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Nano Material Based Optical and Electrochemical Sensors

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Abstract- Nanomaterials display unique features such as Excellent physical and chemical stability, lower density and high surface area. This chapter focus on nanomaterials such as graphene and carbon Nanotubes, how it is electrically and optically sensored with Nanomaterials. Multiple complex biosensors has been focused and even the application of Nanaomaterials also. In past few years a major disease has been affected throughout the world that is COVID-19, how nanomaterials has been used in curing the disease.

Index Terms-Bio Sensors, Carbon Nanotube, Electrochemical, COVID 19

I. INTRODUCTION

Nanomaterial is a material with any external dimension in a nanoscale having internal structure or surface structure in nanoscale . It ranges from 1-100nm at one dimension in a nanometer range. However, when it comes to nanomaterials, there is no uniform globally accepted definition as different organizations have differing viewpoints. According to the Environmental Protection Agency (EPA) , "Nanomaterials can demonstrate distinct characteristics different to the identical chemical component in a broader dimension". It is high toxicity in pure and very low toxicity in natural ecosystems. If it is interact with natural organic material can change toxicity effect of nanomaterial .Major important role of nanomaterial is fabrication of many devices.

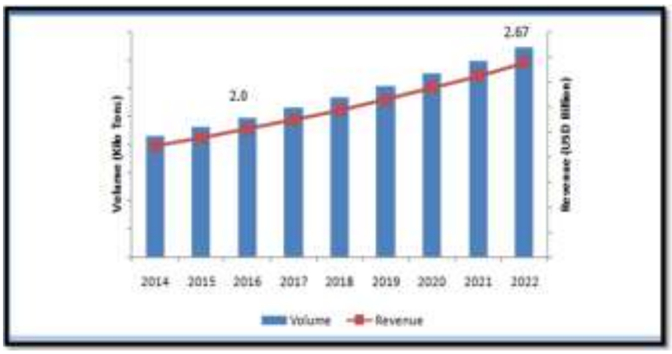


Figure 1: Graphical representation of volume and revenue on nanomaterials till 2022

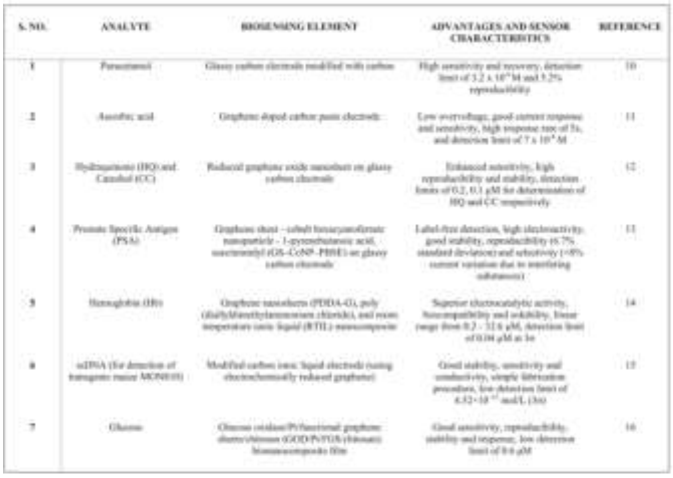
Number of nanomaterial with features have been synthesized by physical and chemical and even biological process.More efficient and expensive by means of physiological process. With remarkable achievements in nanotechnology , nanomaterial-based electrochemical signal amplifications have great potential of improving both sensitivity and selectivity for electrochemical sensors and biosensors. A biosensor is a device that combines a sensitive biological recognition component and a physical transducer to detect analytes of interest. In 1953, Clark et al2 first published a paper containing the fundamental ideas of a "biosensor". Moreover, in 1967, Updike and Hicks3 successfully reported a biosensor for glucose detection. Among all nanomaterials we are going to see about graphite and carbon nanotube. .

