



Biosensors: frontiers in rapid detection of COVID-19

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Abstract

The rapid community-spread of novel human coronavirus 2019 (nCOVID19 or SARS-Cov2) and morbidity statistics has put forth an unprecedented urge for rapid diagnostics for quick and sensitive detection followed by contact tracing and containment strategies, especially when no vaccine or therapeutics are known. Currently, quantitative real-time polymerase chain reaction (qRT-PCR) is being used widely to detect COVID-19 from various types of biological specimens, which is time-consuming, labor-intensive and may not be rapidly deployable in remote or resource-limited settings. This might lead to hindrance in acquiring realistic data of infectivity and community spread of SARS-CoV-2 in the population. This review summarizes the existing status of current diagnostic methods, their possible limitations, and the advantages of biosensor-based diagnostics over the conventional ones for the detection of SARS-Cov-2. Novel biosensors used to detect RNA-viruses include CRISPR-Cas9 based paper strip, nucleic-acid based, aptamer-based, antigen-Au/Ag nanoparticles-based electrochemical biosensor, optical biosensor, and Surface Plasmon Resonance. These could be effective tools for rapid, authentic, portable, and more promising diagnosis in the current pandemic that has affected the world economies and humanity. Present challenges and future perspectives of developing robust biosensors devices for rapid, scalable, and sensitive detection and management of COVID-19 are presented in light of the test-test-test theme of the World Health Organization (WHO).

Keywords Biosensors · SARS-CoV-2 · COVID-19 · Rapid detection

Introduction

In December 2019, severe respiratory distress, with pneumonia-like symptoms was reported in Wuhan, China. The metagenomic RNA sequencing from the bronchoalveolar lavage fluid of the infected patients identified a new RNA virus (Zhou et al. 2020b). Later, the phylogenetic and genomic analyses revealed that the virus shares a close genetic resemblance to the SARS (Severe Acute Respiratory Syndrome) like coronavirus (Lu et al. 2020). Subsequently, the International Committee on Taxonomy of Viruses (ICTV) renamed the novel coronavirus (2019-nCOVID/

COVID-19) as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (Lu et al. 2020). Since 12th March 2020, the pandemic of SARS-CoV-2 has been declared as Public Health Emergency of International Concern (PHEIC) by the WHO. To date, over fifteen million cases have been recorded across the globe. Besides the health crisis, the SARS-CoV-2 pandemic has also brought a socioeconomic crunch across the globe (Nicola et al. 2020). Until now, there are no specific treatment approaches or vaccines to confine the outbreak, like these under clinical trial stages (Hamid et al. 2020). Therefore, there is a necessity for immense diagnostic measures to curb the unprecedented virus transmission and to aid in the rapid diagnosis of COVID-19 and understand its epidemiology for therapeutic advancement.

SARS-CoV-2 has an incubation period of 2–7 days, before the onset of the infection. This stage is mostly asymptomatic and contagious as the virus can spread from one infected person to the other healthy one (Chan et al. 2020). The existing number of infected cases and the actual case fatality ratio (CFR) of the COVID-19 infected patients is still unclear due to a lack of uncertainties in quantifying or detecting the infection (Bohk-Ewald et al. 2020). Therefore,

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the extent of this pandemic is still notional. Testing people or a mass population for any viral infection involves biosensing of presence or absence of analytes such as viral nucleic acids (DNA and RNA), viral proteins, intact viral particles, and antibodies generated by the patient immune response against the virus (Guliy et al. 2019). The list of all viral diagnostic methods is summarized in Table 1.

Although a significant number of methods are available for detecting virus particles, there are several difficulties, that restrict the practical use of these methods. These limitations include:

1. Lower accuracy and sensitivity
2. The need for sample preparation and purification
3. Time-consuming
4. Higher instrument, accessories, and maintenance cost
5. Large-scale availability
6. The complex operation of the instruments
7. A requirement of highly qualified technical personnel
8. Not suitable for rapid, on-site analysis

Therefore, there is a need for newer, efficient methods for the rapid detection of viral analytes, which takes into

consideration the versatility of viruses and their replication niches. Implementation of these methods must ensure higher accuracy, ease of operation and portability, and large-scale availability to test the mass population. The purpose of this review is to comprehend our understanding of different types of biosensors used in the diagnosis of viral respiratory infections, the recent advancement in trends of biosensor research for detection of SARS-CoV-2, and prospects of biosensors in rapid diagnosis of the mass population to contain the spread of this virus.

