Review—A Nanomaterial-Based Sensor for Detecting the COVID-19 Virus through Various Techniques
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The features of NMTs such as graphene, molybdenum disulfide, CNTs and quantum dots for unique sensing applicability are mentioned in this review study. Some notable sensors that have been produced are described based on the particular analyte compound to be determined and the functionalization processes that are used. For COVID-19 determination, biocompatible sensors manufactured from these materials capable of determining specific chemical components are also highlighted, which could support efficient and reliable sensing and rapid diagnosis.

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List of symbols

NMTs Nanomaterials
CNTs Carbon nanotubes
TMD Transition metal dichalcogenides
NEB Narrow emission band
HFQY High fluorescence quantum yields
SARS-CoV-2 Severe acute respiratory syndrome coronavirus 2
QDs Quantum dots
HSTV High surface-to-volume
EC Electrical conductivity
ECRG Electrochemically reduced graphene
NPs Nanoparticles
PSA Prostate-specific antigen
CILE Carbon ionic liquid electrode
MTB Methylene blue
FTGS Functionalized graphene sheets
PA Paracetamol
AA Ascorbic acid
CC Catechol
HQ Hydroquinone
RG Reduced graphene
PDDA-G Poly(diallyldimethylammonium chloride) graphene nanosheet
TDB Tunable direct bandgap
LOD Limit of detection
LOQ Limit of quantitation
LOE Lactate oxidase enzyme
BPA Bisphenol A
CPE Carbon paste electrode
SWCNTs Single-wall carbon nanotubes
MWCNTs Multi-wall carbon nanotubes
Gox Graphene oxide
PAMAM Poly(amideamine)
QC Quantum confinement
FRET Förster Resonance Energy Transfer
TQDs Traditional quantum dots
CQDs Colloidal quantum dots
CDs Carbon dots
TMO Transition metal oxide
UA Uric acid
CAFA Caffeic acid
MTZ Metronidazole
GPT Graphene nanoplatelets
DP Dopamine

GBP Glucose binding protein
N-CDs Nitrogen-doped CDs
FOA Folic acid
MIP Molecularly imprinted polymers
GCE Glassy carbon electrode
TOM Thiolated oligonucleotide modified
MPAS Mecraptopropionic acid stabilized
RT-PCR Reverse Transcription Polymerase Chain Reaction
LFA Lateral flow assays
IgG Immunoglobin G
IgM Immunoglobin M
GGOs Ground glass opacities
ROS Reactive oxygen species
LSPR Localized surface plasmon resonance
PPT Photothermal
GMR Giant magnetoresistance
MNP Magnetic nanoparticle
FET Field-effect transistor
GNi Gold nano-islands
GrS Graphene sheets
UBPOP U bent fiber optic probe
ANP Anti-N protein
P-FAB Fiber-Optic Absorbance Biosensor
SMIF Salmonella Infantis
PPD Photo-dynamic

Owning the unique features, NMTs like graphene, TMD, and CNTs have progressively garnered research attention during the last years for several applications fields. Superior electronic,1 optical,2 mechanical3 and structural4 characteristics of 2D substances and thin films like HSTV ratio, developed flexibility, optical transparency, the appearance of multiple reaction sites and great surface sensitivity, all contribute to efficient sensing and examination of an extensive range of analytes and molecules for applying to sensors.5–14

The exceptional characteristics include large Stokes growth, NEB, large molar absorption coefficient, long excited-state lifetimes, HFQY, superior resistance to chemical degradation, photobleaching, and a great two-photon absorption cross-section QDs are increasingly being used in sensors and imaging. We have discovered the applicability of these sensors for biosensing, particularly for determining the SARS-CoV-2 viral agent during this study. In addition, compare to the previous reports, there are not many reports to summarize the updated data about detecting the COVID-19 virus based on graphene, CNT, molybdenum disulfide and QDs as well as various techniques to analyze the SARS-CoV-2 virus. As a result, this work could be considered an updated report to review the

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Various NMTs Employed to Fabricate Sensors and the Applications

Figure 1 illustrates various nanomaterials applied as a material to fabricate biosensors devices for the health field.

General material.—Graphene.—Graphene is defined as a semiconductor with a zero bandgap and a low defect crystal structure. Graphene has exceptional great EC through its π-bonds, which allow it to convert chemical impulses into electric current via transduction. It also shows improved mechanical qualities like as tensile strength, flexibility, and elastic modulus. Despite its atomic thinness, it possesses a great absorbance and is two fields thermally and chemically stable. Graphene would also be combined with other polymer nanocomposite materials to obtain useful qualities for determining minuscule levels of certain molecules or dangerous toxic components like heavy metals or industrial chemicals.15,16

Graphene could be functionalized with various metal oxide compositions relying on the target molecule or gas to be examined through a sensor. Several graphene-based sensors tools have been fabricated for the examination of specialized compounds17 like paracetamol,18 ascorbic acid,19 aromatic isomers,20 PSA21 and hemoglobin (Hb),22 owning the ease of availability of materials paired with the merit of graphene’s biocompatibility.