II. ELECTROCHEMICAL AND OPTICAL GRAPHENE-BASED BIOSENSORS

The main features of this nanomaterial were recently praised by K.S. Novoselov in his Nobel lecture (December 8, 2010), stating that graphene is "more than just a flat crystal" . This feature makes graphene for the design of both electrochemical and optical sensors,by means of modifying the electrochemical properties of an electrode and to work as label/loading agent for biomolecules and nanomaterials, because of its high surface area and easy

functionalization, in the case of electrochemical transduction; by means of providing fluorescence quenching at any wavelength by means of energy transfer in the case of optical transduction. Graphene is a single layer of carbon atoms connected in hexagonal pattern,it also thin and light in weight. Graphene-modified screen- printed electrodes (SPEs) found applicable in many analytical GO nanoplatelets electroactive properties were also recognized in a DNA electrochemical sensor for single- nucleotide polymorphism detection, based on the interactions between GO nanoplatelets and DNA strands The sensing mechanism was based on the different binding ability of single-stranded (ss) and double-stranded (ds) DNA toward GO nanoplatelets and the stronger ability of graphene to conjugate ssDNA with respect to dsDNA, demonstrating the inherently electroactive property of GOsectors for revealing compounds ranging from clinical diagnosis to environmental pollution. Graphene oxide nanosheets (GONs) were recently exploited as an SPE modifier in combination with titanium dioxide nanofibers (TNFs) to detect adenine by differential-pulse voltammetry Ryoo and coworkers [15] described the use of GO for the development of an optical biosensor to detect microRNAs exploiting peptide nuclei acids (PNA), highlighting the advantages of graphene as high loading capacity nanomaterial for bioreceptor immobilization.

Table 1: Graphene Based Biosensors



S. NO.	ANALYTE	BIOSENSING ELEMENT	ADVANTAGES AND SENSOR CHARACTERISTICS	REFERENCE
1	Paracetamol	Glassy carbon electrode modified with carbon	High sensitivity and recovery, detection limit of 3.2 x 10[illegible] M and 5.2% reproducibility	10
2	Ascorbic acid	Graphene doped carbon paste electrode	Low overvoltage, good current response and sensitivity, high response rate of 5s, and detection limit of 7 x 10[illegible] M	11
3	Hydroquinone (HQ) and Catechol (CC)	Reduced graphene oxide nanosheets on glassy carbon electrode	Enhanced sensitivity, high reproducibility and stability, detection limits of 0.2, 0.1 µM for determination of HQ and CC respectively	12
4	Prostate Specific Antigen (PSA)	Graphene sheet – cobalt hexacyanoferrate nanoparticle - 1-pyrenebutanoic acid, succinimidyl (GS–CoNP–PBSE) on glassy carbon electrode	Label-free detection, high electroactivity, good stability, reproducibility (6.7% standard deviation) and selectivity (<8% current variation due to interfering substances)	13
5	Hemoglobin (Hb)	Graphene nanosheets (PDDA-G), poly (diallyldimethylammonium chloride), and room temperature ionic liquid (RTIL) nanocomposite	Superior electrocatalytic activity, biocompatibility and solubility, linear range from 0.2 - 32.6 µM, detection limit of 0.04 µM at 3σ	14
6	ssDNA (for detection of transgenic maize MON810)	Modified carbon ionic liquid electrode (using electrochemically reduced graphene)	Good stability, sensitivity and conductivity, simple fabrication procedure, low detection limit of 4.52×10[illegible] mol/L (3σ)	15
7	Glucose	Glucose oxidase/Pt/functional graphene sheets/chitosan (GOD/Pt/FGS/chitosan) bionanocomposite film	Good sensitivity, reproducibility, stability and response, low detection limit of 0.6 µM	16

Figure 2: Ion-selective electrochemical sensor using graphene as the ion-to-electron transducer for calcium detection

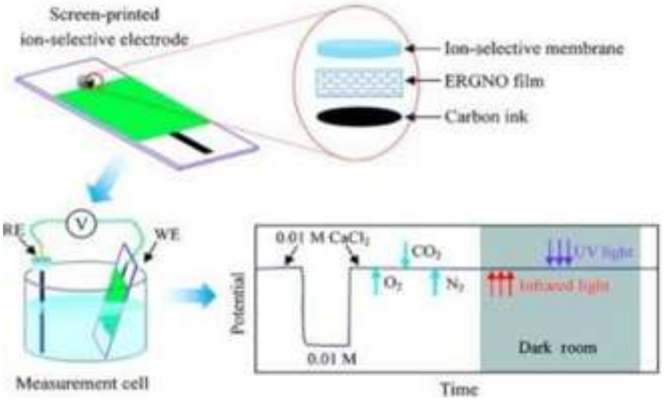


Figure 3

A) Scheme of graphene-based nanomaterials as a DNA biosensor with fluorescent detection [14]. (B) Scheme of strategy for a microRNA sensor based on graphene oxide (GO) and peptide nucleic acids (PNAs) for multiplexed microRNA sensing in vitro