Biosensors in the detection of human respiratory viruses

Sensors consist of chemical or biological receptors and transducers. The receptor interacts specifically with a target analyte and the transducer converts the recognition process into a quantitative signal (Ozer et al. 2020). Biosensors are analytical devices in which biological recognition molecules such as enzymes, antibodies, or nucleic acids are coupled with a transducer and a detector that detects the interacted analyte and gives a digital output. Biosensors can

Table 1 Summary of viral diagnostic methods

Diagnostic tests	References
Nucleic acid detection and amplification PCR, RT-PCR, qPCR Isothermal amplification technologies: (NASBA; LAMP; HDA; RCA; NEAR; SDA; TMA)	Fouchier et al. (2000), Storch (2000), Poon et al. (2005), Zhou et al. (2012), Sasaya (2015) and Souf (2016)
Immunoassays Fluorescent antibody (FA) Staining Hemagglutination inhibition Immuno-peroxidase Staining EIA/ELISA (FPIA, MEIA, CLIA)	Gupta et al. (2015), Mixson-Hayden et al. (2015) and Cebeci Güler and Tosun (2017)
DNA sequencing Sanger sequencers Next-generation sequencers DNA microarrays	Chiu et al. (2008), L�veque et al. (2014), Fischer et al. (2015), Thorburn et al. (2015), Wylie et al. (2018), Jerome et al. (2019), Huang et al. (2019) and Lewandowski et al. (2020)
Mass spectrometric methods MALDI-TOF	L�veque et al. (2014) and He et al. (2014)
Direct visualization of viruses Electron microscopy	Curry et al. (2006), Schramlov�a et al. (2010), Gabald�n and Carret� (2016) and Roingard et al. (2019)
Microelectronics and microfluidics based techniques Lab-on-a-chip (LOC) technologies Point of care (POC) testing Surface Plasmon Resonance (SPR) technique	Foudeh et al. (2012), Szab� et al. (2015), Dak et al. (2016), Koo et al. (2017), Soler et al. (2019) and Zhu et al. (2020a)

PCR polymerase chain reaction, *qPCR* quantitative polymerase chain reaction, *RT-PCR* real-time polymerase chain reaction, *NASBA* nucleic acid sequence-based amplification, *LAMP* loop-mediated isothermal amplification, *HDA* helicase dependent amplification, *RCA* rolling circle amplification, *NEAR* nicking enzyme amplification reaction, *SDA* Strand displacement amplification, *TMA* transcription-mediated amplification, *EIA/ELISA* enzyme immunoassay/enzyme-linked immunosorbent assay, *ESI* electrospray ionization, *FPIA* fluorescence polarization immunoassay, *MEIA* Micro-particle enzyme immunoassay, *MALDI-TOF* Matrix-assisted laser desorption ionization time-of-flight

be applied for medical diagnosis, environmental monitoring, food, water, and agricultural product processing are known (Rodvalho et al. 2015). Viral biosensors offer exciting alternatives to traditional diagnostic assays and can provide inexpensive, sensitive, rapid, miniaturized, and portable platforms when compared to conventional laboratory-based methods (Souf 2016).

In the past few decades, the innovation of biosensor research has witnessed an exceptional and exponential surge in the development and performance, due to advancements in transduction systems, nanotechnology and genetic engineering offer various strategies to improve the detection performance of biosensors (Cheng and Toh 2013). Based on technology incurred, there are four types of biosensors viz, Optical biosensors, Electrochemical biosensors, Piezoelectric biosensors, and Thermal biosensors (Saylan et al. 2019). A summary of different biosensor platforms for the detection of respiratory viral infections is listed in Table 2.