Sun and his colleagues used electrostatic adsorption through ECRG layer with a modified CILE to create an electrochemical DNA biosensor for the MON810 determination, a genetically edited gene sequence. The sensor had great sensitivity and the ERG film helped to boost the probe ssDNA adsorption, which improved the response of MTB, an electrochemical indicator that could interact with DNA.23

The Wu team recorded a sensor including a nanocomposite film fabricated by electrodeposition of modified Pt NPs on the FTGS (which was initially dispersed in a solution of CTS and GCE) and subsequent change of the resultant film with enzymes to harness the electrocatalytic energy of FTGS for glucose-based sensing. Finally, the film was immobilized with glucose oxidase. The biosensor that resulted had excellent sensitivity and responsiveness and great repeatability and long-term stability, indicating that it might be employed for rapid and accurate glucose monitoring. Furthermore, this production approach would be applied to make various graphene-based biosensors.24 For ease of reference, the graphene-based sensors devices have been summarized in Table I.

Carbon dots.—QDs carrying a CC and a functional group shell are known as CDs. They have an extensive scope of distinguishing characteristics, including great biocompatibility and minimal toxicity and the superior optical and electric properties of classic QDs. Straight analyte-CD interactions, CDs post-functionalization and integration with other molecules are all employed in fluorescent CD sensors. The CD sensors tools have been designed for detecting Fe, Cu and Hg ions,25 CCA, AA and DP,26 proteins, and DNA utilizing PL quenching. Determination of folate receptor-positive tumor cells by applying folic acid-modified fluorescent CDs,27 Escherichia coli has been determined by employing mannose-modified fluorescent CDs by attaching the bacteria’s lectin units to the mannose on the CDs, tagging the bacteria.28 Furthermore, papaya-derived water-soluble CDs have been described for detecting bacteria via the same technique.29

Moreover, electrochemical and electrochemiluminescence sensors have been studied. N-CDs were employed by the Louleb team to determine DP in biological fluids (such as serum and urine liquid).30 The quantity of quenching in the N-CDs fluorescence generated by hydrogen bonding from the DP -NH3+ moiety to the surface ligands was quantified and utilized to scale the DP concentration. It has also been reported that a CD-nanomaterial connection could examine epinephrine, glucose, insulin and acetylcholine among other biomolecules.31

Carbon nanotubes.—Owing to exceptional qualities, CNTs, another carbon nanomaterial, have been intensively explored for applications in an extensive scope of fields. Whether one atom thick (SWCNTs) or multiple layers of graphite, the C-C bond makes them the stiffest and most durable fiber (MWCNTs). CNTs are also thermodynamically stable and depending on the production settings, they could be metallic or semiconducting.32 The adsorbed molecules directly after the electrical characteristics of nanotubes through their surface structure and sensitivity is a crucial quality for a sensor.33

A sensitive element, which includes functionalizing the CNT with a particular biomolecule (like protein34) and a transducer35 are common components of CNT-based device sensors. Villamizar and his colleagues reported a bioFET made from a network of SWCNTs that could determine SMIF quickly and sensitively by employing suitable antibodies.36 Such a sensor could be employed to examine other viruses or bacteria. Biosensors made of a mix of NMTs like MoS2/MWCNTs have also been examined to pair the benefits of the separate materials.37

Figure 1. Several nanomaterials for creating biosensors tools. (The origin.)
The sensing technique used by CNT sensors could be inter-CNT (when effects occur within the tubes), intra-CNT (when effects occur at combined points across tubes) or Schottky barrier (when effects occur between the tubes and electrodes). The dominating mechanism is disturbed by the analyte’s potency, kind DAT and CNT flaws.\textsuperscript{38}

Through the metallic states, CNT-based sensors avoid the difficulty of carrier movement around disturbed regions in graphene-based sensors. To improve specialized sensor selectivity, CNTs could be functionalized non-covalently by tiny aromatic compounds, polymers, or metal NPs. On the contrary, covalent functionalization techniques could enhance the sensor’s long-term stability, resilience, and reproducibility.\textsuperscript{39} Table II summarizes several CNT-based biosensors for quick reference.

**Dimensional material.**—These materials are semiconductor nanostuctures with diameters ranging between one to 10 nm with potential barriers enclosing them in all three dimensions. QDs have nanophotonic and electricity characteristics that differ significantly from their bulk counterparts by the virtue of the QC effect and an HSTV ratio. They possess a broad absorption spectrum that gets stronger as you get closer to shorter wavelengths, a substantial Stokes shift and a small emission band that is roughly Gaussian-shaped. The QDs bandgap grows with decreasing diameter due to quantization effects.