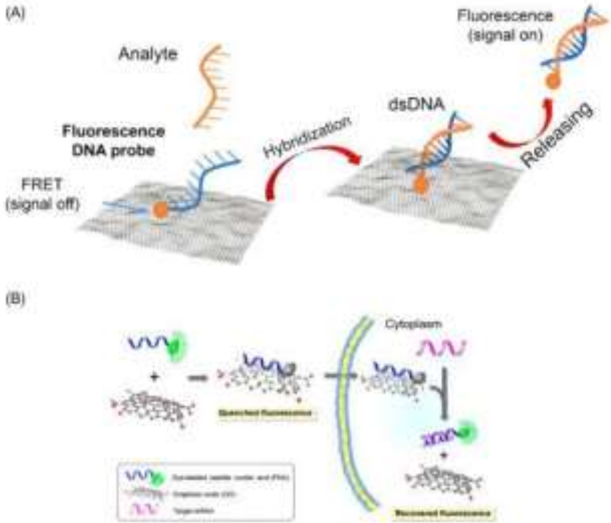


Figure 4

Carbon Nanotubes

In 1991 Sumio Lijima published a ground breaking paper in nature "Heliacal microtubules of graphitic carbon" reporting the discovery of multi walled carbon nanotubes. Carbon Nanotubes (CNTs) are cyclndrical molecular consists of rolled up sheets of single layer carbon atoms with diameter of 1 nanometer to 100nm .Their length can reach several micrometer or even millimeters.The C-C bond make them fittest and most durable fiber.CNTs are thermally stable and may be metallic or semiconducting based on paramaters . CNT- based biosensors usually consist of a sensitive element, which involves functionalization of the CNT with a specific biomolecule such as proteins , and a tranducer . Villamizar et al. reported a bioFET consisting of a network of SWCNTs to enable rapid and sensitive detection of Salmonella Infantis and using appropriate antibodies, such a sensor can be extended for the application of sensing other viruses or bacteria . Biosensors utilizing a combination of nanomaterials such as MoS2/MWCNTs have also been reported to combine the individual benefits of the materials .

III. ELECTROCHEMICAL CARBON NANOTUBE-BASED BIOSENSORS

CNTs electrocatalytic properties own to edge defect sites and metal impurities, combined with the high surface area, suitable to immobilize nanomaterials and/or biocomponents, have been widely exploited to develop electrochemical biosen, CNTs were principally used in combination with other nanomaterials, as in the case of Dong ,who developed a glassy carbon electrode modified with a nanocomposite constituted of MWCNTs–CeO2–Au NPs for methyl parathion detection, with a limit of 3.02×10−11 M. CNTs also showed high capability for bioreceptor immobilization, enhancing the biomolecule loading as well as the electrochemical analytical performances, as demonstrated by Vicentini . In detail, tyrosinase was covalently immobilized onto CNTs by means of (1-ethyl-3-(3-dimethylaminopropyl)- carbodiimide) and N-hydroxysuccinimide, for catechol detection with a detection, nanomaterials possess peculiar characteristics that can be tuned for the different optical transductions, including luminescence, fluorescence, and color changes, as well as extended wavelength range of emission from 700 to 1400 nm, high photostability, low autofluorescence, and deep penetration capability in skin for in vivo imaging among others. Ahn a person who study the interaction mechanisms among protein.In detail, they used CNTs as optical sensors for the label-free detection of protein–protein interactions where each nanotube was encased within a chitosan polymer wrapping modified with nitrilotriacetic acid moieties. After Ni2+ chelation, NTA–Ni2+ complexes work as proximity quenchers, modulating the intrinsic SWCNT fluorescence intensity as a function of distance from the SWCNT surface.

