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Application of Nanomaterial in Biosensors

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ABSTRACT
Nanomaterials are studied for their probable use in biomedical diagnosis study recently, making the field of healthcare bio-sensing a quickly developing one. Nanomaterials give sensor platforms flexibility and might possibly permit switching between several detection methods. The potential for combining several nanomaterials enables the exploitation of their new and synergistic features for sensor development. As a result, we offer a thorough analysis of the uses of nanomaterials in healthcare sensing, including organic, inorganic, and carbon based nanomaterial. These sensing systems can identify a wide range of clinically important molecules, including nucleic acids, viruses, bacteria, cancer antigens, pharmaceuticals and narcotic drugs, toxins, contaminants, and even whole cells in a variety of sensing media, from buffers to more complex environments like urine, blood, or sputum.

Keywords – Nanomaterials, cancer antigens, Biosensing, synergistic.

I. 1.INTRODUCTION OF BIOSENSOR

The International Union of Pure and Applied Chemistry (IUPAC) defines a biosensor as, “a device that uses specific biochemical reactions mediated by isolated enzymes, immunosystems, tissues,organelles or whole cells to detect chemical compounds, usually by electrical, thermal or optical signals”.This definition facilitates an insight into what a biosensor entail. Biosensors have three imperative constituents,

1. Areceptorthat specificallybindsto ananalyte.
2. Atransducerthatgeneratesasignalfollowingthebindingevent.
3. Adetectionsystemto quantifytheitsignaland transformintoutileinformation[1]
4. Leland C. Clark, the father of biosensors, created the Clark Oxygen Electrode, a crucial instrument that provides real-time monitoring of blood oxygen level of patient and has helped millions of surgeries throughout the world become safer and more productive.
5. These detection techniques could be piezoelectric, electrochemical, or optical in nature. Biosensors provide a number of advantages over traditional screening methods like enzyme-linked immunosorbent assays (ELISA), including the ability to be fully automated, improved repeatability, real-time and quick analysis, and frequently the potential for re-use due to surface regeneration. Medical diagnostics, food toxicity, fermentations, environmental safety, biodefense, and plant biology are just a few of the disciplines where biosensing is crucial. [2].

The top causes of death worldwide are ischemic heart disease, lung cancer, cirrhosis, and comparable infectious disorders. Lack of early diagnosis prevents effective and affordable treatments. As a result of its ability to provide quick, dependable, affordable, and user-friendly sensing platforms, biosensors have become more important in the field of medical diagnostics. In comparison to traditional detection methods employing spectroscopy or chromatography, biosensing technology has many advantages. These include of reduced dependence on operational employees with specialised skills, quicker reaction times, mobility, and more sensitivity. For instance, thanks to new biosensors, the time needed to identify infections like anthrax has decreased from 2-3 days to 5 min. [2].

History of biosensors

First commercial biosensor. In 1975, the same year that it was originally introduced, the (Yellow Spring Instrument Glucose Biosensor) It also introduces the first biosensor based on microbes. The first bedside artificial pancreas was created in 1976. The two years between 1975 and 1976 saw the invention of the most significant biosensors. [3].

The first in vivo blood gas pH sensor with fibre optics was introduced in the year 1980. In 1982, the first fibre optic-based glucose biosensors were released. 1983 debut of the first surface plasmon

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resonance immunosensor. In 1984, ferrocene, the first mediated aerometric biosensor, was discovered. Medisense ExacTech introduced blood glucose biosensors in the year 1987. In the year 1990 Launch of Pharmacia BIACore-based biosensor system. And LuanchofLifescanFastTakebloodglucosebiosensorwa sintheyear1998.[4]

Types of biosensors

Bio-recognitionelements.

Antibody

One kind of biosensor is antibody-based biosensor, also called immunosensor. This type of biosensor is focused on an immobilised antibody's (Ab) ability to recognise its linked target, or antigen (Ag). These Ab-based probes must meet highly stringent criteria for the creation of biosensors, including those for high specificity in a complex medium and clearly defined binding characteristics[5].
highstabilityandlarge-scalemanufacturingcapability, particularlyatacheapcost.

Phage

The creation of a phage-based biodetector that can identify some enteric bacteria, like Escherichia coli, in water samples utilising a luminous and substrate-independent output. Without either a concentration stage or an enrichment step, the emission of light, which is particular, enables the identification of 104 bacteria per millilitre in 1.5 hours after infection. [6]

DNA

Recent studies have shown that biosensors are a complete and promising method of detection with the benefits of rapid detection, cost effectiveness, and practicality. The goal of this study is to leverage the principles of DNA hybridization to quickly create a method with excellent selectivity and sensitivity for identifying V. parahaemolyticus.
In the study, X-ray Diffraction (XRD), Ultraviolet-visible Spectroscopy (UV-Vis), Transmission Electron Microscopy (TEM), Field-emission Scanning Electron Microscopy (FESEM), and Cyclic Voltammetry were used to characterise produced polylactic acid-stabilized gold nanoparticles (PLA-AuNPs) (CV) [7]

Enzyme

A significant excitatory neurotransmitter in the central nervous system is glutamate. Various neurochemical probes, such carbon fibre microsensors based on enzymes or microdialysis, may currently detect glutamate signals. enzymatic glutamate microbiosensor that continuously and in real time monitors changes in glutamate concentration from numerous recording locations in the form of a platinum microelectrode array with a ceramic substrate. Additionally, compared to previously reported enzymatic sensors in the literature, the generated microbiosensor is almost four times more sensitive to glutamate. [8].