QDs are ideal probes because they obtain a large molar fluorescence quantum yields and long excited-state lifetimes. They also acquire a great two-photon fluorescence quantum yields and stability. Thus, organic capping ligands would be applied to functionalize QDs based on the application.

**Traditional QDs.**—TQDs are fabricated of II-VI, IV-VI and III-V semiconductors in a core–shell structure and have been considered optical transducers based on PL activation/quenching generated by DNA employing oligonucleotide-modifying and photobleaching. Surface chemistry in absorption cross-section and are resistant to chemical degradation excited-state lifetimes. They also acquire a great two-photon fluorescence quantum yields and long excited-state lifetimes. They also acquire a great two-photon fluorescence quantum yields and stability. Thus, organic capping ligands would be applied to functionalize QDs based on the application.

**2D-QDs.**—2D-QDs are fabricated from 2D NMTs like graphene, TMD, TMGs, and other materials that have decreased their dimensions on both sides and display unique features in addition to those of their greater 2D form. 2D-QDs could be functionalized to improve certain features and hence be applied to a broad scope of sensor devices for determining UA and C6H5NO3, applying electrochemical sensors devices for examining metal ions, chemical sensors devices for examining microRNA and CAFA and electrochemiluminescence sensors for examining metal ions, microRNA, adenosine triphosphate and antigens have been produced.\textsuperscript{63}

MTZ determination using molecularly imprinted polymers on GQDs and GPT\textsuperscript{64} and more recently, DP release examination using a connection of GQDs and MWCNTs\textsuperscript{65} are two examples of electrochemical sensors devices depending on graphene QDs that have been examined. Zhang and his colleagues produced an electrode based on graphene QD built on a gold electrode that could determine H2O2 by taking screening the current lasting H2O2 reduction via electrocatalysis.\textsuperscript{66} Table III summarizes the many QD-based sensor devices.

**TMDs.**—TMDs are a 2-dimensional material type that attracts a large amount of attention since some of them have tunable bandgaps (indirect to direct), which lead to several interesting features including photoluminescence. Molybdenum disulfide, molybdenum diselenide, tungsten disulfide and tungsten diselenide, all parts of the TMD family, have been examined widely for application to sensors, with a particular focus on MoS2 by the virtue of its exceptional conductivity, speed electron transfer rate and ease of availability.\textsuperscript{67} MoS2 could be employed for a broad range of applicability through its modest toxicity and durable nature, including ES and FE and biological applications.\textsuperscript{68}

| No. | Compound determination | Electrode | LOD (μM) | LOQ (μM) | Sensitivity and recovery | References |
|-----|------------------------|-----------|----------|----------|--------------------------|------------|
| 1   | Glucose                | GOD/Pt/FTGS/chitosan | 0.6 | 0.082–0.1201 mM | Great | 24 |
| 2   | PSA                    | GS-CoNP-PBSE/GCE | Label-free | 0.02–2 ng ml⁻¹ | Good | 21 |
| 3   | PA                     | CG/CCE | 0.032 | 0.12–20.2 | High | 18 |
| 4   | Transgenic maize MON810 | ERG/CILE | 4.52 pM | 1 × 10⁻⁵–1 | Good | 23 |
| 5   | AA                     | G/CPE | 0.07 | 0.1–106 | | 19 |
| 6   | Hb                     | PDDA-G/R/TIL | 0.04 | 0.2–32.6 | Great | 22 |
| 7   | CC and HQ              | RG/GCCE | 0.1 and 0.2 | 0.1–200 | Enhanced | 20 |

Note: FTGS: functionalized graphene sheets; PSA: prostate-specific antigen; PA: paracetamol; GCE: glassy carbon electrode; CILE: carbon ionic liquid electrode; ERG: electrochemically reduced graphene; PDDA-G: poly(diallyldimethylammonium chloride) graphene nanosheet; CC: catechol; HQ: hydroquinone; RG: reduced graphene; AA: ascorbic acid; CPE: carbon paste electrode; GQDs: graphene quantum dots; MWCNTs: multi-walled carbon nanotubes; SnO2: tin dioxide; PbS: lead sulfide; Er: erbium; GCE: glassy carbon electrode; CILE: carbon ionic liquid electrode; GD: glucose oxidase; PDDA: polyallylamine hydrochloride; PEG: polyethylene glycol; TQDs: tunable quantum dots; LOD: limit of detection; LOQ: limit of quantitation; QC: quantum confinement; TMD: transition metal dichalcogenide; CNT: carbon nanotube; CQDs: carbon quantum dots; GQDs: graphene quantum dots; MTZ: methotrexate.
Table II. Several reports about CNT-based biosensors.