Figure1.4(A) Scheme of GO and MWCNTs nanocomposite and its application for heavy metal detection ,(B) Scheme of the reaction used to immobilize tyrosinase enzyme on MWCNT

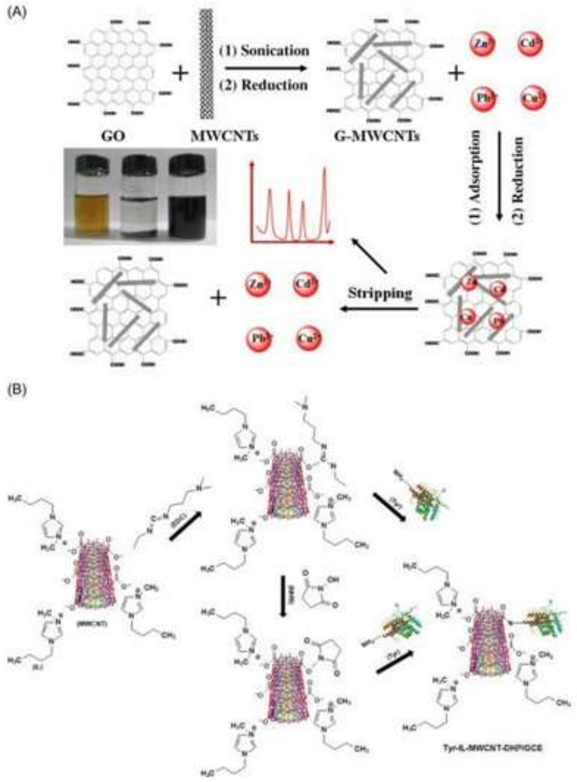
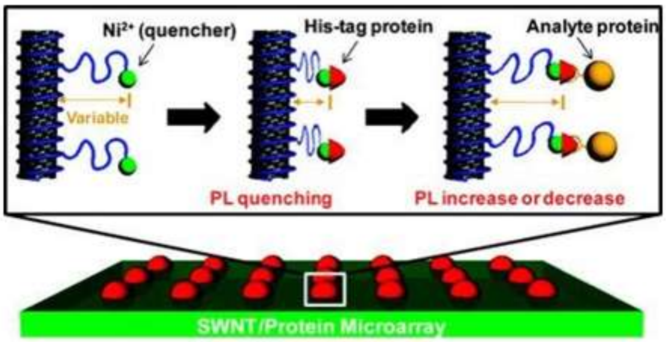


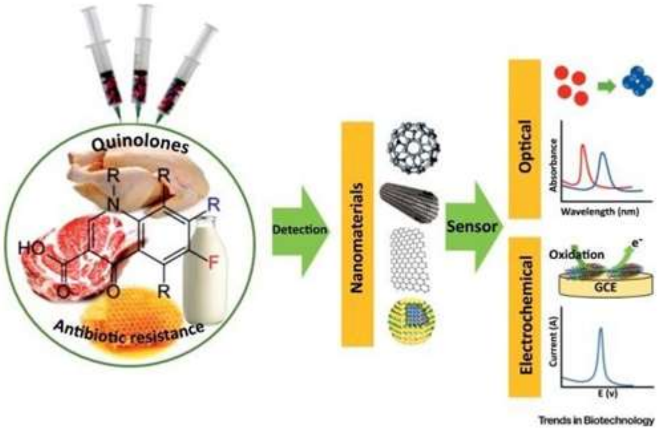
Figure 5: Schematic of the SWCNT array and the signal transduction



IV. OPTICAL AND ELECTROCHEMICAL SENSORS AND BIOSENSORS FOR ANALYSIS OF ANTIOXIDANTS IN FOOD

Antioxidants are a group of healthy substances which are useful to human health because of their antihistaminic, anticancer, anti-inflammatory activity and inhibitory effect on the formation and the actions of reactive oxygen species. Generally, they are phenolic complexes present in plantderived foods. Due to the valuable nutritional role of these mixtures, analysis and determining the amount of food is of particular importance. Sensors and biosensors are regarded as favorable tools for antioxidant analysis because of their special features like high sensitivity, rapid detection time, ease of use, and ease of miniaturization. Antioxidants are able to stop the oxidation ofproduct. Antioxidants in foods can be classified into natural and synthetic. Natural antioxidants consist of the tocopherols (vitamin E), ascorbate (vitamin C), carotenoids, polyphenolic compounds such as flavonoids, phenolic acids, anthocyanins, proteins, and minerals; and synthetic antioxidants include butylated hydroxyanisole (BHA), propyl gallate (PG), tertbutylhydroquinone (TBHQ), and butylated hydroxytoluene (BHT), that are frequently used in food formulations.