TRANSDUCING ELEMENTS

Mass based bio sensors.

A mass-sensitive biosensor is any device that has capture probes embedded in its sensitive surface and measures a property that scales with mass. Micromechanical cantilever-based sensors, quartz crystal microbalance (QCM) and surface acoustic wave (SAW) devices, and evanescent wave-based sensors like surface-plasma resonance (SPR) are examples of aptamer-based, mass-sensitive biosensors.[9]

Magneto electric

In a variety of multiferroic materials, the existence of coupling between the ferroelectric and magnetic order parameters has been proven using dielectric spectroscopy in the presence of an applied magnetic field. [10].

Piezo-electric.

Smart hydrogels that respond to pH changes by swelling or contracting and are frequently used in drug delivery systems, chemoresponsive polymer nanocomposites that change stiffness in the presence of a chemical regulator, and chemoresponsive polymer nanocomposites that resemble the architecture of some echinoderms are examples of materials that are responsive to chemicals. [11].

Electrochemical biosensors

There is a lot of potential for low-cost, simple-to-use portable devices using electrochemical technologies, including environmental monitoring and medical diagnostics. As a result of its widespread use in glucose monitoring, amperometric devices are currently the most used method for biosensing. Glucose biosensing has
demand up to 70% of the biosensor market for diabetic individuals to check their blood sugar levels several times per day, making it an intriguing commercial area. [12].

Optical biosensors

Optical biosensors are device which analytically biorecognise the biological sample by its transducer and shows result through amplifier. The

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most widely used optical biosensors are surface plasmon resonance (SPR)-based biosensors, including SPR imaging and localised SPR. [13].

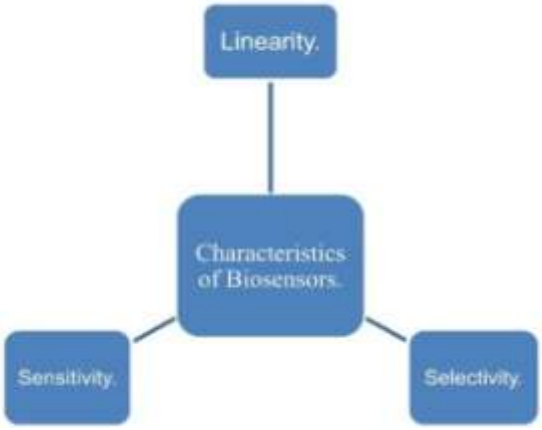

Fig1.Characteristics of Biosensor

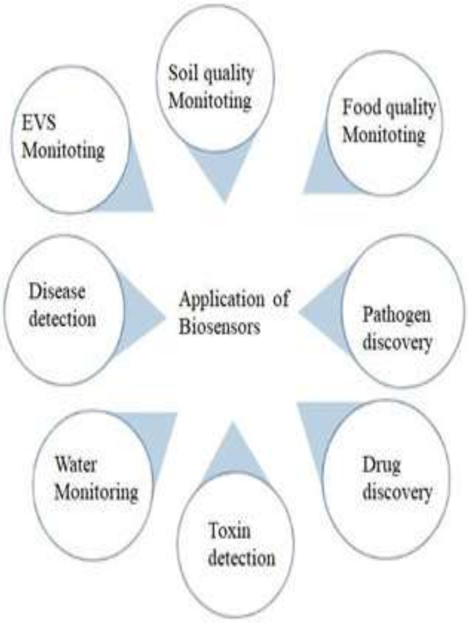

Fig2.Application of Biosensors

Introduction of Nanoparticle

In recent decades, the field of nanotechnology has experienced rapid expansion. Numerous nanoparticles with altered physical and physicochemical properties can be created by altering the chemical composition, atomic, arrangement, or dimension of nanomaterials. Since Norio Taniguchi first used the term "nano" in 1974 [14].

Nanomaterials are substances with at least one dimension between 1 and 100 nm. These materials have noteworthy differences in their basic physical and chemical properties from the bigger size of the same materials since most of their constituent atoms or molecules are positioned on the surface due to their small size. Quantum effects resulting from discontinuous behaviour due to the quantum confinement of delocalized electrons are another element that significantly alters the properties of nanomaterials. These nanoparticles have substantially more atoms on their surfaces than in their bulk, which results in lower binding energies and a lower melting point[15]. These particles' characteristics heavily depend on their form. For instance, the characteristics of nano-rods and nanospheres made of the same material may differ dramatically. Since the spatial confinement of electrons at the nanoscale produces a quantized energy spectrum, they behave almost exactly like small molecules or individual atoms in terms of their electrical behaviour. Similarly, due to the presence of numerous unpaired electron spins from hundreds of atoms, nanoparticles have magnetic moments and work best at diameters of 10-29 nm due to supermagnetism, making them excellent as contrast agents in magnetic resonance imaging (MRI). There are many different ways to categorise nanomaterials as a result of all these factors[16].