| No. | Compound determination | Electrode | LOD (μM) | LOQ (μM) | Sensitivity and recovery | References |
|-----|------------------------|-----------|----------|----------|--------------------------|------------|
| 1   | Sub-femtomolar DNA     | DNA/GNPs/MoS₂/MWCNT/GOx | —        | 10−10⁷ fM | Great                    | 37         |
| 2   | Glucose                | Bi-enzymatic CNT/PAMAM dendrimer | 2.5      | 4.0–1.2 mM | High                     | 34         |
| 3   | SMIF                   | CNTFETs   | 100 cfu/ml | 100–500 cfu ml⁻¹ |             | 36         |

Note: SMIF: salmonella infantis; MWCNT: multiwalled carbon nanotube; Gox: graphene oxide; PAMAM: poly(amidoamine); FET: field-effect transistor;
| No. | Determination compound | Material                                                                 | Operation process                                                                                                                                                                                                 | References |
|-----|------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 1   | MTZ                    | MIP/GQDs/GNPl/GCE                                                        | On the surface area of the electrode, MTZ accumulates at GQD-MIP recognition sites                                                                                                                                 | 64         |
| 2   | Cancer cells           | FOA-CDs probe                                                            | FOA leaving the CD surface to bind with the folate receptor on the cancer cell causes fluorescence to recover                                                                                                                                                               | 27         |
| 3   | Glucose                | Luciferease enzyme-GBP/CdTe QDs                                          | The GBP that separates QD and enzyme binds to glucose, shortening the donor-acceptor distance and increasing BRET emission                                                                                                                                               | 48         |
| 4   | DNA                    | TONT/MPAS CdSe/ZnS QDs                                                   | FRET pathway from QDs to dye molecules incorporated by telomerase in DNA undergoing replication/telomerization causes fluorescent quenching of QDs.                                                                                                                      | 40         |
| 5   | Peroxide               | GQD/GE                                                                   | The current generated by the reduction of H$_2$O$_2$ during electrocatalysis is measured                                                                                                                                                                                   | 66         |
| 6   | DP                     | CDs                                                                      | Nonradiative electron-hole recombination causes luminous CDs to be quenched H-bonding between the DP-NH$_3^+$ moiety and the N-CDs surface ligands causes quenching                                                                                                           | 26         |
| 7   | Recombinant proteins   | Covalently linked carboxylate QDs to primary amine group connected Ni$^{2+}$ and NTA ligand | The binding of fluorescent Ni-NTA QDs to histidine in his-tagged proteins allows for the determination                                                                                                                                                                 | 46         |
| 8   | MicroRNA               | GQDs as a platform for immobilizing horse-radish peroxidase             | TMB electrochemical reduction catalyzed by HRP-GQD leads to a growth in current                                                                                                                                                                                             | 63         |
| 9   | Proteases              | QDs were linked to GNP by a peptide sequence that matched the goal protease | Through the impaired FRET procedure caused by the goal protease breaking the peptide chain, quenched fluorescent AuNP-QDs emit a large amount of light                                                                                                                     | 42         |
| 10  | *Escherichia coli*     | CDs with mannose modifications                                           | Bacterial tagging using fluorescent CDs that bind the bacteria’s lectin units and mannose                                                                                                                                                                                    | 28         |

Note: CDs: carbon dots; FRET: forster resonance energy transfer; N-CDs: nitrogen-doped CDs; DP: dopamine; GBP: glucose binding protein; FOA: folic acid; MPAS: mercaptopropionic acid stabilized; MTZ: metronidazole; MIP: molecularly imprinted polymers; TONT: thiolated oligonucleotide; GNPl: graphene nanoplatelet; GQD: graphene QD.
The structure flaws in MoS₂ could be utilized for surface change or functionalization and mono or a few layers of MoS₂ nanosheets show confinement effects, all of which contribute to improved sensor qualities. The examination of biomolecules such as DNA and lactate has been summarized utilizing MoS₂-based sensors. MoS₂ could be semi-conducting with a TDB or metallic (I T) based on the type.

For determining PSA, Lee and his project team suggested a MoS₂-based label-free biosensor (Scheme 1) with a simplified dielectric-free architecture. Huang and his team demonstrated an electrochemical biosensor made of MoS₂ nanocomposites. Thus, the unique features of MoS₂ paired with effective production processes open novel possibilities for nanophotonic, electricity and electrochemical biosensor applications. Table IV summarizes several MoS₂-based biosensors for ease of reference.

This above scheme could be explained briefly in the following: MoS₂ material is employed to modify to the working electrode and then, anti-total PSA antibody is attached to the surface of the electrode for antigen determination. The resulting antigen/antibody-modified electrode is subsequently incubated with the prepared MoS₂/anti-free PSA antibody to form a sandwich-shape system. The LOD of this biosensor is related to the large specific surface area of MoS₂ and the conductivity of graphene could enhance the electron transfer rate. Therefore, the corresponding electrochemical responses of electroactive indicator are improved.

**The Determination of the COVID-19 Virus Based on Various NMTs**

Before the WHO designated the global outbreak of the extremely contagious virus a pandemic on March 11, 2020, the first human cases of SARS-CoV-2 or COVID-19 were reported in Wuhan, China in December 2019.