Antioxidants combat diseases that are derived from oxidative stress such as heart disease, cancer, diabetes, cardiovascular diseases, neurodegenerative disorders, AIDS, ageing, arthritis, asthma, autoimmune diseases, Alzheimer’s disease, Parkinson’s dementia, hypertension. Several methods have been developed for identifying antioxidant capacity that differ in their procedures, complexities and applications [14]. Generally, antioxidant activity can be measured by instruments such as high performance liquid chromatography (HPLC), gas chromatography (GC), Fourier transform infrared spectroscopy (FT-IR), nuclear magnetic resonance (NMR), and capillary electrophoresis (CE) [15]. Also, several assays, such as oxygen radical absorbance capacity (ORAC), Folin-Ciocalteu (FC), 2,20- azinobis-3ethylbenzothiazoline-6-sulfonic acid)/Trolox equivalent (ABTS/TEAC; antioxidant capacity, 2,2-diphenyl-1- picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP) and cupric reducing antioxidant capacity (CUPRAC) are used for antioxidant analysis



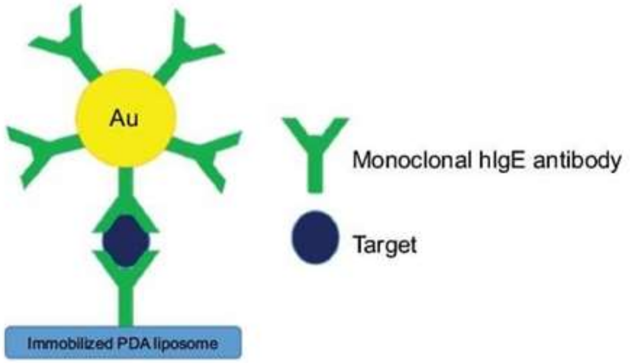
Trends in Biotechnology

Nanomaterial-Based Biosensors for Biological Detection

Nanomaterial-based biosensors have become one of the major topics in the field of diagnostics. Analysis results are displayed through transforming the biological reaction into a measurable signal, which can be used for qualitative and quantitative determinations. The biological recognition component part of biosensors usually includes nucleic acids, enzymes, antibodies, receptors, microorganisms, cells, tissues, and even some biomimetic structures. Physical transducers vary significantly with the source of the quantifiable signal, and utilize mostly optical and electrochemical systems. In addition, as demands increase, all constituents in the biosensors can be designed and manufactured in large quantities at a low cost to satisfy the needs of users.

AuNP-based Biosensors

AuNp is most commonly used nanomaterial in the field of biosensor . Development of optical and electrochemical biosensors has become very popular due to the unique properties of AuNPs. A major advantage of using AuNPs in biosensors is the increase in detection signal, or response, for analytes that are especially low in concentration. For example, a biosensor based on a boron-doped diamond (BDD) electrode has recently been constructed by Wei et al19 to detect the presence of organophosphate pesticides (OPs), which are harmful for human health, but used widely in agricultural industry. AuNPs conjugated with polyclonal antibodies and added on the polydiacetylene liposomes to enhance fluorescence signals. As shown in Figure 1.6, Won and Sim22 demonstrated about 100-fold increase in sensitivity by employing AuNPs to detect human immunoglobulin E (hIgET). This sandwich setup allowed detection of hIgE as low as 0.1 ng/mL.



GR based Biosensors

GR-based biosensors GR is made of a single layer of sp2 carbon bond atoms that arrange into a 2D lattice that is known for its electron mobility, thermal conductivity, high surface area, and electrical conductivity. These characteristics of GR allow rapid electron transfer for the detection of biomolecules using biosensors.GR has often been coupled with AuNPs in biosensor designs. An elegant method biosensor was prepared by Gupta et al31 using mercaptophenyl boronic acid (MBA)-terminated Ag@AuNPs/ graphene oxide (Ag@AuNPs-GO) nanocomposites in connection with surface-enhanced Raman spectroscopy (SERS). bacterial DNA detection could also be accomplished using GR-based biosensors. Zainudin et al37 described the drop-casting of RGO suspension onto GCE, followed by addition of 1-pyrenebutyric acid (PyBA). The carboxyl group of PyBA was activated via EDC/NHS, and then modified with probe DNA to detect Escherichia coli cells.