Srno.	Disease	Nano-particlename	DrugName
1)	Alzimer	Berberin	Metformin
2)	Anti-fungal	Gold,Platinum, Zinc	AmphotericinB
3)	Anti-protozoal	Silicon,Germanium	Metronidazol
4)	Anti-viral	Polylacticacid	Lactoferrin
5)	Chemotherapy	Abraxane	Doxorubicin
6)	DiabetesMellitus	Curcumin	Metformin
7)	Gastro-intestinal	Chitosan	Nifidepin
8)	Glaucoma	Zirconia,Alumina	Pilocarpine
9)	Hepatitis	Liposomes	Doxil

Nano materials market size

India's nano gold industry is expanding as a result of rising demand from the electronics and healthcare sectors as well as benefits related to gold nanoparticles. In terms of kind, the water soluble category dominated in 2019. By contrast, the in vitro diagnostics market would continue to be profitable by 2027. The India nano gold market was assessed to be worth $201.4 million in 2019 and is anticipated to reach $499.7 million by 2027, showing a CAGR of 17.0% from 2020 to 2027[17], according to a report released by Allied Market Research. India's nano gold industry is expanding as a result of rising demand from the electronics and healthcare sectors as well as benefits related to gold nanoparticles. Government restrictions on environmental contamination, on the other hand, limit growth to some level. However, it is anticipated that increased interest in and trend toward biological synthesis methods, together with R&D into the use of nanogold in electronics and healthcare, will lead to prosperous business opportunities.

The market for nanomaterials was estimated to be worth USD 8.5 billion in 2019 and is projected to increase at a CAGR of 13.1% from 2020 to 2027. As the prediction progresses period, the market is anticipated to be driven by the high potential for product adoption for aerospace applications in order to increase the strength and durability of aircraft parts. The market is expected to be driven by quick advances in medical technology, expansion in the medical diagnostics sector, and different benefits of medical imaging applications. Additionally, it is anticipated that increased government spending on biotechnology and pharmaceutical R&D as well as increased attention to nanotechnology research will accelerate market growth for nanomaterials [18].

On the basis of chemical constitution, nanomaterials can mainly be classified into:

1) Only one carbon atom consisting carbon allotrope
2) Inorganic nanomaterials from metal or non-metal elements such as Au, Ag,SiO2.
3) Organic polymeric nanomaterials

On the basis of dimension and size, nanomaterials can be classified into:

1) **Zero-dimensional**:- All three dimensions of a material exist at the nanoscale in zero-dimensional (0D) materials, for example, nanoparticles made of gold, palladium, platinum, silver, or quantum dots. With a diameter ranging from 1 to 50 nm, nanoparticles can be spherical in shape. Zero-dimensional nanomaterials have been discovered to have various cube and polygon forms. [19].

2) **One-dimensional:-** These nanomaterials can have two other dimensions that are macroscale, one dimension that is in the range of 1-100 nm. One-dimensional nanomaterials include nanowires, nanotubes, nanofibers, and nanorods. One-dimensional nanostructures can be produced by certain metals (Au, Ag, Si, etc.), metal oxides (ZnO, TiO2, CeO2, etc.), quantum dots, and other materials.

3) Two-dimensional:- In this class of nanomaterials, two dimensions are in nanoscale and one dimension is in macroscale. Nano thin- films, thin-film multilayers, nanosheets, or nanowalls are two-dimensional (2D)
nanomaterials. The area of two-dimensional nanomaterials can be several square micrometers keeping thickness always in the nanoscale range.

4. **Three-dimensional-** There are no dimensions at the nanoscale in three-dimensional (3D) nanomaterials; all dimensions are at the macroscale.Blocks, which can be as small as one nanometer or as large as one hundred nanometers or more, are the building blocks of bulk materials, which are 3D nanomaterials [20].Based on structural differences, each of these nanomaterials can be further categorised intoseveralsubtypes,as shownbelow,

1.Organic

- **Electro-spunNanofibre**–Cellulose,Bio-cellulose, GNF.
- **Fullerene**- C60,C70.
- **02.Inorganic-**
- **Metals** -Ag, Al,Au, Cu, Zn.
- **Metaloxides**–CuO,ZnO,TiO
- **QuantumDots** –CdSe, ZnS.

2.Hybrid-

 Organic ,Inorganic

The novel structure can be given innovative properties that are different commencing higher dimensional materials by shrinking nanoparticles and turning them into zero-dimensional structures. Nanomaterials are typically spherical or quasi-spherical nanoparticles having a diameter of less than 100 nm, as opposed to bulk high-dimensional nanomaterials. Nanomaterials have a great deal of adaptability for biomedical applications, including nanomedicine, cosmetics, bioelectronics, biosensor, and biochip. These unique properties include optical stability, wavelength-dependent photoluminescence, chemical inertness, cellular permeability, and biocompatibility. [21].

 A biosensor is thought to be a trustworthy and frequently portable equipment for the quick and economical determination of analytes such as

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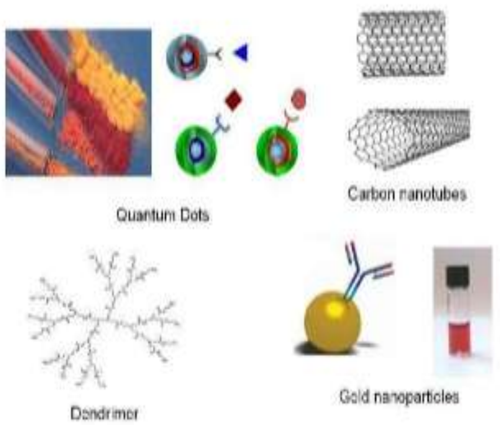
biomolecules, antigens, proteins, biotoxins, DNA, viruses, bacteria, and other types of analytes. Developing highly sensitive biosensors by boosting their active surface area, electrochemical activity, conductivity, or optical performance is one of the field's biggest difficulties. Due to their conductive qualities and unique optical features, nanoparticles are used as a strong sensing material and a crucial probe to improve the sensitivity of biosensors and hence their analytical performance. [22].