Recent trends in biosensors for detection of SARS-CoV-2

The COVID-19 pandemic is becoming more severe due to its continued global spread and the unavailability of appropriate therapy and diagnostics systems. International health agencies are making serious efforts to manage the COVID-19 epidemic by exploring every aspect of therapy development with special attention to investigating smart diagnostics tools needed for rapid and selective detection of the COVID-19 protein. The quest for rapid testing of mass populations for COVID-19 was documented by innovative methods in biosensor development (Nguyen et al. 2020). All possible targets of SARS-CoV-2 are depicted in Fig. 1 for testing viral genomic RNA, membrane proteins, and spike glycoproteins,

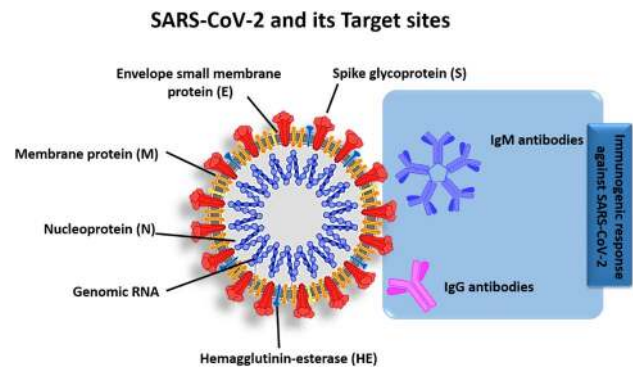


Fig. 1 Schematic structure of SARS-Cov-2 and its possible targets for diagnosing

which insist on immediate immune response upon binding to the host ACE-2 receptors (Liu et al. 2020). The humoral response is mediated by IgM and IgG antibodies, that are used to detect the COVID-19 disease and also used for its possible therapy known as plasma therapy (Chen et al. 2020; Zhang et al. 2020).

To overcome the issues mentioned above with conventional methods such as Lateral Flow Assay, ELISA, and colorimetric assay, etc. are time-consuming as well as low accuracy techniques. Many researchers worldwide are working on affordable, rapid, and highly sensitive methodologies or devices to detect ‘the deadly viral pathogen’. To overcome limitations of qRT-PCR based assay, a recently highly specific RT-LAMP (Reverse Transcription Loop-Mediated Isothermal Amplification) assay based method is available for detection of SARS-CoV-2 (Zhu et al. 2020b; Park et al. 2020; Yu et al. 2020). In addition to the conventional RT-LAMP method, Zhu et al., evaluated the one-step RT-LAMP mediated with Nanoparticles-Based Biosensor (NBS), RT-LAMP-NBS assay for rapid and accurate diagnosis of

Table 2 Types of biosensors for respiratory virus detection

Types of portable Biosensor	Virus	Recognition element	Other viruses detected	References
Electrochemical Bio/Immuno-sensor	Influenza A virus	M1 protein	Parainfluenza; Rhinovirus; Middle East respiratory syndrome coronavirus (MERS); Severe acute respiratory syndrome (SARS-CoV)	Schmidt and Hawkins (2016), Dziabowska et al. (2018) and Saylan et al. (2019)
Optical Bio/Immuno-sensor	MERS	Recombinant Spike protein S1 (Human betacoronavirus 2c EMC/2012)	SARS-CoV; H ₅ N ₁ influenza virus; Human Adenovirus; Respiratory Syncytial Virus (RSV);	Layqah and Eissa (2019), Ravina et al. (2020) and Santiago 2020)
Piezoelectric immuno-sensor	SARS-CoV	Spike protein S1	Influenza Virus; Adenovirus; RSV; MERS	Kizek et al. (2015), Yuan and Han (2016) and Lee et al. (2018)
Thermal Biosensor	SARS-CoV	RNA-dependent RNA polymerase (<i>RdRp</i>) gene	MERS; SARS-CoV-2	Saylan et al. (2019) and Woo et al. (2020)