Noble Metal Nanomaterial-Based Biosensors for Electrochemical and Optical Detection of Viruses Causing Respiratory Illnesses

Noble metal nanomaterials, such as gold, silver, and platinum, has their unique properties such as superior conductivity, plasmonic property, and biocompatibility. Due to their unique properties, researchers have used them to fabricate biosensors. Viruses are infectious pathogens that require hosts for parasitic entry and cause significant disease due to their properties of propagation and genetic replication (Mokhtarzadeh et al., 2017; Abid et al., 2021). A biosensor is a medical platform to detect environmental components or biocomponents using numerous techniques, such as electrochemical detection using redoxproperties,fluorescencedetectionwithfluorescentdyes,and surface-enhancedRamanscattering(SERS)bythe unique optical properties of materials (Goode et al., 2015). Noble metals are metallic elements such as ruthenium, rhodium, palladium, gold, and silver with outstanding resistance to high temperatures and chemical reaction. Noble metal nanomaterials have been used as catalysts to reduce pollutants from exhausts because the surface of noble metal nanomaterials functions as the active sites for redox molecules and increases catalytic activities when the surface is in a zero-valent state. The gold nanoparticle (AuNP) has unique properties, including high electrical conductivity, biocompatibility, and stability (Sardar et al., 2009). Surface modification of the gold surface can be easily achieved using a thiol group via the gold –thiol covalent attachement.

Platinum (Pt) as an excellent catalyst because of its high stability in acid electrolytes and remarkable catalytic property for hydrogen redox reactions. In addition to the high cost associated with its rarity in nature, Pt—a small particle that is not a bulk-form—is conventionally used for chemical and biological applications

V. ELECTROCHEMICAL BIOSENSORS FOR VIRUS DETECTION

Electrochemical sensing technologies, such as cyclic voltammetry (CV), amperometry, and electrochemical impedance spectroscopy (EIS), can analyze electrochemical activities like the reduction and oxidation of biomolecules or chemicals (Cho et al., 2020; Noori et al., 2020). Because these sensing methods are based on electron transfer, it is essential to increase electron transfer rates and electrode surface area to enhance the electrochemical signal and increase sensitivity (Shin et al., 2020; Zhang L. Y. et al., 2020). AuNPs have the characteristic of electrostatic interactions or physisorption with a protein; therefore, they can be used to immobilize antibodies on the electrode. With these properties, a fluorine-doped tin oxide electrode with AuNPs and SARS-CoV antibody was fabricate.The viral RNA was electrochemically detected on a screen-printed carbon electrode composed of graphene oxide, mediator, and probes (Zhao et al., 2021). (B) Influenza virus was captured between// antibodies in sandwich-structured biosensor composed of Pt-porous zinc oxide-hemin and AuNPs.

The influenza virus was electrochemically detected through the catalytic oxidation of p-NP after catalytic reaction of p-NPP inside the Pt-porous-zinc oxide hemin structure (Yang et al.,2016). (C) The influenza virus was detected by the colorimetric biosensor. In the presence of target DNA from the influenza virus, negative charged AgNPs were well-dispersed because of the hybridization of probe and target DNA, with a bright color. In contrast, the AgNPs were aggregated with probe DNA in the absence of target DNA, which cause the solution color to darken (Teengam et al., 2017). (D) The influenza virus was optically detected using quenching effect. When the influenza

virus was capture by the antibodies, the intensity of QDs immobilized AuNPs decreased by steric hindrance (Nasrin et al., 2020). AuNPs have the characteristic of electrostatic interactions or physisorption with a protein; therefore, they can be used to immobilize antibodies on the electrode. With these properties, a fluorine-doped tin oxide electrode with AuNPs and SARS-CoV antibody was fabricated. When the SARS-CoV spike protein wasimmobilized on the electrode by the antibody-antigen reaction, the peak current of the electrode was increased. Based on the results, the biosensor successfully detected SARS-CoV spike protein with LOD = 7.8 × 10−1 pg/mL using DPV (Mahari et al., 2020)

Optical Biosensor for Virus Detection

Optical properties of noble metal nanoparticles are desirable in the field of biosensors. Optical phenomena including colorimetry, fluorescence, and SERS have been used in various fields.In optical biosensors, the specific colors of noble particle have been widely used because their colors can be detected with the naked eye. The color of the AuNPs changes from red to purple when the AuNPs are agglomerated.