Nanomaterialsinbiosensors

such as carbon nanotubes, silica nanoparticles, dendrimers, nanoparticles of noble metals, gold nano-shells, quantum dots of super para magnetic material, and polymeric nanoparticles—as well as nanomaterials and structures—such as semiconductors and conducting polymer nanowires are being used in biosensor applications .Nanomaterials new and distinctive physical or chemical properties can help in the development of biosensors with enhanced analytical capabilities. [23].

- High surface / volume ratio.
- Novel eletro-optical properties.
- ncreased catalytical activity.
- Enhanced electron transfer.



Carbon-based nano materials

Carbon nanotubes: Single-walled carbon nanotube field effect transistor used as the chemical sensor, with a thin layer of single
stranded DNA (ssDNA) adhered to the tube's outer wall. Methanol, trimethylamine, propionic acid, dimethyl methylphosphonate (a sarin imitator), and dinitrotoluene (a TNT derivative) have all been detected at the ppm level by these sensors. Based on a capacitive field-effect structure functionalized with a dendrimer and multilayers of carbon nanotubes, the penicillin biosensor [24].

Buckypaper: A buckypaper-based, mediator-free electrochemical biosensor with improved stability and sensitivity for glucose measurement. A thin sheet known as "buckypaper" is created from a mixture of carbon nanotubes. [25].

Fullerenes : Fullerenes are a family of electroactive chemicals that shows great promise. This new class of chemical is particularly promising as mediators in aerometric biosensors due to a few distinct properties. They are stable in numerous redox forms, exhibit multiple redox states across a wide range of potentials, and have a very poor solubility in aqueous solutions. [26].

Graphene Quantum Dots

An effective nanomaterial made of one or more layers of graphene with special characteristics that combine graphene and carbon dots is called graphene quantum dots (GQD) (CDs). Precursors for its synthesis include carbon-rich substances including fullerene, macromolecules, polysaccharides, and graphite. A novel class of graphene nanostructures known as graphene quantum dots has modest transverse dimensions and atom-thin graphitized planes[27]. The photoluminescence of GQDs is one of their standout characteristics. Numerous investigations have shown that altering the dimension, shape, or dopant of GQDs can affect the PL excitation and emission wavelength. The detection of numerous ions and biomarkers, as well as the diagnosis of serious disorders, are now common uses for GQDs-based sensors[28]. The detection of biomarkers including ascorbic acid, dopamine, DNA, and amino acids is also greatly aided by GQDs-based biosensors. A sensitive and quick-turning fluorescence nanosensor based on orange emission GQDs was created in a recent work to detect ascorbic acid. Ascorbic acid has the ability to neutralise free radicals and restore the fluorescence of GQDs that have been o-benzoquinone-quenched. The sensor benefited from features like universality and excellent selectivity thanks to a fluorescence switch mode like this[29].

GQDs-based biosensors are capable of more than just detecting tiny chemicals; they can also be used to detect malignancy. Tumor pH levels are lower than those of healthy tissues because they can conduct adenosine triphosphate hydrolysis and create lactic acid in anaerobic and energy-deficient environments. This trait has been clinically used to diagnose cancer effectively. To discriminate between malignancies and healthy tissues, a pH-responsive fluorescent sulfurnitrogen-doped GQDs probe (pRF-GQDs) was developed. When the pH was below 6.8, the pRFGQDs displayed green PL, and when the pH was over 6.8, they changed to blue PL, which matched the acidic extracellular microenvironment found in solid tumours. The intensity of the fluorescence was inversely proportional to the degree of acidosis, and the fluorescence switch could be reversed. The manufactured pRF-GQDs shown outstanding stability. After 24 hours of continuous irradiation, the fluorescence intensity remained unaltered. The tumour locations of the tumor-bearing animals displayed a potent green PL signal after the injection of pRF-GQDs. The adoption of this GQDs-based biosensor as a universal fluorescence probe for tumour diagnosis has a lot of potential[30].

Carbon Quantum Dots

Carbon quantum dots (CQDs), also referred to as carbondots, are fluorescent nanoparticles with diameters less than 10 nm. Carbon quantum dots have worse crystallinity when compared to graphene quantum dots. This is because there are more surface imperfections and less crystalline sp2 carbon in the carbon quantum dots. Carbon quantum dots are frequently utilised in the domains of bioimaging, drug administration, and biosensing because they have good optical properties in fluorescence, chemiluminescence, and electrochemiluminescence. Carbon quantum dots may be quickly and easily produced and functionalized, similar to Graphene quantum dots. The topical chemical characteristics, optical properties, surface reaction activity, and biocompatibility of carbon quantum dots can all be improved through doping or surface functionalization, increasing their sensitivity as biosensors. [1].

Numerous CQD-based electrochemical and fluorescence sensors have been discovered, and their use in metal ion sensing has been expanding quickly. In the vicinity of the gate electrode, the combination of Cu2+ and Carbon quantum dots changed the capacitance of the double electrical layer, which in turn changed the channel current. The detection limit of Cu2+ in the CQDs-modified sensor was as low as 11014 due to.

