Chapter

Role of Graphene and Graphene Derived Materials to Fight with COVID-19

Vamsi Krishna Kudapa, Ajay Mittal, Ishita Agrawal, Tejendra K. Gupta and Rajeev Gupta

Abstract

The COVID-19 pandemic is a genuine biosafety occasion that is causing an extreme effect on the worldwide society and economy. Various challenges associated with the outbreak of this pandemic include diagnosis, prevention, and proper medication. Engineered nanomaterials such as graphene and graphene derived materials could be the potential solution in preventing COVID-19. This study endeavors how the improvement of novel materials can assist researchers with handling the difficulties in biosafety. In recent years, 2D graphene had caught much consideration due to its efficient electrical properties and encouraging presentations, comprising methods to combat or identify drug-resistant bacterial contaminations. The bacteria lose its integrity when exposed to the graphene surface because of its efficient viral inhibition tendency.

Keywords: graphene, contact angle, superhydrophobic, mask, COVID-19

1. Introduction

Graphene belongs to the group of carbon comprising of a single layer of atoms organized in a 2D honeycomb structure [1]. Pristine graphene usage is limited due to its difficulty in bottom-up synthesis [2], lesser solubility [3], and the lower tendency of accumulation due to had proved challenging due to difficult van der Waals interactions [4]. To overcome the above limitations, alternative compounds may be derived from graphite or other carbon sources through top-down approaches, which can also incorporate functionalized oxygen groups on its surface. The protonated solvents has the tendency to form multi-layered graphene oxide by the process of graphene oxidation, which contains hexagraphene oxidenal based graphene structure. These derivatives are proven as efficient fillers in several polymer nanocomposite materials because of their uniform distribution across the polymer matrices [5]. This property has increased the functionality of graphene derivatives in paints, efficient and precise sensors, flexible displays, efficient solar panels, packing materials [6], sensitive electronic devices prevention [7], for resisting the corrosion on different materials [8] and in bio-imaging, biosensors, antibacterial agents, 3D bio printing, photo thermal therapy, drug delivery, gene therapy, and tissue engineering (**Figure 1**) [9].