We could employ numerous ways to detect COVID-19 thanks to ongoing medication studies across the scope from the initial diagnosis to treatment—some even stressing the very real prospect of a disease breakout in the years leading up to 2020. These consist of NA Tests-Gene-based identification of viral genomic RNA utilizing RT-PCR examination tests as the golden standard, Serological Immunoassay, CT imaging, and biosensors. In Fig. 2, these are depicted. The current testing criteria, on the contrary, provide certain difficulties. The following is an explanation of the basic operation and the benefits and drawbacks of the recent diagnostic examination.

RT-PCR examinations are employed to define viral RNA. Enzymes transform RNA to DNA, which is replicated billions of times in the PCR machine due to temperature cycles and then fluorescent indicators are bound, giving a positive outcome if the fluorescence surpasses a value set as a limit.

RT-PCR examinations do not show whether a person had a previous infection and has since recovered because they only determine the existence of an active virus at the examining time. They need to remove lipids, proteins, and other compounds from nasopharyngeal and nasal swab samples before they could extract RNA. Furthermore, because the virus is dispersed unevenly throughout the respiratory tract, negative examination findings would indicate the disappearance of the virus only at the sample collection center, rather than the disappearance of the virus overall. Because models must be transferred to a specialized laboratory from the place of collection/examining, response times are normally 48 h. False negatives are the result of an improper swab collection center or inadequate viral particles in the sample.

Since they are generally considered to be exceedingly sensitive for detecting SARS-CoV-2, sensitivity has been summarized as modest as 59% in Refs. 81, 82. The explanation for the modest sensitivity would be that RNA is easily degraded, which could have been averted by storing it immediately frozen. Therefore, mishandling models would lead to inaccurate determination. The host RNA is degraded and released as shards into the bloodstream during the SARS-CoV-2 viral damage, taking RT-PCR determination difficult. By functioning as signal enrichment techniques, nanomaterials such as gold nanoparticles or fluorescent biomarkers could help isolate these RNA snippets and overcome the determination challenge. They obtain a shelf life that could reach 12 months in almost all of the studies.

LFA or “Antibody” examinations as they are commonly known, identify a human’s immune reaction to a virus infection agent. To regulate mobility, a blood model is paired with a buffer liquid in the model pad of the examination strip. The model analyte binds with antibodies conjugated with fluorescent nanoparticles like colloidal gold, on the release pad. The model now contains the capturing antibody tagged to the goal analyte and reacts with a nitrocellulose membrane with several examination lines, leading to the colorization of the suitable test line referring to the existence of IgM or IgG.

**Scheme 1.** The mechanism of the reactions on the electrode.
They possess a longer lifespan, up to 24 months.\textsuperscript{85} No need for refrigeration, clearly comprehensible visual findings, are easier to employ at the point of care and do not demand any extra processing device. It takes thirteen minutes to get from finger-stick to results. They could, for instance, support the diagnosis of post-infection diseases like MIS.\textsuperscript{86}

A part of the key study areas stems from a deficiency of LFA in the digitization of visual information into quantitative output. Furthermore, because analysis duration is determined by model viscosity, enzymes could not be applied to improve examination responsiveness. A sensitivity range is created through a restriction on the overall volume of model consumed.\textsuperscript{87} Because studying the COVID-19 virus agent continues still in its early stages, there are not many ways of knowing how long COVID-19 antibodies will stay. Thus, a negative examination result does not rule out the probability of the past infection agent. Antibodies might not even be determined in cases of mild illness.

CT Scans: Victims’ chest CT scans are abnormal, with viral pneumonia infection images serving as the baseline. Many investigations concentrate on the appearance of COVID-19 in the lungs in the shape of lobular and patchy GGOs, lesions, nodules or cavitation and have found that images alter at various phases of the illness agent.\textsuperscript{88–90} Thus, a CT scan could be employed to track the procedure of a disorder.

CT scans had better sensitivity than RT-PCR, with results of 88.012 percent versus 59.10 percent and 98.102 percent versus 71.25 percent mentioned in Refs. \textsuperscript{81, 82}. Because the progression is straightforward and the equipment is readily vacant in the hospital, this technique could be applied as a quick screening tool, at least for initial screening, especially in areas where RT-PCR examination kits are in short supply. Nevertheless, pictures acquired from a COVID-19 victim CT scan might look like those delivered from an influenza infections agent, rendering this technology dangerously unreliable in some situations. These CT scans expose children and pregnant women to radiation, making them potentially unsuitable for them. The chest CT appearance is regarded to be non-specific, despite its great sensitivity; the precision in discriminating COVID-19 infection agent from non-covid viral pneumonia by comparing CT characteristics of the two has been recorded as modest as 60 percent.\textsuperscript{91}

Differentiating among symptoms caused by COVID-19 infection and symptoms caused by other pneumonia-like illnesses or lung problems is a difficult task for radiologists.

