming researchers in this field. Our aim was to show the importance of the research on commercial use of these materials in electrochemical sensing sectors.

2. METAL BASED NMS FOR ELECTROCHEMICAL SENSING

Nanostructured metals, MONPs, and nanocomposites that incorporate MONPs are all examples of metal-based NMs. The development of optoelectronic devices is partly owing to the semiconductive metal oxides' good electrochemical properties, such as broad band gaps, high excitation energies, and biocompatibility. These features make the oxides appropriate for use in the fabrication of electronic devices. Silver oxide (Ag₂O) is a p-type semiconductor. It has a quantum size-effect and has an optical band gap that extends from 0.49 to 3.1 eV. Ag₂O nanocomposites with other semiconductors and metal oxides have explained as functioning as a sensing mediator in the process of developing electrochemical sensors for 3-methoxyphenol and uric acid. At room temperature, the direct optical band gap of TiO₂ is between 3.2 eV and

3.35 eV. As being n-type semiconductor, TiO_2 offers exceptional optoelectrochemical properties, which are vital to the creation of electrochromic displays with chemical sensors [13]. Titanium dioxide (TiO_2) is a material that continues to improve that can be used in electrochemical sensors and biosensors (see Figure 1) [14]. By integrating detecting elements, electrochemical sensors are quickly gaining popularity as a technique for the detection of environmentally toxic contaminants. Cr_2O_3 , ZnO , SnO_2 , WO_3 , $\alpha\text{-Fe}_2\text{O}_3$, as well as Co_3O_4 are some of the substances that are adopted as sensing substrates for toluene [15]. TiO_2 is an outstanding sensor material that can locate tetracycline, hydrogen, glucose, formaldehyde, uric acid, and hydrogen peroxide. Because of having large band gap, TiO_2 has excellent optoelectrochemical features. TiO_2 has indeed been widely used as an excellent sensor material [16]. At room temperature, Co-doped Mn_2O_3 - ZnO NPs have the potential to be implemented for the enhancement of higher-sensitive 4-nitrophenol chemosensors. In general, chemo-sensing research has been conducted with transition-metal oxide nanostructures for the purpose of recognizing and quantifying various toxic chemicals. Those same chemicals include phenyl-hydrazine, methanol, formaldehyde, ethanol, chloroform, dichloromethane, and others. These chemicals are not safe and toxic and are not environmentally friendly [2].

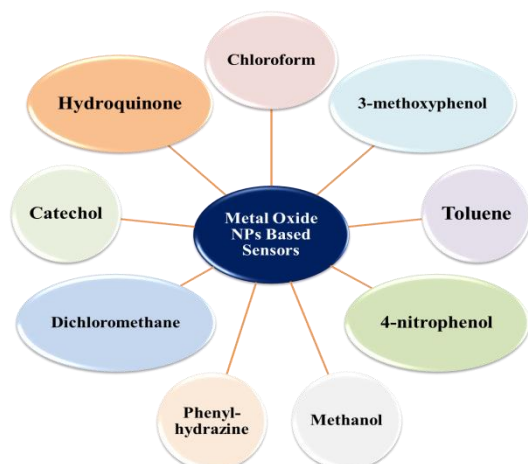


Figure 1. Environmental toxin sensing by MONPs based sensors.

The design of ZnO NPs based electrochemical sensor is useful for the detection of 4-nitrophenol [5]. Al_2O_3 , which offers desirable photoelectronic properties, has also been utilized as a chemical and biological sensor due to its versatility. In addition to its usage in catalysis and wear-resistant materials, colorants, and electrical and optical devices, Cr_2O_3 , who is also an active transition metal oxide, has been put to use. In conjunction to this, the binary combination of ZnO and Al_2O_3 has been exploited as a sensor for the detection of catechol, hydroquinone, and methyl violet dye. There have been reports that $\text{ZnO-Cr}_2\text{O}_3$ is a robust sensor material that can detect both ethanol and LPG [6]. Although graphene oxide (GO) operates as a reductant for itself, it is possible to strongly anchor Pd NPs onto a GO surface by blending GO with an aqueous solution of K_2PdCl_4 and doing so without the inclusion of any other reductants or surfactants. Electrochemical biosensing

systems can be benefited tremendously from the incorporation of ultrafine monodispersed metal NPs on non-carbon support materials, such as TiO_2 - SiC heterostructures [14]. ZnO -CPE, metal oxide modified carbon paste electrode, is vital not only for the detection of molinate toxic metabolites but also for understanding those. This is because ZnO boasts a number of desirable aspects [17]. Electrocatalysis incorporates ZnO NFs that have been coated with GOS Nanocatalyst for the objective of biomarker detection [18]. NPs made of materials like metals oxides, when combined with CNTs, have the potential to enhance the performance of analytical instruments. Because transition metal oxides, also termed as TMOs, have semi-conductor properties, they have superior bioactivity [19].