SARS-CoV-2. In this assay, LAMP primer sets, F1ab (opening reading frame 1a/b), and np (nucleoprotein) genes of SARS-CoV-2 were simultaneously amplified and detected in a one-step and single-tube reaction, and NBS could easily interpret these detection results. The sensitivity of SARS-CoV-2 RT-LAMP-NBS was 12 copies (each of the detection targets) per reaction. This made it less error-prone in amplifying the non-SARS-CoV-2 templates, thus giving a higher specificity and low false positives results. Additionally, this report revealed 100% sensitivity for the detection of COVID-19 in clinical samples (oropharynx swab samples) and it took about one hour for detection (Zhu et al. 2020b). Further, the use of modern gene-editing CRISPR-Cas (Clustered Regularly Interspaced Short Palindromic Repeats) system for the detection of the virus was studied (Zuo et al. 2017). This technique can also detect bacteria, microRNAs, and cancer mutations, in a simple and easily scalable manner, merely by changing target-specific crRNA/sgRNA. Recently, nanoparticles (NPs) gained enormous interest due to their biological activity and sensing properties (Holzinger et al.

2014; Navale et al. 2015b, c). The gene-editing technique was modified as a biological sensor using CRISPR-Chip coupled with a graphene-based Field Effect Transistor (FET) that can detect up to 1.7 fM quantity of nucleic acid without the need for amplification within a short span of 15 min (Hajian et al. 2019). Recently, it was also established for the detection of COVID-19 infection in less than 40 min. The CRISPR-Cas12-based lateral flow assay technique is easy to implement and an accurate and good replacement for real-time RT-PCR based diagnostics (Schematic Fig. 2a) (Broughton et al. 2020). The FET-based biosensing devices utilize the coating of the graphene sheets of the FET with a monoclonal antibody against the SARS-CoV-2 spike protein (Fig. 2b). They determined its sensitivity using antigen protein, cultured virus, and nasopharyngeal swab specimen from COVID-19 patients. This FET biosensor device could detect 1 fg/mL concentration (conc.) of SARS-CoV-2 spike protein in phosphate-buffered saline (PBS) and 100 fg/mL conc. in the clinical transport medium (Seo et al. 2020). Numerous nanoparticle-based electrochemical biosensor