Different study groups doing on NMB biosensors are said to have addressed a little, however, not all the problems outlined above. Quick response, better selectivity as well as sensitivity, portability and cost-effectiveness belong to the pros of adopting NMB biosensors.\textsuperscript{92,93} Furthermore, most NM could be suitably functionalyzed to acquire developed features and pros such as biocompatibility and excellent biosensor reproducibility.\textsuperscript{94}

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Given several benefits, the greatest potential for on-site applications has not been realized; the tool is not widely available for commercial usage and existing logistical support is restricted to basic examinations. The compared Table V shows various significant qualities that serve as grounds for comparison when considering nano biosensors as determination devices that supplement traditional approaches.

Having many notable advancements in biosensors devices for COVID-19 determination, not least because biosensors provide the same merits of mobility, sensitivity and compactness as chip-based sensors tool and modest model demand. As indicated in Fig. 3, the mechanism of detection of a biosensor includes biorecognition factors, transducers, and a processor for information interpretation. The biologically sensitive substance serves as a determination template, while the transducer oversees transforming the analyte’s contact with its receptor enter to an electric response. Finally, the signal is filtered and amplified properly before being output.

Table VI outlines various current sensor advances that have shown promise in responding to the new coronavirus and would be the focus of the following words.

Anti-S antibodies are diagnostic indicators because the S1 spike protein is a significant facilitator of viral entry.\textsuperscript{100} Even throughout the incubation stage and during asymptomatic instances, S1 determination reliably reveals the appearance of the virus itself.\textsuperscript{101, 102} For examining the SARS-CoV-2 S1 spike protein, a new bio-electrochemical biosensor\textsuperscript{103} uses membrane-engineered cells electron injected with human S1 antibody as the biorecognition factor. It reacts to antigens (goal analytes-S1 protein) interacting with inserted antibodies on the cells, causing changes in cellular bioelectric characteristics. This cost-saving, ultra-fast sensor could distinguish among various protein contents. The sensor might also be utilized to identify related coronaviruses by varying the binding of antibodies corresponding to different domains of the S1 subunit.\textsuperscript{104, 105} P-FAB designed by IITM scientists, uses a multimode U bent fiber-optic probe to determine SARS-CoV-2 N-protein\textsuperscript{106} from non-invasive saliva models.\textsuperscript{106} The sensor had a determination limit of 10–18 M and other advantages including flexibility and sensitive and specific determination. The N-protein such as the spike protein is a significant structural protein of the SARS-CoV-2 virus with a strong immunogenic action that aids viral RNA replication and is exist during the infection’s early steps.\textsuperscript{107} The reaction of N protein from the saliva samples with detector antibodies (anti-N-protein) in the biofunctionalized sensing area leads to an absorbance increase that would be measured. COVID determination could be particularly sensitive with a point-of-care biosensor-based tool.\textsuperscript{108, 109} A new nanophotonic biosensor fabricated to define the SARS-CoV-2 RNA sequences\textsuperscript{110} and targeted at real-time monitoring of virus content

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**Figure 2.** Different techniques for examining COVID-19 (The origin).
Table V. Standard COVID-19 examinations and nano biosensors factors to compare.

| Factor                  | CTS                          | SIS   | RT-PCR                 | Nano biosensors                                      |
|------------------------|------------------------------|-------|------------------------|------------------------------------------------------|
| Time to respond        | 0.5–1 h                      | 0.5 h | About 2 days           | The determination time is not greater than 0.5 min.  |
| Results precision      | Non-specificity causes incorrect-positive outcomes: as modest as 60.05 percent precision has been discovered. | Incorrect negatives are caused by antibodies that are undetermined | Incorrect negatives could occur when a swab is taken at the wrong location or there is not insufficient viral content in the model. | Indicating promising in overcoming the difficulty of incorrect positives and negatives recorded by conventional RT-PCR testing. |
| Sensitivity            | Greater than RT-PCR, with 88.03 percent versus 59.24 percent and 98.12 percent versus 71.32 percent, respectively. | 87.32 percent to 97.24 percent | Positive in bronchoalveolar lavage fluid 93.18 percent | Possesses an extremely great sensitivity as well as a very modest LOD of $1.02 \times 10^{-18}$ M. |
| Portability            | Within a special facility    |       | The examination could be done at the point of care with lateral flow tools | The examination is performed at a specialist lab that is not close to the model collection location | Portable equipment for economic point-of-purchase usage |