Cu2strong +'s binding to CQDs. The use of CQDs in the quick quantitative detection of heavy metal contamination in water is another illustration of ion detection.[31] Furthermore, the detection of intracellular biomolecules is also possible usingcarbon quantum dots. Selenoproteins play a role in many biological processes and have been linked to a number of human disorders, including cancer and cardiovascular conditions. a brand-new fluorescent nanoprobe based on CQDs for in vitro selenol fluorescence imaging. Following selenocysteine treatment, selenolate readily divided the 2,4-dinitrobenzenesulfonyl chloride fragment of Carbon quantum dots to create yellow-green fluorescence Carbon quantum dots. Selenol fluorescence imaging of exogenous and endogenous selenol in living cells was made possible by the produced nanoprobe's excellent sensitivity and selectivity to selenol. The functionalized Carbon quantum dots were anticipated to be utilised for the detection of additional biological analytes by the addition of various identifying components[32].

Additionally, CQDs have been successfully applied in the diagnosis of cancer. For the detection of the tumour invasive biomarker b glucuronidase, an extremely sensitive fluorescence sensor device based on nitrogen-doped CQDs (N-CQDs) has been developed (GLU). [1] In this sensor platform, the GLU substrate was 4-nitrophenyl-catalyzed d-glucuronide, and the fluorophore was N-CQDs with green PL. P-nitrophenol, a GLU catalytic product, served as a potent absorber to snuff out N-CQDs' fluorescence. Therefore, the fluorescence intensity of N-CQDs may indicate the activity of GLU. The as-prepared sensor had a high sensitivity for GLU detection, with a 0.3 U/L detection limit.

This sensing approach avoided intricate fluorophore modification or covalent link connections between receptors and fluorophores, which gave rise to a novel notion for the development of sensitive sensors to identify tumour biomarkers using fluorescent CQDs[33].

Fullerenes

A molecular allotrope of carbon called fullerene was found in 1985 by Kroto et al. The most prevalent fullerene, C60, is made up of five to six sp2 hybrid carbon rings that come together to create a truncated icosahedron. High electron affinities, high surface-to-volume ratios, and structural stability are characteristics of fullerenes. These qualities make fullerenes useful in a variety of fields, including electronics, biology, and medicine. Fullerenes can be utilised to create diverse biosensors because they have good biocompatibility, inertia, and affinity for a variety of organic compounds. Fullerenes are utilised in

the ultra-sensitive detection of analytes in various chemical and biological components, such as amino acids, DNA, and biomarkers for early-stage cancer diagnosis. They do this by magnifying detection signals. [1].

Fullerenes are frequently utilised to build electrochemical biosensors to find amino acids because of their substantial electroactive surface area. An electrochemical sensor based on C60 that can quantitatively separate D- from L- serine is an illustration of this. It is necessary for the central nervous system to function. The analytical performance of this sensor was quite strong, with a detection limit for both isomerides of 0.24 ng/mL. The experimental findings demonstrated the durability of the C60-based electrochemical sensor in water samples for up to three weeks while maintaining the original performance without current fluctuation. As a result, compared to previously reported sensors, this sensor demonstrated higher detection sensitivity, stability, and repeatability. It might be an effective method for identifying schizophrenia in clinical patients. [34].

Fullerenes can be used in cancer diagnostics just like graphene quantum dots and carbon quantum dots. For instance, a2,3-sialylated glycans can be detected by using a sandwich-type electrochemical biosensor based on 4-MPBAn- C60-PdPt. Au-poly (Au-PMB) was fixed with Maackiaamurensislectin (MAL) to provide a specialised identification tool for 2,3-sialylated glycans. To further increase the load capacity and conductivity of the sensor, amino-functionalized fullerene (n-C60) was added to the surface of the Pd-Pt bimetallic alloy. The n-C60 nanomaterial showed strong electron transferability, which may increase the biosensor's sensitivity and speed up electron transfer rate[35].

The detection threshold was found to be 3 fg/mL (S/N = 3). Additionally, this sensing technology demonstrated strong recovery and stability, suggesting potential uses in clinical research We have now covered three different zero-dimensional carbon-based nanomaterial types that are utilised in various sensors, including PL, electrical, electrochemical, and electrochemiluminescence ones that can be used for ion detection, biomolecular identification, and disease diagnosis. Research on zero-dimensional carbon-based nanomaterials is still in its early stages, despite the fact that many scientists have taken note of them. The atomic level structure of materials cannot be controlled by current synthesis techniques. Furthermore, the fluorescence quenching

mechanism of nanomaterials made of zero-dimensional carbon has not been adequately addressed. In order to create biosensors with greater clinical utility, it will be necessary to investigate the synthesis accuracy and optical and electrical properties of 0D carbon-based nanomaterials [1].

Quantum Dots

Quantum dots are often created using atoms from groups II-VI or III-V of the periodic table as fluorescent semiconductor nanocrystals. The most popular Quantum Dots, CdTe, CdSe, and InP, have potential uses in a range of biomedical sectors, including treatment, bioimaging, and biosensing. The biocompatibility of inorganic Quantum Dots is frequently questioned due to the toxicity of heavy metals.Tosomeextent,This problem is solved by the synthesis of Quantum Dots in aqueous solution, which improvesnotonlythe biocompatibilitybutalsothewatersolubilityandstability [36].