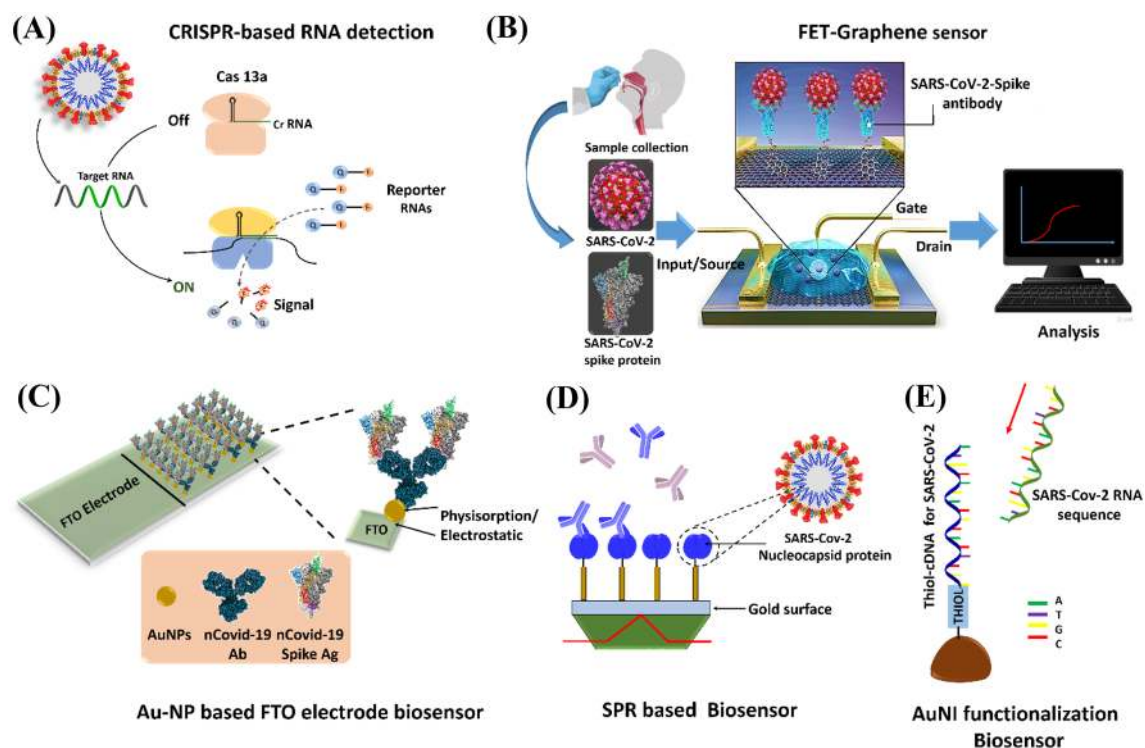


Fig. 2 Biosensors for SARS-CoV-2 virus detection. **a** CRISPR based nucleic acid (RNA) detection. RNA transcripts containing the target sequence (green) are recognized by RNA guided Cas endonuclease and CRISPR-RNA (Cr-RNA) carrying the complementary sequence. The formation of the Cas-crRNA-RNA-transcript tertiary complex switches on the ‘collateral cleavage’ activity, thereby dramatically applying the fluorescent signal in the presence of the target RNA. *Q* quencher, *F* fluorophore (Zuo et al. 2017; Broughton et al. 2020). **b** Schematic diagram of COVID-19 FET based biosensor operation. SARS-CoV-2 spike antibody is conjugated onto the graphene sheet

via 1-pyrenebutyric acid *N*-hydroxy-succinimide ester, which is an interfacing molecule, as a probe linker (Seo et al. 2020). **c** The FTO electrode consist sensing area made up of AuNPs conjugated with nCOVID-19 Ab either by physisorption or electrostatic bonding (Mahari et al. 2020). **d** Surface Plasmon Resonance (SPR) based biosensor for COVID-19 detection. Activation of the AffiCoat surface, the nucleocapsid protein of SARS-CoV-2 are bound to the SPR chip, and remaining activated sites were passivated with ethanolamine. **e** Schematic diagram of the 2D gold Nanoislands (AuNIs) functionalized with complementary thiol-cDNA ligands