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Footnotes:
91 Incorrect positives causes incorrect-positive outcomes: as modest as 60.05 percent precision has been discovered.
92 Incorrect negatives are caused by antibodies that are undetermined.
93 Incorrect negatives could occur when a swab is taken at the wrong location or there is not insufficient viral content in the model.
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95 Sensitivity Greater than RT-PCR, with 88.03 percent versus 59.24 percent and 98.12 percent versus 71.32 percent, respectively.
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the atmosphere is responsive to SARS-CoV and could make a distinction among RNA of SARS-CoV and SARS-CoV-2, highly associated viruses with slightly different RNA sequences. It is fabricated of GNI onto which DNA receptors that are compatible with the virus’s RNA sequences are grafted. The RNA’s existence is determined by molecules attaching to the functionalized nanostructure. Similarly, plasmonic biosensors combining the PPT and LSPR phenomena are being examined for employment in clinical diagnostics. They have a broad scope of substrate materials to choose from, ranging from metallic NPs like gold to 2D films made of Gr and silicon nanowires and extensive scope of architectures that would be easily manufactured in laboratories to produce the needed biocompatibility. The Qiu team developed a dual-function LSPR sensor tool for its great selectivity as well as sensitivity for determining SARS-CoV-2 and its modest LOD (0.22 ppm concentration). The difficulty of false positives or negatives recorded by routine RT-PCR testing could be mitigated using a biological sensor.

Through their exceptional nanophotonic characteristics, NPs could be employed as FPs for biomolecular imaging and determination. Additionally, for QDs, nanosensing processes based on Au, C, Silica, and magnetic NPs have been intensively investigated in connection to cellular determination and screening of illnesses. They have a broad scope of substrate materials to choose from, ranging from metallic NPs like gold to 2D films made of Gr and silicon nanowires and extensive scope of architectures that would be easily manufactured in laboratories to produce the needed biocompatibility. The Qiu team developed a dual-function LSPR sensor tool for its great selectivity as well as sensitivity for determining SARS-CoV-2 and its modest LOD (0.22 ppm concentration). The difficulty of false positives or negatives recorded by routine RT-PCR testing could be mitigated using a biological sensor.

GO, nano-size GO is called GQD, few-layer graphene and fluorographene, to mention a few, are valuable as biosensing system components. Graphene is naturally inert, with zero bandgaps, demanding chemical functionalization with both organic and inorganic compounds, despite its fascinating properties. Controlling its electronic activity through chemical alteration would allow it to be employed in nanoelectronics tools by regulating the bandgap. Rolling as a SARS-CoV-2 sensor detector, a FET-based biosensor tool based on surface-modified graphene sheets was currently found. The diagnostic antigen was viral spike protein, and the equipment was equipped with SARS-CoV-2 spike antibodies receptors; the outcomes revealed that the antigen could be reliably detected in both cultivated virus and clinical models.

The mitochondrial ROS manufacturing in the lung cells has been defined as a prominent adverse impact of the COVID-19 pandemic virus. Iran scientists presented a novel technique based on biosensing the ROS responsible levels for activating the NLRP3 inflammasome, a member of the innate immune system. It measures ROS in pure sputum models from victims employing an electrochemical biosensor constructed with MWCNTs changed electrodes. The capacity to take a virus agent’s infection diagnostic in no symptoms situations by using easily responding to variations in the levels of ROS during the sputum and the prospect of real-time disease determination during not exceeding ½ min are two major merits of the tool sensor. The examinations that have already been performed on victims have shown encouraging outcomes for precision and sensitivity, offering a good comparison point with the existence of clinical testing.

**Nanotoxicity, Side Effects of NMTs and the Alternative Solutions**

Because of the considerable attention being paid to enhancing nanomedicine and nano-biomedical engineering, several researchers occasionally examine the negative effects of nanotechnology separately. In order to assess whether NPs are successful in harming the individual’s body, it is necessary to consider their special characteristics like tiny sizes, large surface areas and forms, which greatly expand their application. Because perfused organs like the liver, spleen, lungs, heart and kidney receive a sizable amount of any material that make its way into the body through adsorption or injection, they might be dangerous to cells if there is an increased production of oxidative stress and inflammatory mediators in various tissues. As a result, NMTs may be hazardous to the kidneys, liver, heart, immune system and genome.

The smaller the size of the NPs, the simpler it is to translocate them to the surface and alter cellular digestion by interacting with subcellular organelles. This is based on the size, shape and surface area of the NMTs. According to Patel and Nanda’s study, which compared CuO nanorods and CuO nanospheres, the nanorods with higher surface areas were more hazardous because they discharged more ions. While highly purified CNTs have short-term toxicity and could be classified as biocompatible, handling of CNTs has reportedly been linked to the same handling issues as asbestos. NMTs employed in medication delivery build up in the liver, where an overactive immune response might result in...
Table VI. SARS-CoV-2 biosensors tools have been advanced currently and indicate the attempt to the applications.