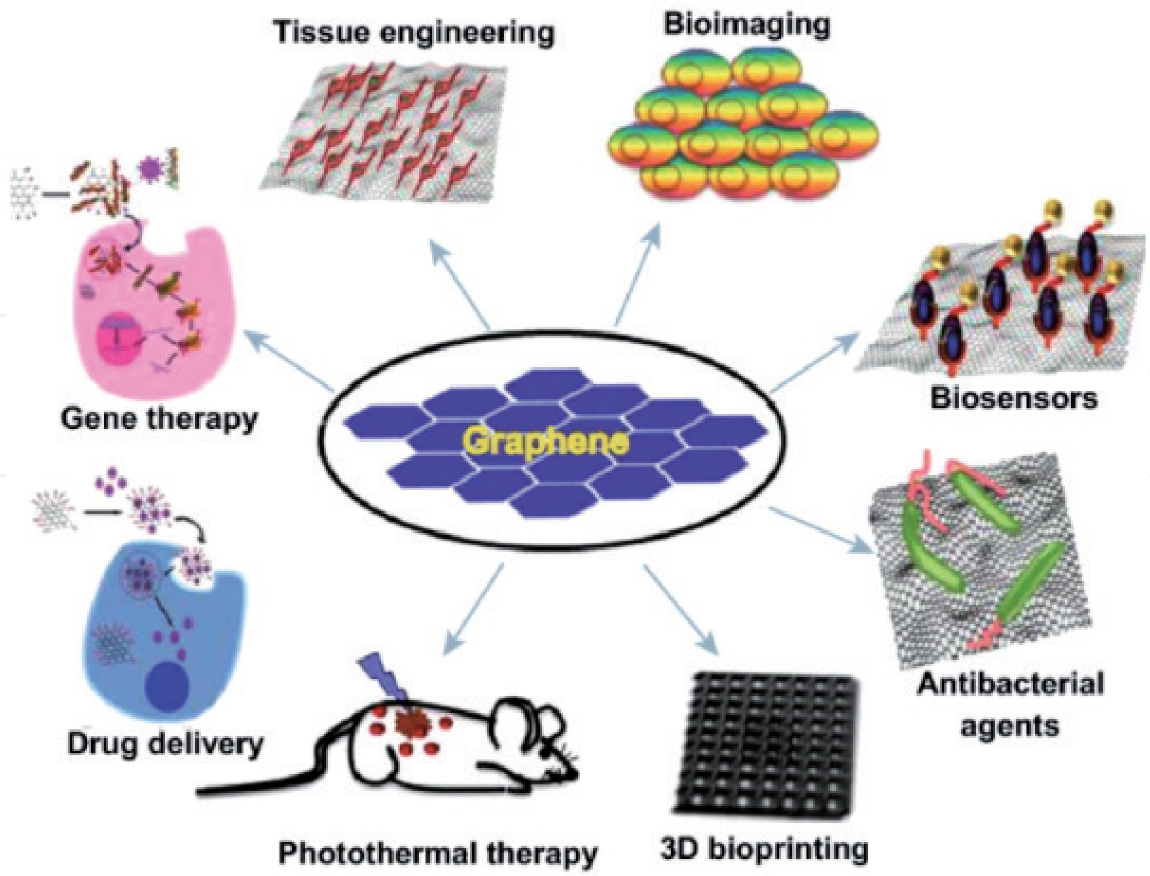

Figure 1.
Role of graphene in the area of bio-imaging, biosensors, antibacterial agents, 3D bio printing, photo thermal therapy, drug delivery, gene therapy and tissue engineering. Reprinted with the permission from [9].

Palmeri and Papi [10] studied different ways of interactions between various graphene-based materials and the viruses, which reveals that the graphene-based materials, can help in killing or blocking the viruses. Several recent studies have also revealed that graphene derivatives can be considered as a potential material for protecting from the COVID-19 virus [10, 11].

2. Mechanism of graphene based materials for prevention of COVID- 19

Earlier research suggests that graphene has a great viral hindrance limit. In 2012, the primary proof of graphene antiviral impacts was realized when fine layers of reduced graphene oxide -Tungsten oxide were misrepresented for photo inactivation of virus infecting bacteria under obvious light illumination [12]. Recent studies exhibited how the coronavirus spike S1 protein receptor-restricting area can cooperate with heparin and alternated compliance. It has suggestions for the advancement of initial remedial by adapting heparin and glycosamminoglycans-based antivirals [13], including treatment of graphene oxide based surface with sulfuric acid or sulfate. Sulfur reacted NPs functionalized with reduced graphene oxide had been effectively used to collect and photo thermally pulverize herpes simplex infection type 1 utilizing near-infrared (NIR) light [14]. This information brings up how graphene oxide detention could be combined with NIR medicines of lungs. As Gr and GrO absorbers fall under the NIR tissue transparency window, they allow the incident light deep into the body. The combination of carbon dots and natural antimicrobial polyphenol curcumin is proved to be an efficient model for preventing COVID-19 [15]. The respiratory syncytial infection is treated through the combination of Cyclodextrins-functionalized sulfonated graphene and curcumin-stacked cyclodextrins functionalized sulfonated graphene, GSCC. The sulfonate clusters on the GSCC can simulate the cell exterior and restrain RSV disease by an economical inhibition mechanism, recreating cell receptors utilized for infection connection. GSCC NPs impacts are because of a twofold component, by curcumin-intervened viral inactivation and by the self-consciousness of the infection connection to the host cell layers [16].

3. Fabrication of graphene based superhydrophobic coating

Revealed in December 2019, another lethal SAR-CoV-2 infection begins circling among the people [17] and spreads through the respiratory beds [18]. Additionally, an individual can likewise get in contact with this infection by interacting with the debased articles or exteriors and afterward getting in touch with mouth, nose, or eyes. A new report states that SAR-CoV-2 has a variable life span on different surfaces [19]. In comparison with Cu and cardboard, the adherence of coronavirus is estimated to be greater on the surfaces of plastic and tempered steel. Besides, the infection is affirmed to be steadier on smooth surfaces compared with uneven surfaces like printing/tissue papers, wood, and materials. Much more problematic is the discernible degree of the infection on the outside film of the surgical masks, which is 7 days [16]. These virus-infected touch surfaces, which can retain the virus for longer periods can spread the virus at a faster rate. In the current epidemic circumstance, where the coronavirus infections are dramatically expanding every day worldwide, improvement of the effective enemy of coronavirus protecting surfaces or coatings can be a potential solution for minimizing the spread of the virus through any source [20, 21]. Graphene or graphene derivatives are suitable for their antibacterial properties [22] and the study by Sametband [23] revealed the antiviral characteristics of graphene oxide and slightly reduced sulfuirnc acid treated graphene oxide against herpes simplex virus Type-1 by a specified unique mechanism. Comparable to receptor heparin sulfate cell surface, graphene oxide and its derivatives contain groups of negative charge elements and so the two moieties challenging each other in connection with HSV-1 as shown in **Figure 2**. Nanomaterials can be considered as main inhibitor in defending the Vero cell from the disease. The viral reduction effectiveness of graphene oxide, reduced graphene oxide, graphene oxide-polyvinylpyrrolidone (PVP) composite, graphene oxide poly (diallyl dimethyl ammonium chloride) composite with forerunners graphite