3. MOF FOR ELECTROCHEMICAL SENSING

Crystalline MOFs are a material that is built around a metal core that is held together by organic ligands. MOF has a number of remarkable qualities, including an enormous surface area, a high porosity, an excellent catalytic performance, an abundance of active sites, and an unrivaled degree of tunability. Several different kinds of MOF, such as Cu-MOF, Zr-MOF, Ni-MOF, and Co-MOF, are used in the construction of electrochemical sensors. Cu-MOF is now being used in sensor technology for the detection of glucose, patulin, and hepatitis B virus DNA (see Figure 2). This material suffers from a number of drawbacks, including a lack of conductivity, uneven forms, and huge particle sizes. The modification of Cu-MOF is an essential step in the process of enhancing its characteristics. Doped N-Cu-MOF is a variant of the unconventional material known as Cu-MOF. Cu-MOF is characterized by its superior architecture, well-defined order, and strong electrochemical activity. N-Cu-MOF is a type of doped Cu-MOF [20]. It has been shown that sensors based on MOFs are a viable option for determining the relationships between functional organic species and Lewis alkaline sites. Species of MOFs based on lanthanides may perform sensing functions. In addition to being able to identify organic solvent molecules, they are able to detect metal ions. The detection of picric acid's sensitivity may be accomplished by using Tb-MOF in its capacity as a fluorescence sensor. In this context, organic components may function as luminous groups, and can offer binding interactions that can be employed for sensation [21]. Growing interest has been shown in the use of MOF, as extremely selective and selective platforms for the creation of sensors. These frameworks may be used for either fluorimetric detection or electrochemical detection [22]. MOFs have the potential to be surface modifiers that may be used for electrochemical sensing. Because of a MOF substrate's wide specific surface, loading it with NPs is made easier, which helps to increase the conductivity and amplify the electrical impulses. In addition, the formation of biosensors and the accumulation of target analytes both benefit from the strong contacts that may occur between the functional groups of MOFs and biomolecules. These interactions can take the form of hydrogen bonding, stacking, or electrostatic force [23]. In addition, the large porosity and surface areas of MOFs enable them to load the guest molecules and/or catalyze the targets with high electrocatalytic activity,

both of which have the potential to provide inherent sensitivity for the electroanalysis. In spite of the fact that the porosity of MOFs increases the active area of the electrode, signal transduction remains one of the most difficult problems to solve owing to the high fraction of building ligands. In addition, the majority of MOFs have crystalline products that are on a macroscale, which contributes to the limited repeatability of the electrocatalytic reaction. In order to fulfill the practical applications of MOF-based electrochemical sensors, more development in the conductivity and design of MOFs is still needed. This is necessary in order to increase the performances of MOFs [24]. It is possible for the electrical and physiochemical characteristics of MOFs to be improved using a variety of ligands and linkers. In order to successfully manufacture effective electrocatalyst MOFs, a number of conventional ligands, including 2,5-dihydroxyterephthalic acid and 1,3,5-benzenetricarboxylic acid, have been used. The MOF-74 family is formed by the coordination of 2,5-dihydroxyterephthalic acid with divalent transition metals [25].

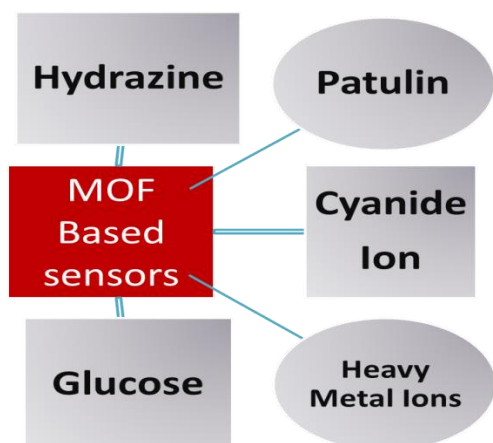


Figure 2. MOFs in electrochemical sensing.