| No. | Target substance                        | Determination material | Merit and time to examination                                                                 | References |
|-----|-----------------------------------------|------------------------|------------------------------------------------------------------------------------------------|------------|
| 1   | ROS exists in the lung cells            | Modified electrode with MWCNTs | With no symptoms, a real-time and sensitive determination is not greater than 0.5 min is applied to screen viral infection agent | 97         |
| 2   | RNA                                     | Gni/DNA receptors—RNA sequences | Virus content in the atmosphere is being monitored in the real-time                              | 90         |
| 3   | SARS-CoV-2 spike protein S1             | MEE electro/S1 antibody human | Differentiation between various protein contents located at a breakneck speed.                  | 82         |
|     |                                         | GrS/SARS-CoV-2 spike antibodies | Determination during the incubation lasting/in instances with no symptoms                        | 82         |
| 4   | Surge protein from a virus              | MNP                    | Determination of viruses from clinical models without preprocessing is very accurate and reliable | 98         |
| 5   | Biological fluids/serum-derived viral proteins | MNP | Levels of noise in the surroundings are modest and the tool is portable                          | 99         |
| 6   | SARS-CoV-2/N protein                    | ANP/GNPs/UBPOP          | Model pre-preparation is minor, and determination is quick and accurate, even for modest compound content | 85         |

Note: ROS: reactive oxygen species; ANP: anti-N protein; UBPOP: U bent fiber optic probe; MNP: magnetic nanoparticle; Gni: gold nano-islands; GrS: graphene sheets; MWCNTs: multiwalled carbon nanotubes; SARS-CoV-2: severe acute respiratory syndrome coronavirus 2.
irreversible damage; silica or quartz dust build up might also result in silicosis and pulmonary fibrosis.\textsuperscript{132}

These NMTs have a huge potential for use as coronavirus disinfectants, largely because of their special characteristics, which include inherent anti-viral features consisting of the production of ROS and PPD, PPT abilities. Additionally, employing biodegradable NPs could help reduce harmful impacts of NMTs on the environment and human health, that is polymeric, lipid-based. This might be some alternative solutions that could be applied in the future because of the influence of NMTs for the long-time usage.

Conclusion and Future Challenges

A piece of equipment called a sensor must have a broad scope of applications, including great specificity and sensitivity, to distinguish the proper analyte from other pollutants or analytes. To be used in biological systems, it must be non-toxic and disposable to prevent the spread of infectious illnesses. Other needs consist of the capacity to multiplex biomolecule sensing for increased precision, quick reaction timing with little postprocessing, extended life and cost-efficiency to boost the biosensor’s affordability. Contemporary biosensors are limited because they fail to meet 1 or more of the demands at the commercial level, hence ongoing study is aimed at overcoming these constraints to develop more precise and sensitive biosensors.

To apply graphene-based tools sensors for a broad range of commercial applications, researchers are finding efficient capturing factors to attach goal molecules toward the surface area’s sensor and methods to tackle the issues of graphene’s electrical conductivity being susceptible to environmental changes making the examination process and outcomes unreliable and inconsistent.\textsuperscript{133} CNTs are functionalized with receptors like proteins or other microbes to fabricate CNT-bioFETs for biological purposes. While such tools have numerous pros, one drawback is background electrostatics and efficiency to boost the biosensor’s affordability. Contemporary biosensors are limited because they fail to meet 1 or more of the demands at the commercial level, hence ongoing study is aimed at overcoming these constraints to develop more precise and sensitive biosensors.

The NPs cores poisonous research utilized as sensor components would also indicate their biocompatibility in living material.\textsuperscript{134} The QDs elimination with diameters not exceeding 5 nm by renal filtration is a part of the efficient obstacles when using QDs as imaging probes.\textsuperscript{135} The NPs cores poisonous research utilized as sensor components would also indicate their biocompatibility in living material organisms.\textsuperscript{136,137}

Outside the well-studied usage in electronics, graphene and the derived materials are promising prospects for medicinal uses, including medication delivery,\textsuperscript{138} gene therapy,\textsuperscript{139} DNA sequencing,\textsuperscript{140} and bio-imaging\textsuperscript{141} and biosensing.\textsuperscript{142}

Given the usefulness of biosensors in the determination and controlling of infectious illness control, it would be worthwhile to surpass present hurdles like sensitivity, precision, ease of mobility for point-of-care tools and affordability once they are commercialized. Recent biosensor study attempts to build durable biosensors that would be regenerated and reused, allowing for long-term employment and price savings. The efficient integration of polymers, NMTs and biology appear to be the primary factor in producing better and more potential biosensor tools.

This work could be considered the latest overview to help future research have more information that would develop the virus detection scientific and might be a reliable reference with the valuable scientific for the following research, especially in the situation that the world must face to the pandemic infection. Compared to previous reports, this article is the first work to update the latest data about determining infectious virus based on NMTs sensors as well as contribute a new report to the determination of infectious virus by assessing the toxicity, side effects of NMTs-based sensors and giving the alternative solutions. In addition, the mechanism of the reaction on the electrode with the explanation have also provided to help improving the quality of the work and several latest references in various fields have been updated to improve the reliability and the persuasiveness for the present work.

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