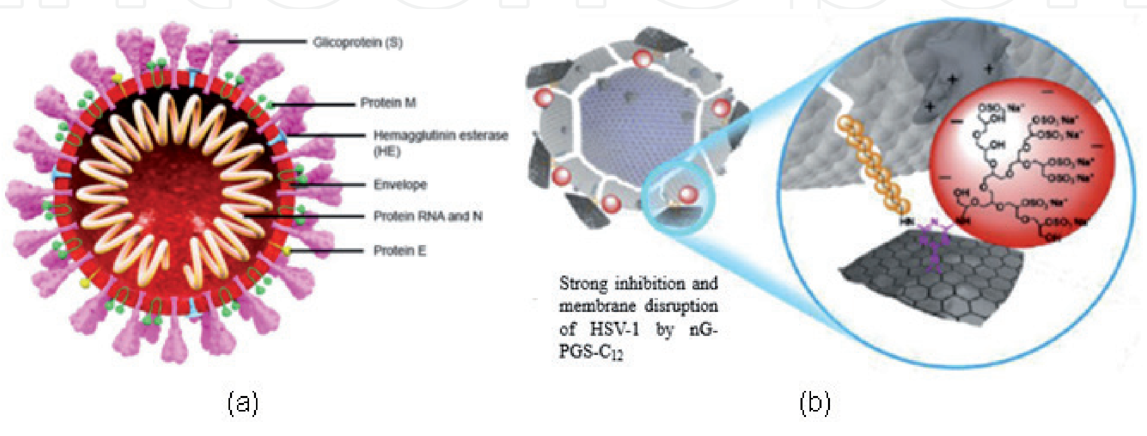

Figure 2.
(a) COVID-19 structure [2], (b) pictorial representation of the mechanism of breaking the long chain of virus envelope. Reprinted with the permission from [16].

and graphite oxide was analyzed by Ye et al. [24]. This research has opened a huge antiviral tendency of graphene oxide against Pseudorabies infection and porcine pestilence looseness of the bowels infection. He concludes that antiviral characteristics of graphene oxide are ascribed to its adversely charged, high-pitched structure. The graphene oxide formed with PVP, non-ionic polymer demonstrated intense antiviral movement, nonetheless, PDDA (cationic polymer) bound graphene oxide uncovered no infection hindrance, proposing negative charge as an essential for antiviral characteristics. Song and other authors [25] has revealed the graphene oxide based label-free technique to identify and sterilize natural infections, for example, Enterovirus 71 and endemic gastrointestinal avian flu an infection, which have incredible ecological strength and less affectability for carbon-based purifiers and detergents. Redox reactions between the graphene oxide layer and the viruses due to the physico-chemical process will act as an important parameter in destroying the viruses. Under higher temperature environment, the antiviral efficiency of the graphene oxide sheet will be improved. Chen and the co-authors [26] revealed that graphene oxide sheets are accounted for to display critical antiviral restraint possibilities towards covered feline COVID and connecting silver particles into graphene oxide structure widens its antiviral capability in the direction of non-enveloped infectious bursal disease virus. Yang et al. [27] synthesized curcumin stacked β-CD functionalized sulfonated graphene composite and researched its antiviral competence beside negative sense respiratory syncytial infection (RSV). The results demonstrated that GSCC could thwart RSV from tainting the host cells by deactivating the contamination clearly and blocking the association of the disease and have prophylactic and medicinal effects towards the contamination. Du et al. [28] researched the antiviral effect of graphene oxide - Silver nanoparticles composite as an afterthought impacts of porcine regenerative and respiratory problem disease. The outcomes propose that the presentation of infection with graphene oxide -Ag NPs composite block the infection to enter the host cell with a accuracy of 59.2% and advances the creation of IFN-invigorating qualities and interferon-α which hinders the infection expansion. Accordingly, Graphene-based surfaces have enormous probability in the improvement of antiviral surfaces and coatings for keeping fouling from harmful and infectious infections including corona virus, and could control the illness transmission [29]. Especially, for coronavirus infection, structures with higher carboxyl groups and less endurance of this infection on Cu surfaces, graphene oxide/reduced graphene oxide -SO_3 coatings enhanced with Cu nanoparticles/Cu particles could be a inspiring possibility for the advancement of hostile to coronavirus surfaces. These materials are important in successfully catching and destabilizing the infection structures and limiting their endurance time on different covered surfaces [30]. The schematic representation of the viral restriction process from the graphene or graphene derivative based coatings is understandable from **Figure 3**.