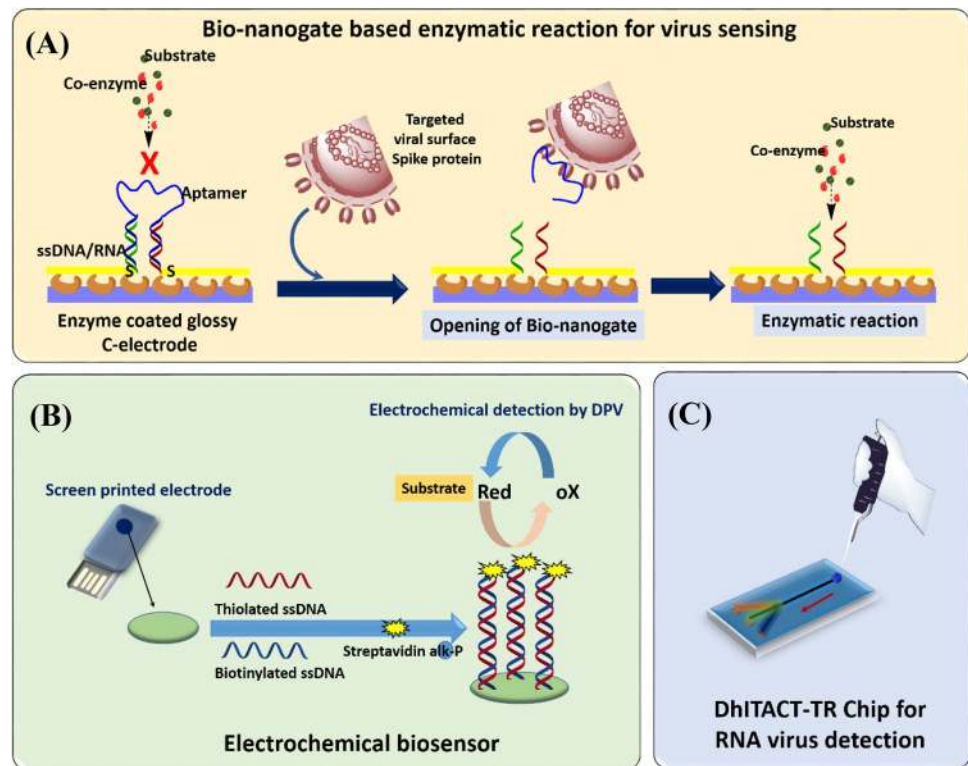
devices are also known for virus detection (Caygill et al. 2010). Recently Mahari et al., developed an in-house built biosensor device (eCovSens) which were fabricated with Fluorine Doped Tin Oxide (FTO) electrode together with gold nanoparticles (AuNPs) and nCOVID-19 antibody. They are very specific to detect the nCOVID-19 spike antigen. At optimal conditions, these FTO-Immunosensor could detect the nCOVID-19 antigen, ranging from 1 fM to 1 μ M concentrations. This eCovSens device can detect nCOVID-19 antigen at 10 fM concentration in a standard buffer. This device displays the results rapidly, within 10–30 s (Fig. 2c) (Mahari et al. 2020). Surface Plasmon Resonance (SPR) and Localized Surface Plasmon Resonance (LSPR) based viral biosensors were referred earlier (Park et al. 2009; Lee et al. 2018). These thermoplasmonic techniques are highly applicable in nucleic-acid detection and also in viral disease diagnosis. Recently, this SPR based sensor was reported for detecting nucleocapsid antibodies, which were specific against the SARS-CoV-2 in undiluted human serum instead of oropharynx swab. This SPR sensor coated with a peptide monolayer and functionalized with SARS-CoV-2 nucleocapsid's recombinant protein detected anti-SARS-CoV-2 antibodies in the nM range. Thus, this bioassay is rapid, label-free which can diagnose samples within 15 min of sample/sensor contact (Fig. 2d) (Djaileb et al. 2020). For the detection of current pandemic (SARS-CoV-2), dual-functional, plasmonic biosensor Plasmonic Photothermal (PPT) and LSPR were also explored. The 2D gold nanoislands (AuNIs) functionalized with complementary DNA (cDNA) receptors and combining PPT effect and LSPR sensing technique, provides an alternative and promising solution for the detection of clinical COVID-19 by nucleic acid hybridization (Fig. 2e). This dual-functional LSPR biosensor exhibits a high sensitivity towards the selected SARS-CoV-2 sequences, with a detection limit up to 0.22 pM conc. which allows precise detection of the specific target in a multigene mixture (Qiu et al. 2020).

Future perspectives of biosensors for the detection of SARS-CoV-2

Currently, to overcome this 2020 pandemic of SARS-CoV-2, there is much interest in developing rapid, reliable, and sensitive novel biosensors for COVID-19 diagnostics which would be a single step identification or sensing method that eliminate separation (extraction of nucleic acid), incubation or use of any signal-reporting agents. Biosensors for COVID-19 are mostly designed on the surface nucleoproteins, which binds to the host angiotensin-converting enzyme 2 (ACE-2) receptor and the internal genetic material; is very specific (Liu et al. 2020). Detection of biomarkers from human hosts different from