The inherent hydrolytically stable property of particular MOFs may potentially provide an extra benefit for aqueous-phase sensing. It is of significant interest to researcher recently. Zeolitic imidazolate frameworks (ZIFs) are vital subclass of MOFs. These NMs are chemically and thermally stable. Since the discovery of this MOF subfamily, various variants of ZIFs have been developed and have been the subject of in-depth research due to the wide variety of uses to which they may be put. Because it has aligned CHO group inside the pores of the expanded three-dimensional (3D) framework, ZIF-90 is a significant candidate for the post-synthetic modification. This makes it stand out among the rest of these compounds. The sodalite topology of the cage structure, which has pore openings that are suitably big, makes it possible for ZIF-90 to be easily converted into post-synthetically changed forms. ZIF-90 satisfies the prerequisites for usage as an effective fluorometric sensor due to its highly luminous nature as well as its stability in hydrolytic environments. This allows the substance to be put to use in a variety of applications. Dicyanovinyl (DCV) is widely regarded as one of the most effective fluorescent cyanide-ion detectors. A method to molecular recognition that is

based on reactions results in improved selectivity. Because of this, it is efficient [26]. MOFs provide for excellent precursors as well as templates in the process of synthesizing 3D metal oxides. This was simply discovered very lately. The ability of NiCo_2O_4 generated from ZIF-67 to detect heavy metal ions has been shown by a significant number of researches. Within the context of this study, ZIF-67 serves both as a template and a precursor for the creation of NiCo_2O_4 nanocages through solvothermal and pyrolytic processes, respectively. As part of this study, the electrochemical activity of NiCo_2O_4 NCs has also been examined in order to determine whether or not the DPASV method of detecting Hg^{2+} can be successful. Because of their nanocage-like structures and their rough, porous surfaces, NiCo_2O_4 NCs may be distinguished from both the template and the precursor. In order to be effective in absorbing Hg^{2+} , NiCo_2O_4 NCs need a large amount of available surface area per unit volume. It was discovered that NiCo_2O_4 NCs/GCE had a broad linear range. The fact that it has such a low detection threshold allowed for the discovery of this, which was made possible by the great sensitivity it has toward Hg^{2+} . In order to achieve this objective, both ZIF-67 and Co_3O_4 had to be made. This allowed for a research into the impact of component-dependent Hg^{2+} detection to be carried out [27]. Carbon materials that are produced from MOFs have been given the name C-MOFs. These materials have many advantages over the original framework structure material, including a greater surface area, higher conductivity, and improved thermodynamic and mechanical stability. In addition to this, they have been included into the production of electrochemical sensors. However, the material is useful for expediting the transmission of electrons from the acetaminophen (AP) to the electrochemical sensors because of its ability to do so. In the presence of the electrocatalytic effect of PCA, the Zn/Ni-ZIF-8-800 may serve as an appropriate location to initiate the redox reaction of AP. The incorporation of Zn/Ni-ZIF-8-800 into the PCA@Zn/Ni-ZIF-8-800 hybrid has the potential to provide it with excellent conductivity in addition to a wide surface area. As a result, the conventional C-MOFs Zn/Ni-ZIF-8-800 has been chosen to serve as the modifier. Zn and Ni may readily combine to produce an alloy using a straightforward carbonization procedure, which results in Zn/Ni-ZIF-8-800 with excellent conductivity. It has not yet been reported that an electrochemical sensor for the detection of AP that is based on bare GCE modified with PCA and Zn/Ni-ZIF-8-800 modified bare GCE has been developed. This is the best information [28]. Because of this, it is possible to produce a high-performance sensing material for detecting hydrazine by employing a hybrid material that has a highly uniform dispersion of AuNPs embedded in a well-aligned architecture of MOF-derived nanocomposites. This may be accomplished by the use of a hybrid material [29]. In the field of electrochemical sensors, the material Cu-BTC, which is a classic example of a MOF, has been the primary focus of study. It has been shown that prepared Cu-BTC frameworks may be used for the purpose of locating both tartrazine and sunset yellow. Comparatively, the linear concentration range for tartrazine is between 1.0×10^{-9} and $1.0 \times 10^{-7} \text{ mol L}^{-1}$,