Zhong et al. [31] fabricated graphene layer-based superhydrophobic low-melting temperature nonwoven surgical masks through dual-mode laser-induced forward transfer method with excellent self-cleaning and photo thermal property. These functional masks are reusable after sunlight sterilization because the surface temperature can quickly increase to 80 °C under sunlight. In addition, these functional masks show the tendency of salt-rejection, which increases its usage lifetime. The superhydrophobic surgical masks, which are, produced through roll-to-roll production, give efficient protection against viruses. SEM image of pristine surgical mask reveals that the melt-blown fibers of 20 μm were smooth and exhibiting non-super hydrophobic properties. The wetting tendency of this mask is estimated through a static contact angle, which is observed to be 110°, representing a hydrophobic

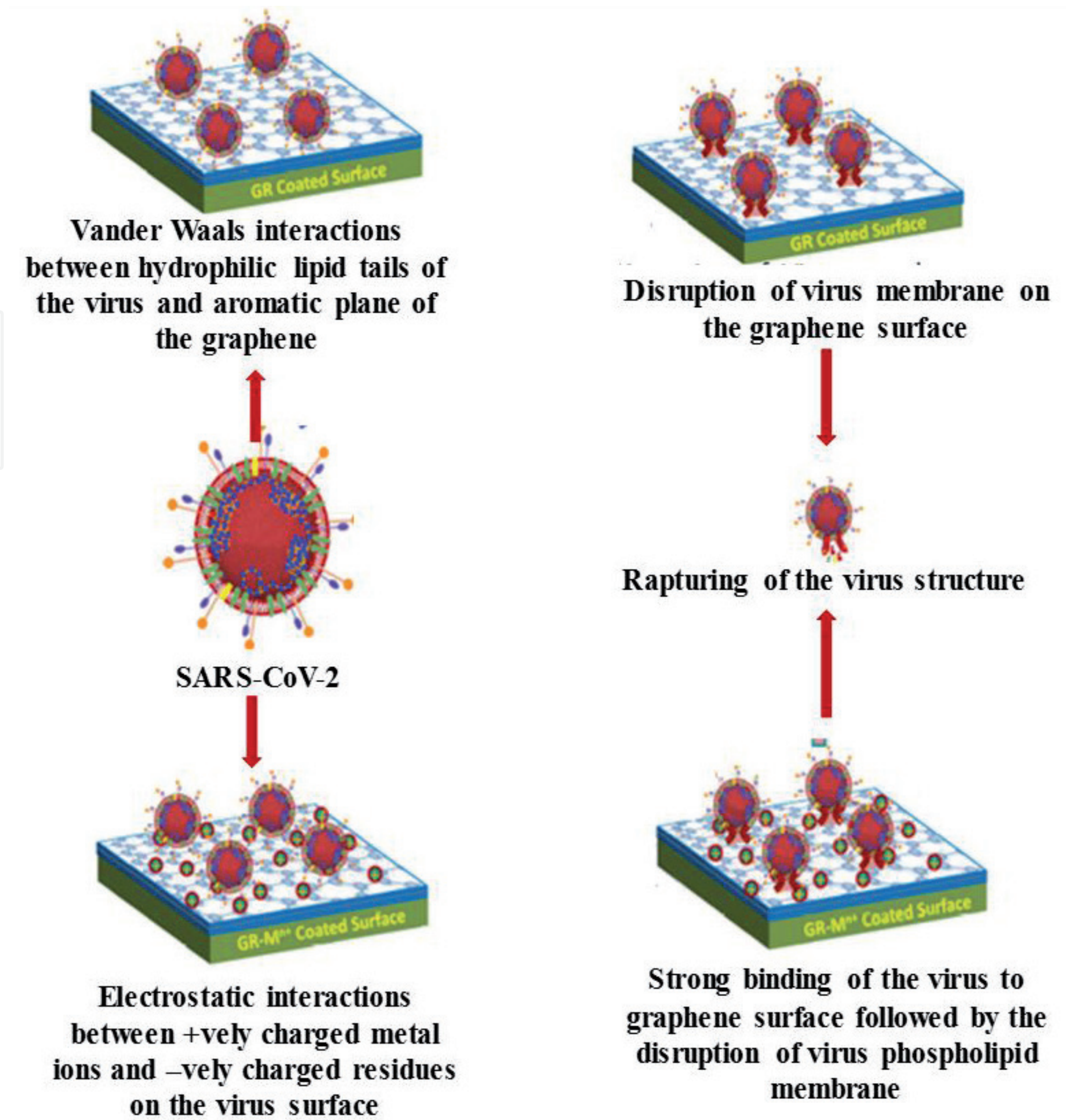

Figure 3.
Sequential representation of the graphene or graphene derivative based coatings in repelling various viruses including coronavirus. Adapted image [30].

surface. The disadvantage observed with this mask is that the droplets are attaching to the surface. After using dual-mode laser-induced forward transfer method, it was observed that nanostructured flakes were seen on the mask surface varying its size from 100 nm to few micrometers and the contact was observed to be 141°, which represents its superhydrophobicity (**Figure 4**).