Alternatives to the cytotoxic CdTe and CdSe QDs that are currently available on the market include the emerging heavy metal-free Quantum Dots known as SiQDs. A variety of fluorescence, chemiluminescence, and bioluminescence sensors have been created using quantum dots because of their special optical characteristics, including increased brightness, resistance to photo bleaching, a high absorption coefficient, a narrow emission spectrum, and size-tunable light emission. This section will concentrate on the recent use of quantum dots in biosensing. Quantum dots have been used extensively in disease detection due to their distinct photochemical stability and high PL quantum yields. For the simultaneous detection and subtyping of various influenza viruses (H9N2, H3N2, H1N1), high-luminance Quantum Dots and magnetic nanoparticles were functionalized on an integrated microfluidic device. H9N2, H3N2, and H1N1 cDNAs could be identified simultaneously within 80 minutes with a very low sample and reagent usage (only 3 L) by using superparamagnetic beads and QDs-assisted multiple DNA hybridization detection on microfluidic chips with regulated micro-magnetic fields. This approach proved practical, cost-efficient, and extremely sensitive, making it a potent technology platform for the quick detection of several influenza viruses[37].

Additionally, cell identification and dynamic evaluation can be done using water-soluble and low-toxic Quantum Dots. The nondestructive study of living cells using an unique PEC biosensing platform that combines near-infrared (NIR) Ag2S QDs with AuNPs. The photoelectrochemically active species of water-dispersed Ag2S QDs have good PEC characteristics in the NIR. The linear range in this

method was 1102 to 1107 cells/mL under NIR illumination at 810 nm, while the detection limit was 100 cells/mL. All of these experimental findings demonstrate that NIR QDs are well suited for use in the development of fresh PEC systems for the detection of biomolecules[38].

Additionally, QDs-based biosensors can be used as universal instruments to find cancer and brain illness biomarkers. In order to enable the ultrasensitive detection of microRNA in human prostate cancer cells, a new type of ECL biosensor based on CdSe and ZnS QDs combines target recovery amplification with a double-output conversion approach. Another study used an Ag2S QDs fluorescent nanoprobe in the second near-infrared (NIR-II) window to image early biomarkers of traumatic brain injury in vivo in real-time (TBI).

The energy transfer from Ag2S to A1094 chromophore rendered Ag2S' fluorescence inactive. A1094 was bleached by the TBI precursor biomarker peroxynitrite after intravenous administration, resulting in a speedy recovery of Ag2S QDs fluorescence. This NIR-II in vivo turn-on sensing and imaging technique suggested that Quantum Dot fluorescence imaging in clinical applications has a wide range of potential uses.

In general, the introduction of numerous quantum dot biosensing applications in this section has substantially improved understanding of quantum dots as prospective biomaterials for biosensing applications. Quantum dots have a strong affinity for biomolecules, and because of their unique chemical and optical characteristics, they can be used as optical sensors to identify different types of biomolecules. It is anticipated that further QDs-based research will be done in the areas of pathogen detection, non-destructive study of living cells, and disease diagnosis. [1].

Magnetic Nanoparticles

Pure metals (Fe, Co, Ni), alloys (FeCo, permalloy, alnico), and oxides with strong saturation magnetization make up magnetic nanoparticles (MNPs), which range in size from 1 to 100 nanometers (Fe3O4, CoFe2O4). MNPs have drawn a lot of attention for the treatment of hyperthermia, biosensing, and drug delivery because of their high saturation magnetization and superparamagnetism. Biosensors with zero dimensions Magnetic nanparticles are important in the realm of sensing because they provide practical answers to the long-term issue of low detection limits and non-specific effects. Modification of the size, content, and magnetic properties of MNPs enhances their use in the ultralow detection of proteins, disease

biomarkers, and pathogens. [1].Upon combining magnetic nanoparticles with particular recognition molecules, proteins can be captured using these particles. As an illustration, PSA-labeled MNPs that specifically collect PSA as a protein analyte. The (anti-PSA)-MNPs quickly transported PSA into nanopores after capturing it in the ambient magnetic field. (Anti-PSA)-MNPs would create a sandwich complex in the nanopore with the anti-PSA antibodies once they had trapped PSA. In order to avoid inaccurate counting, The (anti-PSA)-MNPs that failed to capture PSA were then eliminated by reversing the magnetic field.

This nanopore sensor's detection limit was 0.8 fM, which was far higher than that of earlier nanoporesensors[39]. With the right antibodies, this MNPs nanopore blocking approach might be applied to other proteins. MNPs are shown to offer enormous potential in the early detection of cancer. For the creation of liquid biopsies to track the development of diseases, the capability of biosensors to detect ultralow quantities of circulating microRNAs in the blood is significant.

A network of gold-coated MNPs that has been altered by probe DNA for the purpose of analysing entire blood's nucleic acids. For the first time, the sensor determined the amount of microRNA in untreated blood samples. Its ability to track minute variations in microRNA mice blood concentration developing tumours was demonstrated in vivo. The device was transformed into a promising tool for cancer diagnostics thanks to the usage of electrically reconfigurable DNA Au-MNPs network to supersensitively and directly detect microRNAs. An MNPs-Abs-based fluorescence spectroscopy technology was used in a different investigation to examine ovarian cancer biomarkers. Polyclonal antibodies were used to create a sandwich technique. Magnetic force was used toremove sandwich particles from the sensor medium, and real-time monitoring of fluorescence changes at predetermined concentrations was performed. [40].