while the concentration range for sunset yellow is between 0.3×10^{-9} and 5.0×10^{-8} mol L⁻¹. Additionally, it has been shown and validated that a Cu-BTC-based electrochemical sensor may be used as a device for the purpose of lead detection [87]. An electrochemical platform that can perform individual as well as simultaneous studies of heavy metal ions (HMIs) in solution has been constructed by integrating ZIF-67 NPs into the layers of EG. This platform was built in order to take use of the SWASV approach. The constructed structure exhibited a desirable form, an abundance of active sites, and a significant amount of electrochemically active surface area. Additionally, it was effectively used in HMI detection. Because of the material's reasonably adequate pore capacity, it is possible for hazardous heavy metal ions to be adsorbed by the material. In addition, the synthetic ZE-2 has a plethora of nitrogen centers, which makes it superior in terms of its ability to combine with Hg²⁺ and other HMIs [30]. In spite of this, research on the electrochemical examination of ZIFs materials is very seldom documented; thus, it is important to investigate the applicability in HMIs detection. In addition, element doping, which is a means for modifying the physical and chemical characteristics of NMs, may often play a surprisingly beneficial role. This is because it is a method for adjusting the properties of NMs. In order to construct a Fe-Co bimetallic MOF, a straightforward method with sodium hydroxide as the mediator was used to incorporate Fe elements into ZIF-67. Electrochemical experiments confirm that iron was incorporated into the MOF throughout the preparation process, which results in an increase in OER activity. The electrical structure of ZIFs may be altered by inserting foreign elements into the lattices, which may make it easier to realize particular electrochemical analytical characteristics. This can be beneficial [31]. In comparison to single-metal MOFs, bimetallic MOFs are capable of exhibiting better levels of activity, selectivity, and stability in the applications. It has been discovered that bimetallic Co-Zn-MOF may have an extremely great capacity to take in CO₂ molecules. It has been established that bimetallic MOFs may be used in the production of electrode materials for charge energy storage. In comparison to the electrochemical performance of monometallic compositions, the monometallic compositions of these electrode materials that are made of bimetallic compounds are said to be capable of displaying a significantly increased level of electrochemical performance. On the other hand, bimetallic MOFs have not been researched for use as electrode materials for electrochemical sensors as of yet in order to detect BPA [32]. The development of NPs/MOF composites has resulted in a notable increase in the number of applications for MOF composites that include electrochemical sensing. These frameworks have the absolute benefit of both the NPs and the MOFs that make them up. To begin, a Cu-MOF supported Au-SHSiO₂ NPs composites based modified electrode was used to generate the first NPs loaded MOFs. This electrode was used for the electrochemical measurement of hydrazine. It has been established that composites made of reduced graphene oxide (rGO) and MOFs have a synergistic effect, which results in improved electrochemical performance. The sensation of

hydrazine in ambient water samples have been demonstrated to be feasible using gold NPs that have been encased in CeO₂ and synthesized. These NPs have been incorporated in rGO [33].