antibodies or immunoglobulins could be the approach for developing new biosensors for COVID-19 infection. Recently, several host biomarkers such as hematological (lymphocyte count, neutrophil count, neutrophil–lymphocyte ratio (NLR)), inflammatory (C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), procalcitonin (PCT)), immunological (interleukin (IL)-6 and biochemical (D-dimer, troponin, creatine kinase (CK), aspartate aminotransferase (AST)), especially those related to coagulation cascades in disseminated intravascular coagulation (DIC) and acute respiratory distress syndrome (ARDS) are identified. Other novel biomarkers can be identified through the accurate analysis of multiple case studies, in particular, homocysteine and angiotensin II could play a significant role (Ponti et al. 2020). In recent years, nanomaterials such as gold and carbon have gained vast interest in sensor technology and have produced promising devices for sensing the virus and its biomolecules. These nanomaterials fused with analyte such as complementary single-stranded nucleic acid aptamer could be a new strategy for detecting SARS-CoV-2 in clinical samples. Aptamers are single-stranded RNA or DNA oligonucleotides which depend on hydrogen bonding, electrostatic, and hydrophobic interactions, and they represent an alternative to antibodies as recognition agents. Aptamer based bio-nanogate bifunctional biosensor specifically respond to the viral surface spike protein S1 as a target molecules, and control enzymatic reaction for electrochemical measurements (Fig. 3a) (Wang et al. 2015; Acquah et al. 2016). The current scenario is heading in developing sensitive, portable, and space-friendly biosensor devices. Electrochemical based biosensors are based on electrode material and form factor, and widely being used for virus detection based on, antibodies, aptamers, and imprinted polymers (Cesewski and Johnson 2020). Ebola virus was diagnosed using the electrochemical-based DNA-sensing device, by an enzyme-amplified detection, which improved the sensitivity and selectivity of the sensor. As shown in Fig. 3b, the thiolated DNA capture probe sequence has been immobilized on the screen-printed electrode surface and hybridized with biotinylated target strand DNA. This strategy could be useful for detecting the SARS-CoV-2 virus by changing the immobilized thiolated nucleic acid sequence. This technique could detect 4.7 nM conc. of complementary nucleic acids. This biosensor is selective and yields reproducible results (Ilkhani and Farhad 2018). Another electrochemical, paper-based biosensor was deployed for the detection of the chikungunya virus. These electrochemical paper-based biosensors used the ultra-high charge-transfer efficiency AuNPs associated with magnetic NPs (Fe₂O₄). This paper-based biosensor is simple, sensitive, biodegradable, and economic for mass production. The detection of COVID-19

Fig. 3 Schematic representation of possible biosensors for detecting SARS-CoV-2. **a** Aptamer based Bio-nanogate biosensor for virus spike protein-specific detection. **b** Electrochemical biosensor for detecting nucleic acids in the sample. **c** DhITACT-TR Chip for robust detection of target pathogen in a single-step injection of RNA extract



needs to be modified as per the specificity of the virus (Singhal et al. 2018). Meso/macroporous cobalt (II) oxide nanoflakes based electrochemical biosensor could detect 0.28 ng/ μ L conc. of specific RNA/DNA samples (Mohammadi et al. 2017).

For developing new biosensors, non-labeling techniques such as SPR, Surface-Enhanced Raman Scattering (SERS) and Quartz-Crystal Microbalance (QCM) technologies have shown promising development in biosensor research for viral samples. Such biosensors are in use for the detection of RNA viruses, such as influenza A/B, SARS-Corona, Ebola, MERS, Zika, and Dengue (Ilkhani and Farhad 2018; Soler et al. 2019). Ngo et al., developed a plasmonic SERS-active nanowave chip for single-step detection of nucleic acid. These techniques could also be used to develop a new biosensor for COVID-19 detection, as they allow detection of host genetic biomarkers for respiratory viral infection and a specific nucleic acid sequence (Ngo et al. 2016). The Ag-NPs hybridization in a quartz crystal microbalance DNA-QCM sensing system might be useful for the detection of RNA viruses over the conventional PCR based approaches (Chen et al. 2009). Detection of nucleocapsid protein is one of the keys to detecting viruses. Localized Surface Plasmon Coupled Fluorescence (LSPCF) fiber-optic biosensor was studied a decade ago for diagnosing different SARS viruses. This plasmon-based biosensor has combined sandwich immunoassay with the LSP technique and detects 0.1 pg/mL to 1 ng/mL SARS-CoV N protein in serum samples.

This biosensor could also detect the SARS-CoV-2 virus (Huang et al. 2009). Similarly, Park et al. (2009) revealed a self-assembled fusion protein-based SPR biosensor for rapid and acute diagnosis of the SARS virus.