The use of MNPs-based biosensors for other illness diagnostics has also been investigated. For the purpose of detecting the asthma biomarker eosinophil cationic protein, functionalized Au-Fe3O4 core-shell structures (ECP). The cysteamine-tagged heparin (Hep.) modified core-shell magnetic nanostructures increased the variations in electrochemical signals, enhancing the sensitivity of the biosensor. For the logarithmic analysis of ECP concentrations, this approach offered a broad linear range of 1–1000 nM, with a

determination coefficient of 0.992 and a detection limit of 0.30 nM. By substituting a pertinent probe-target combination for the Hep-ECP pair, it might be used to sensitively detect different analytes [41].

MNPs can be utilised to build biosensors for disease detection because of their distinctive optical and magnetic features. For pseudomonas aeruginosa quick detection, a low-cost colorimetric biosensor based on MNPs. Within a minute, the detection limit dropped to 102 cfu/mL. This biosensor is anticipated to be a quick medical tool for diagnosing infections linked to pseudomonas aeruginosa. As is well known, infectious diarrhoea brought on by the norovirus (NoV) can spread quickly and is very contagious. A created a hybrid AuNP-MNP nanocomposite for the highly sensitive Norovirus detection.

In conclusion, significant progress has been made in the use of MNPs for pathogen, disease, and single-molecule detection. MNPs can be attached to the sensor surface or utilised as labels in biosensing devices. The development of MNPs for a range of biosensor applications depends on their structure, content, and choice of surface functional groups and target molecules. Additionally, biological systems, which contain a lot of oxidising and reducing chemicals, require MNPs to be stable. To prevent the MNPs from accumulating or changing their precisely controlled magnetic characteristics, the functionalized MNPs must have a stable covering. In order to greatly increase the sensitivity and stability of biosensor components, it is crucial to modify the composition of MNPs and immobilise the proper functional groups on the surface. [37].

Gold Nanoparticles

Conductive materials having a substantial surface area and distinctive optical characteristics are called gold nanoparticles (AuNPs). The surface plasma in gold nanoparticles was restricted to achieve strong LSPR. It is feasible to create multifunctional AuNPs that can be utilised as optical and electrical biosensors by modifying the size, shape, and polymerization of AuNPs. Currently, there is a lot of research being done on functional AuNPs that are utilised to find pathogens, proteins, nucleic acids, and biomarkers for diseases like cancer and neurological disorders. [42].

By enhancing the electron transfer between the redox centre and the electrode surface, AuNPs' outstanding electrical conductivity can provide a large number of active sites for the biosensor electrode's very sensitive detection of cancer biomarkers. In order to create a bimetallic

nanocrystal platform for the extremely sensitive detection of carcinoembryonic antigen (CEA), for instance, gold nanoparticles were used[43].

With a very low detection limit (0.5 pg/mL), this nanohybrid-based biosensor showed good electrochemical sensitivity to CEA detection, indicating that the AuNPs-based sensor had potential use in the diagnosis of tumours. This was brought about by the addition of Au and Cu, which increased Au's active surface area and improved the interaction between these two elements. AuNPs have been used to find a number of clinically important substances, including neurotransmitters and antigen. Levodopa supplementation is the recommended course of treatment for Parkinson's disease (PD), a prevalent neurological condition. Levodopa overdose can cause emotional incontinence and dyskinesia, however. Levodopa levels can therefore be continuously monitored using an electrochemical detection device based on AuNPs[44]. In order to increase the electrode's electrical conductivity and electro catalytic performance in this system and thus the sensor's sensitivity, AuNPs were utilised to alter the electrode. Levodopa in human serum could be detected by this sensor at concentrations as low as 0.5M. AuNPs were employed in a different study to identify the hepatitis B surface antigen. Hepatitis B surface antigen is detectable by a gold nanoparticle-based immunosensor with a detection limit of 14 pg/mL and a linear concentration range of 0.12–30 ng/mL. The manufactured immunosensor was anticipated to be used in clinical immunoassays because of its low cost, simplicity of operation, and time-saving qualities[45].

Pathogen detection commonly makes use of gold nanoparticles. Zika virus (ZIKV) outbreaks in the tropics have recently posed significant threats to world health. a brand-new glassy carbon electrode-based oxidised impedance DNA biosensor. AuNPs has high surface area andhigh conductivity therefore the payload of the DNA probeincreasedobviouslyandtheelectrochemicalresponsesensitivityofthedevelopedbiosensorwas significantly improved. The device's detection limit was established using electrochemical impedance spectroscopy and was discovered to be 0.82 pM. (EIS). After 90 days of testing using EIS, the sensor's reply was about 98.0% of its initial response, proving the biosensor's high degree of stability. This device was intended to be used as a marketable functional diagnostic tool for ZIKV. AuNPs can also be used to make fluorescent sensors for disease detection because of their distinctive optical features. Lee et al. coated gold nanoparticles onto carbon nanotubes to provide a platform for plasmon-assisted fluoro-immunoassays. A minimum detection level of

0.1pg/mL was required for the influenza virus. The selectivity of this fluorescence immunoassay technique for the influenza virus was likewise favourable and was 100 times higher than that of commercial diagnostic kits[46].