4. CNT FOR ELECTROCHEMICAL SENSING

The extraordinary electrical conductivity of CNT is one of the primary reasons for their huge trend. CNT has the potential to perform the function of an electron reservoir, which can accelerate charge transport and hence diminish recombination of photo-generated charge carriers. Recent research has found evidence of nanocomposites based on CNTs, which have proved their utility in the sectors of catalysis, electronics, and solar devices [34]. The incorporation of CNTs on polymeric NFs optimizes the capabilities of the electrical fibers, most significantly the conductivity. This makes it possible for composite NFs to be exploited as electrochemical sensors, considering the fact that the majority of polymers are not conductive. This kind of enhancement is accessible through the interactions of nanotubes with polymeric NFs. The method of electro spinning has been implemented in order to facilitate the amplification of this phenomenon [35]. The chemical functionalization and increased durability of the CNTs film electrode will both contribute to improvements in the faradaic responses. This will be achieved by expanding the number of target locations that are conveniently located near one another. The controlled adsorption of CNTs on the self-assembled monolayer (SAM) of organosulfurs generated on the gold electrode is a technique that is more exact than dip-coating and the construction approach of stacking layers one on top of the other [36]. CNT-based sensors include a high analyte resolution as a result of the strong heterogeneous electron transfer rate between the analytes and the electrode surface. Carbon nanotube embedded nafion polymer composites have been deployed in the design of the electrochemical sensors. These products exhibit stability and would be used as nanoelectrode arrays [37]. Detecting sulfide can be made a great deal simpler by using CNT glassy carbon and fiber electrodes that have been enhanced with CNT. The use of CNTs as the primary focus of electrochemical research is a relatively recent development. The combination of their mechanical, electrical, and chemical properties gives them their unique characteristics. The electrical properties of these materials have allowed for improvements to be made to the electron transport processes of a wide variety of physiologically significant species, including proteins, NADH, neurotransmitters, cytochrome c, and cysteine (see Figure 3). Utilizing the electrical properties of various materials allowed for the successful completion of this task. In a similar manner, sulfide is oxidized, and CNT-modified glass carbon electrodes have the potential to be used in order to detect this process more accurately [38]. For the purpose of determining the amount of microcystin-LR present in the sample of water, a biosensor made of multiwalled carbon nanotubes (MWCNTs) was employed [39]. It has been shown that glutaraldehyde may be used in the synthesis of composites consisting of MWNTs and chitosan (AChE). As a consequence of this study, stable biosensors that were capable of quickly detecting and

quantifying triazophos were developed. As a result of their ability to speed up the electrochemical oxidation of thiocholine generated by enzymes, MWNTs were able to reduce the working potential. This method is advantageous in that it is simple, quick, and superior to earlier electrochemical AChE biosensor design iterations in terms of its ability to identify pesticides. The suggested sensor was shown to be both stable and sensitive enough for use in conducting AChE-inhibitor tests and monitoring the environment [40]. It's possible that the redox sections of enzymes may be coupled to CNTs, which would make it easier for electrons to go from the enzyme hub to the electrode surface. Because of this, it is no longer necessary to use cofactors or mediators. Oxidase and dehydrogenase were both brought into CNT so that glucose and ethanol could be found. Oxidases that work on glucose and alcohol, as well as dehydrogenases that work on both of these substances, are included in this category. Using enzyme-CNT biosensors, one is able to determine the presence of uric acid, lactate, ascorbic acid, and polyphenols [41]. Recently, researchers working in the field of electroanalysis have been concentrating their efforts on electrodes that have CNTs. Electrocatalysts on electrode surfaces, such as CNTs and metallophthalocyanine complexes, which are structured in channels, may work more effectively. After applying amitrole to an acid-treated basal plane pyrolytic graphite electrode and then covering it with a polymer of iron (II) tetra-aminophthalocyanine complex (FeTAPc). The electrocatalytic response to sub-nanomolar amitrole accumulation may be improved with the combination of the use of CNTs and metallophthalocyanine [42]. The transmission of electrons is facilitated by CNTs, which is the root cause of this phenomenon. Because CNTs cannot be dissolved in any aqueous solution, this is a significant setback for the study that is being conducted. It is to everyone's good fortune that recent research has uncovered innovative methods for the production of electrodes and the modification of their surfaces [43]. Nanotubes made of carbon, either single-walled or multi-walled, are a fantastic material for use in surface-based electronics of any kind. The metallic properties of MWCNTs may be attributed to the presence of a single layer of metal. Since it is simpler to swap out metallic SWCNTs for other electrodes, this material should be used wherever possible. During the modification process, single-wall and multiwall CNTs are fused together in order to increase the nanotubes' overall functionality as a unit. A sensor has been fabricated by layering graphene and MWCNTs on top of an electrode composed of carbon ionic liquid. It is now possible to do an analysis of the direct electrochemistry of hemoglobin using immobilized nafen-hemoglobin. These sensors are held in place by an electrode made of a carbon ionic liquid. The cyclic voltammetry test revealed direct electron transport from the hemoglobin hybrid electrode. When functioning as an electrochemical biosensor, this electrode does not need the presence of an intermediate. It was shown that the modified electrode has a high electrocatalytic capacity for the reduction of a number of different compounds, with detection limits of 0.0153 mM, 34.9 nM, and 0.282 mM, respectively. This class of chemicals includes substances such as hydrogen peroxide, trichloroacetic

acid, and sodium nitrous oxide, amongst others. The incorporation of CNT-GR resulted in an increase of about 3.6 times the redox peak current. This spike was caused by the synergistic effects of graphene and MWCNT hybrid, which were produced when two different types of materials were mixed [44].