Ionic liquids are the well-known solvents, that are synthesized by various combinations of cations and anions, and widely used in green chemistry and other biological applications (Navale et al. 2015a; Venkatraman et al. 2019). Most of the biosensors or other viral detection methods are required quick and stable RNA extraction steps. Lately, hydrophobic magnetic ionic liquids are used for isolation of RNA (as well as DNA) and also aided in the preservation of RNA, and hence it could be used during the initial step of viral RNA extraction. Recently Zhou et al., developed a DNA nano switch; an automated, low-cost, and rapid detection method for RNA viruses specifically using the Zika virus as a model system. This method detects viruses in a non-enzymatic manner and could detect at nanomoles of an RNA virus. This assay requires only a sample preparation step using either RNA extraction or isothermal pre-amplification. Recently, similar authors also evaluated such automated DNA nano-switches to detect SARS-CoV-2 RNA in human saliva (Zhou et al. 2020a). A novel DNA hydrogel formation by isothermal amplification of complementary target (DhITACT-TR) system has been successfully used for detection of the MERS virus, which is highly sensitive and could be diagnosed by the naked eye, as well as fluorescent detection within a short time (Fig. 3c). This biosensor is

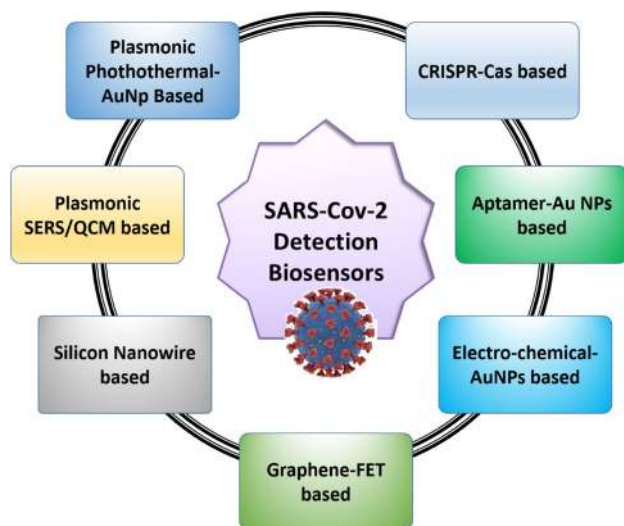


Fig. 4 The schematic diagram for biosensors for detection SARS-Cov-2 virus includes CRISPR-Cas based RNA detection; aptamer-Au NPs based viral spike protein detection; electrochemical-AuNPs based viral RNA detection; graphene-field effect transistor biosensor for virus detection, silicon nanowire-based viral spike protein detection; non-labeling plasmonic techniques such as Surface Plasmon Resonance (SPR), surface-enhanced Raman scattering (SERS) and quartz-crystal microbalance (QCM) based biosensor for COVID-19

much better than conventional PCR based methods, which requires only RNA extracts and faster (Jung et al. 2016). Layqah et al., evaluated an immunosensor for the diagnosis of MERS-CoV, based on carbon electrodes (DEP) modified with AuNPs, wherein spike protein S1 was used as a biomarker. This assay was performed in just 20 min with a detection limit as low as 0.4 and 1.0 pg/mL for HCoV and MERS-CoV, respectively. This biosensor is a highly selective, single step, sensitive, and accurate (Layqah and Eissa 2019). Apart from AuNPs, Silicon nanowire (SiNW) based biosensor devices are also accurate and sensitive to detect viral infections, this could thus be used for detecting recent pandemic SARS-Cov-2 virus (Shen et al. 2012) (Fig. 4).

Concluding remarks

In conclusion, this review summarizes an overview of the traditional viral detection techniques and modern biosensor-based methods for the detection of the SARS-CoV-2 virus in the COVID-19 pandemic. Traditional techniques like PCR and sequencing are time-consuming and may have specific individual false positive outputs. However, these methods might not fulfill the new challenges (such as rapid mutations) and demands (for mass populations) for the faster and direct detection of viral pathogens. Sensors are mostly based on detecting virus surface proteins and internal genetic material. In near future, emerging new technologies such

as rapid cum portable RNA extraction preps, CRISPR-Cas based paper strip, aptamer-based bio-naogate, nucleic acid hybridization, DhITACT-TR chip-based, graphene-FET, Au/Ag nanoparticles based electrochemical biosensor, optical biosensor, and surface plasmon (SPR, SERS, and QCM) based innovative platforms could pave the efficient ways of rapid, highly sensitive and more promising biosensing cum diagnostic devices for COVID-19 and other unprecedented pandemics.

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Compliance with ethical standards

Conflict of interest The authors have declared no conflict of interest.

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