The phenomenon can be applied for detecting SARS-CoV-2 using antibodies (spike/membrane/envelope antibodies of SARS-CoV- 2)functionalized AuNPs (f-AuNPs) (Ventura et al., 2020). When SARS-CoV-2 interacted with f-AuNPs as an antigen-antibody reaction, f-AuNPs were agglomerated on the surface of the virus, resulting in a color change. Matsumura et al. enhanced the color signal by developing signal-enhanced Pt-latex nanoparticles to detect the influenza virus and applied them in an immunochromatographic test (ICT). The color of PtNPs can be enhanced by a latex organic nanocomposite, with a more vivid color than PtNPs. SERS is a powerful tool for detecting viruses because it enables label-free, highly sensitive detection.

Noble Metal Nanomaterials Have Been Used as a SERS-Active Probe Because of Their Unique SPR Property.

Nanomaterial-based Multiplex Optical Sensors

Multiplexed analysis has attracted considerable interest in the biological and biomedical fields due to its high throughput and detection accuracy.Almost all types of signals, including optical, electrical, thermal, magnetic and mass, have been used for multiplexed detection. Through the light–matter interaction, optical signals such as spectral wavelength and intensity, and lifetime due to absorption, emission and scattering, can be harnessed for multiplexed encoding.

Nanomaterial-based Optical Biosensors for the Detection of Foodborne Bacteria

Nanomaterial-based optical biosensors have been widely used in monitoring foodborne bacteria. Foodborne bacteria (including Salmonella, Escherichia coli, etc.) can cause a number of illnesses and result in social and economic losses. However, the conventional tools used in foodborne bacteria monitoring demonstrate poor specificity, while also being insensitive, labor-intensive and time-consuming

Application of Nanomaterials in the Field of New Energy Environment

With the development of urban modern industry, the impact of motor vehicle exhaust on the urban environment is getting worse and worse. The waste material recycling enterprises generally have small operating scale and backward technology, and the investment in the development of renewable resource recycling technology is seriously insufficient. Nanomaterials can clearly distinguish oxides and solid oxides by using their unique electronic layer structure, so that automobile exhaust can stop polluting volatilization under high-temperature conditions .At present the application ability of nanomaterials in automobile exhaust purification still needs further development. Practice has proved that nanomaterials have good purification functions. Starting from the aspects of controlling and changing the molecular structure of gases, the catalytic properties of rare earths are used to desulfurize and denitrify flue gas and fully demonstrate the absorption capacity of nanomaterials. In the process of fossil energycombustion, the mechanism of rare earth is generally manifested in the effect of catalyzing the synthesis of molecular structure. On the basis of not affecting the molecular structure of the material, the effect of the surface chemical state of the rare earth on the burning ability of fossil fuels is expanded as much as possible.

Biosensors For Covid-19 Diagnosis

The first human cases of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) or COVID-19 were recordedin Wuhan,China in December,2019 before the World Health Organization declared the global outbreak of the highly contagious virus a pandemic on March 11, 2020.Nucleic Acid Tests-Gene based identification of viral genomic RNA using Reverse Transcription Polymerase Chain Reaction or RT-PCR tests as the gold standard, Serological Immunoassays adopted in conjunction with RT-PCR to get very high detection rates (98.6%). RT-PCR Tests detect viral RNA.

Enzymes convert RNA to DNA, which is replicated billions of times due to temperature cycles in the PCR machine, followed by binding of fluorescent markers which give a positive result if the fluorescence crosses a threshold value. Despite the fact that these are generally considered highly sensitive for SARS-CoV-2 detection, sensitivity has been reportedas low as 59%, Reason for low sensitivity could be easy degradation of RNA which can be prevented by immediate frozen storage conditions.