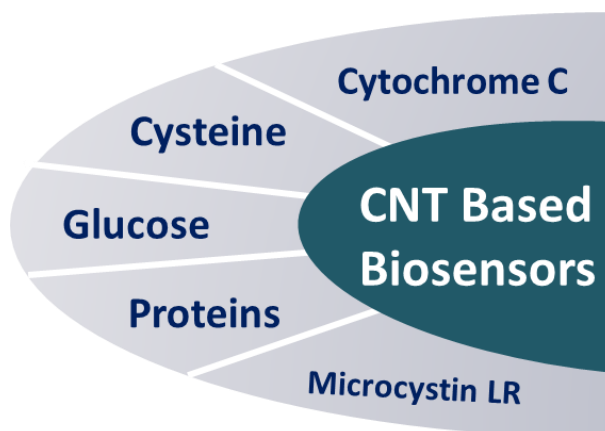


Figure 3. CNT in biosensing.

The first stage in the process of developing a CNT-modified biosensor electrode was to include enzymes and CNTs into a Teflon binder. Glucose oxidase and NAD⁺/NAD⁺ were added to the three-dimensional CNT/Teflon matrix in order to produce low-potential amperometric biosensors for glucose and ethanol. These biosensors were able to detect both glucose and ethanol. It was possible to accomplish this goal because to the electrocatalytic characteristics of CNT. A higher electron flow was shown to be associated with reduced surface fouling. When compared to graphite/Teflon counterparts, the CNT/Teflon biocomposite was shown to have a greater degree of sensitivity. As a means of verification, replacements made of graphite and Teflon was used. Because the open ends of CNT behave electrochemically like electrodes, this team has been able to demonstrate that biomaterials can now be imprinted with nanobarcodes, and biorecognition events can be amplified. This discovery allows for the imprinting of nanobarcodes on biomaterials, as well as the amplification of biorecognition events. Utilizing electrochemical nanobiosensors has made it feasible to detect both cancerous cells and bacteria that are the cause of sickness [45].

5. CONCLUSION

In this comprehensive review, we have explored the significant contributions of NMs to the advancement of optoelectronic devices and electrochemical sensors. The performance of these devices has been improved by the remarkable characteristics of nanostructured metals, MONPs, and nanocomposites including MONPs. As diverse sensing substrates, metal oxides including TiO₂, ZnO, Al₂O₃, and Cr₂O₃ have become essential tools for environmental monitoring and medical applications because these can identify a variety of hazardous substances and biomarkers by using electrochemical methods. Because of their excellent qualities, large surface areas, and tunability, MOFs have become outstanding materials for electrochemical sensors. With improved electrochemical activity, doped N-Cu-MOF has demonstrated potential. MOFs have a lot of

potential for surface modification and selective sensing, despite difficulties with signal transduction and reproducibility. Further extending the range of sensing applications are bimetallic MOFs and MOF composites containing NPs that have shown increased performance. Exciting opportunities for improving electrochemical sensing technologies exist thanks to the ongoing development of MOFs. CNTs have played an important role in the fabrication of electrochemical sensors due to their exceptional electrical conductivity. Since CNTs were added to polymeric nanofibers, the sensors' conductivity was improved, making them useful in a variety of applications. High analyte resolution and success in detecting a range of chemicals are two advantages of CNT-based sensors. Innovative methods in electrode fabrication have resulted from research aimed at enhancing electrocatalytic responses utilizing CNT-modified electrodes. Furthermore, the combination of CNTs with graphene has demonstrated synergistic benefits, providing improved redox peak currents in biosensors. New opportunities for illness diagnosis and bio recognition events have been made possible by electrochemical nanobiosensors including CNTs. As the use of NMs in optoelectronic devices and electrochemical sensors has greatly advanced these domains, so the commercial use of these in several industries is now needed. Our observation concludes that if these materials get commercial use, the industry will be benefited. To apply in industry commercially there may be some obstacles which should be overcome by further research of commercial uses.

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