Silver Nanoparticles

Silver nanoparticles (AgNPs), which are frequently utilised in medical diagnosis, share many of the same physical and chemical characteristics as gold nanoparticles. AgNPs' shape, size, and degree of aggregation all affect their optical characteristics because of the LSPR absorption. However, due to worries regarding cytotoxicity, silver nanoparticles have fewer applications than auNPs[47]. Nevertheless, because of AgNPs' antifungal and antibacterial qualities, their usage in biomedical research is being promoted more and more. AgNPs also offer appealing electrical characteristics.

They have a higher extinction coefficient and are more susceptible to electrochemical oxidation than AuNPs of the same diameter. Due to their high plasmon resonance properties, AgNPs have been widely employed in SERS-based biosensors to enhancing enactment in the field of biosensing. AgNPs-based nanocomposites can be employed for biomolecular sensing of cancer cells and cancer treatment because they have outstanding identification capacity and specific reaction in tumour microenvironment. The GSH level in the tumour microenvironment is interesting since it is much greater than in healthy tissues. A multipurpose carbon nanoparticle (CPs) MnO2-AgNPs nanosensor for cancer diagnostics and GSH sensing[1].

In order to test different medications and track how they affect the human body, silver nanoparticles have also been used. For the purpose of determining how caffeine (CAF) affects the concentration of estradiol (EST) in women of childbearing age, a sensitive biosensor based on electrochemical reduced graphene oxide nanocomposites and AgNPs (AgNPs: ErGO/PG) was recently created (18–35 years). Detecting methylamphetamine using SERS with Ag core-shell nanoparticles (MAMP). Core-shell SERS performed better than AuNPs in comparison.By adjusting the concentration of the methylamphetamine adaptor modified on the surface of the sensing platform, the very sensitive methylamphetamine detection was made achievable. The methylamphetamine sensor had a detection limit of 0.16 ppb and a large dynamic range of 0.5 ppb to 40 ppb. All of these findings suggested that AgNPs could be employed for in vivo drug content detection and quick screening of illegal drugs that are abused. [48].

One of the most popular antibacterial nanomaterials is silver nanoparticles. AgNPs are

widely used in the creation of electrical analysis platforms in addition to serving as antimicrobial agents because of their special capabilities, including increased electron transport and regulated electrode microenvironment. 3D-ZnO nanorod arrays with silver nanoparticles functionalized with vancomycin for the detection and eradication of harmful microorganisms. Van's precise identification of gram-positive bacteria informed the design of the electrochemical platform.

With a detection limit of 330 cfu/mL, it is extremely sensitive to the detection of staphylococcus aureus. Additionally, the platform demonstrated a high level of antibacterial activity (99.99%) as a result of the combination of Vancomycin and silver nanoparticles' bactericidal effects.[49].

This section summarises and discusses the most recent advancements in AuNPs and AgNPs in the biosensing sectors, such as the detection of cancer indicators, infections, and medication analytes. Despite the impressive advancements, there are still many obstacles in the clinical application of noble metal nanoparticles. The procedures for their production and modification must be improved in order to create multifunctional noble metal nanoparticles with superior optical and electrical properties. Finding functional molecules is extremely important for enhancing sensor specificity. Through effective functionalization, noble metal nanoparticle selectivity can be enhanced. Additionally, more investigation is required into the connections between the composition, structure, and functionality of noble metal nanoparticle sensors[50].

Polymer Dots

Polymer dots typically have strong fluorescence brightness and high photostability as sophisticated nanomaterials. Polymer dots have gained popularity as intriguing biosensors flouroscent probes frequently utilised in detection of biomolesules in recent years. [51]. A coreactant-free dual amplified ECL sensing system employing conjugated Polymer dots as luminophores is employed for the highly sensitive detection of mRNA.High carrier mobility conjugated polymer dots could generate an extremely potent ECL signal without the use of a coreactant, increasing the sensor's sensitivity. This sensing platform consequently demonstrated a minimum RNA detection limit of 3.3 aM. With the development of coreactant-free ECL biosensors made possible by these conjugated Polymer dots, the use of Polymer dots for clinical analysis has increased[52].

In terms of biosensing, the aforementioned developing nanomaterials have significantly improved ion detection and biomolecular detection. Investigations on their metabolism, biodegradation, and long-term

toxicities are similarly lacking, as are experimental studies on their use in illness diagnostics. Additionally, innovation in synthesis techniques and the execution of large-scale preparation should be prioritised. It's also important to note that the functional alteration can help these zero-dimensional nanomaterials' use in the biosensing industry. [53].

II. CONCLUSION

The development of biosensors has truly benefited greatly from nanotechnology. The field of biological detection has undergone a revolution. The general mechanics have improved in speed, intelligence, cost, and usability. The utilisation of nanomaterials and nanostructures, such as those found in quantum dots, nanoparticles for the immobilisation of enzymes, and hybrid nanostructures with various functions, has considerably improved the transduction mechanisms. Future makes a compelling case for these flexible, fast, and dynamic recognition systems given their multifaceted possibilities. These materials are currently being taken into consideration more and more for the fusion of chemical and biological sensors in order to speed up, simplify, and improve the performance of the entire process.

The use of these materials for sensing a number of important regulatory events and pathways has been sparked by the advent of nanomaterials and miniaturisation research. The discovery of nanomaterials is advancing at an intense rate, and this has made sensing technology more and more durable, adaptable, and dynamic. Without a doubt, due to the technical difficulties involved, developing biosensors for a task is still very time-consuming and expensive. However, the use of nanomaterials has proven to be a major boon for this technology, primarily because of the accommodating and effective experimental support it provides

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