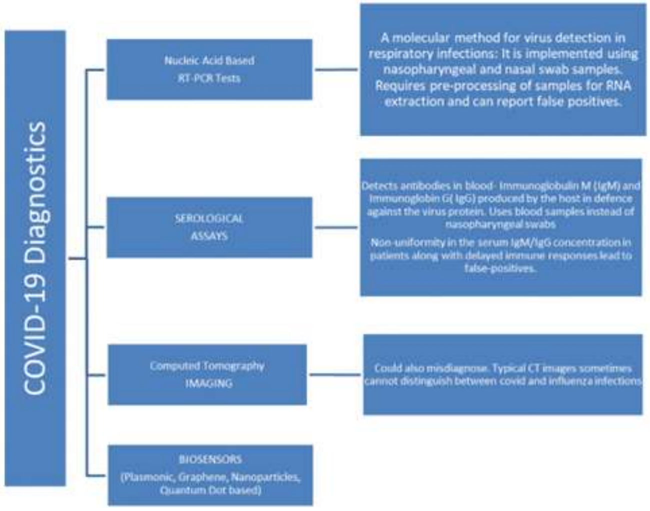
Therefore, mishandling samples could result in poor detection. During SARS-CoV-2 viral attack, the host RNA gets damaged and is released as fragments into the bloodstream, making their detection by RT-PCR challenging. Use of nanomaterials such as gold nanoparticles or fluorescent biomarkers can help isolate these RNA fragments and can overcome the detection problem by acting as signal enrichment tools. They typically have a shelf life upto 12 months. One challenging area for radiologists is to differentiate between COVID-19 infection and symptoms arising from other pneumonia like infections or lung disorders. Work done by various research groups working towards nanomaterials based biosensors has reportedly addressed some, although not all, of the above mentioned drawbacks. Pros of using NM based biosensors include rapid response, enhanced selectivity and sensitivity, portability and cost effectiveness.

Moreover, most nanomaterials can be appropriately functionalized to obtain enhanced properties and advantages, including biocompatibility, along with producing satisfactory reproducibility of the biosensors. A novel optical biosensor designed to identify the RNA sequences of the SARS- CoV-2 [98], and aimed at real time monitoring of virus concentration in air, has been shown to be responsive towards SARS-CoV and exhibits the ability to distinguish between RNA of SARS-CoV and SARS-CoV-2, closely related viruses with slightly varying RNA sequences.

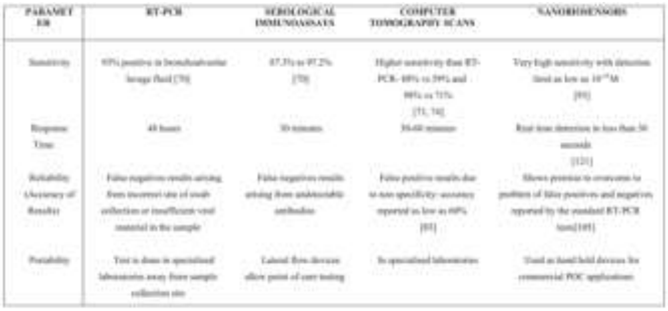
It consists of gold nanoislands upon which DNA receptors complementaryto the RNA sequences of the virus, are grafted. Molecules binding to the functionalised nanostructure help determine the presence of said RNA. Nanoparticles (NPs), as a consequence of their remarkable optical properties, can act as fluorescent probes for biomolecular imaging and detection.

Nanosensing systems based on Gold, Carbon, Silica and magnetic NPs in addition to Quantum Dots, have been extensively exploredin relation with cellular detection and monitoring of diseases . Functionalization using surface engineering on nanoparticles could be a useful tool to target the novel coronavirus.

Method of COVID-19 Diagnostics



Comparison of Parameters for Standard COVID-19 Tests and Nanobiosensors



Some Recently Developed Biosensors Showing Potential for SARS-COV-2

VI. CONCLUSION

This review article shows that the Nanomaterials are used in many ways .Past 10 years researches made a lot of sources regarding the use of nanomaterials in various fields like agriculture ,medicines, fuels, and so on..In thus we seen that the Nanomaterials mainly used as how biosensors are helpful in with Nanomaterials for detecting signal transduction .By using Nanomaterials biosensors diseses has been detected virally.COVID-19 is a major disease that has been spread all over the world pandameic ,we seen how nanomaterials used for COVID-19 pandameic and some of the Major applications in Nanomaterials biosensors. And we seen that how Nanomaterials using based on electochemiaclly and optically.

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