The multi-layered masks for combatting COVID-19 need to be designed as per World Health Organization guidelines i.e. the innermost layer should behave like a hydrophilic surface and the rest two layers i.e. middle and outside layers are to be in hydrophobic nature. There are several combinations of different materials and fabrics, which have a greater tendency to increase the efficiency of filtration and breathability. As the porosity of the layer increases from the 3rd layer to the 1st layer, the extent of droplet filtration will also increase (**Figure 5**). He also reveals that tightly woven fabric in the third layer will attain 80% particle filtration efficiency and enhances breathability. The filtration effectiveness of any mas depends on the most penetrating particle size, which is in the range of 0.04–0.4 μm. The extent of MPPS filtration varies with the velocity at which filtration is done, fiber porosity & diameter, and particle size distribution [32].

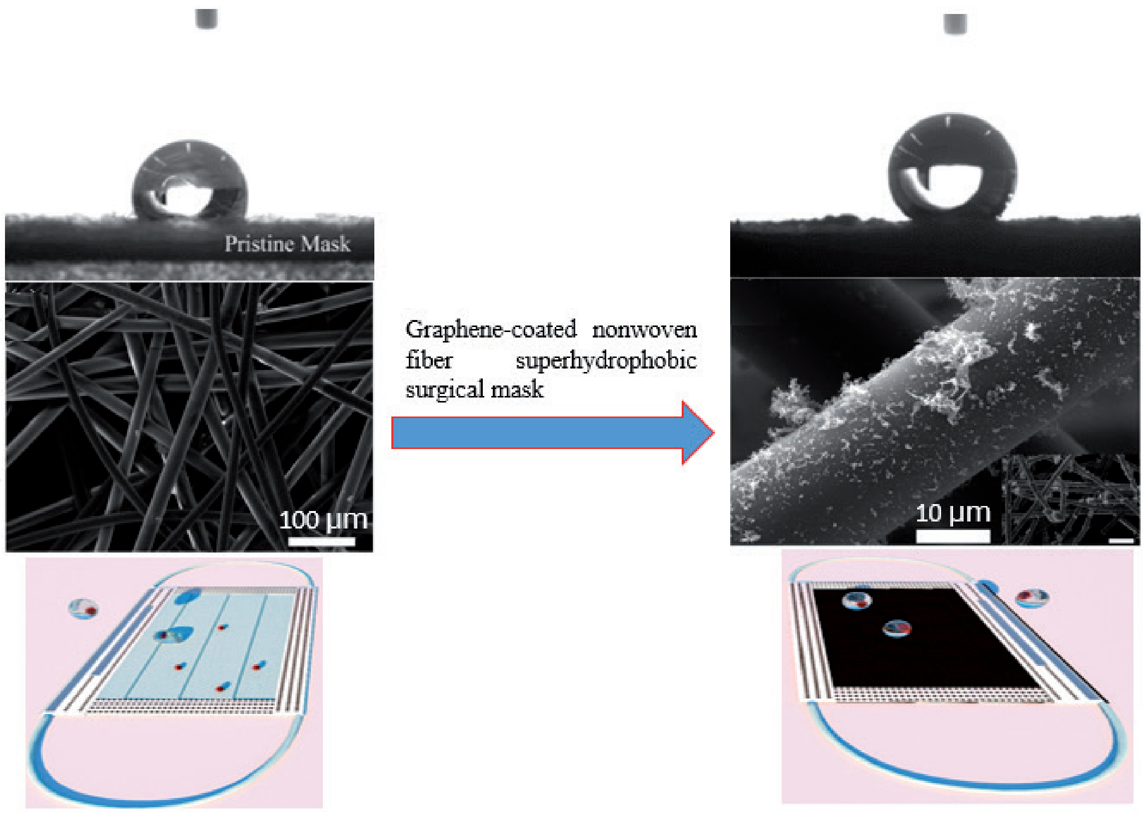

Figure 4.
Contact angle measurement and SEM images on uncoated and coated graphene nonwoven fiber surgical mask Reprinted with the permission from [31].

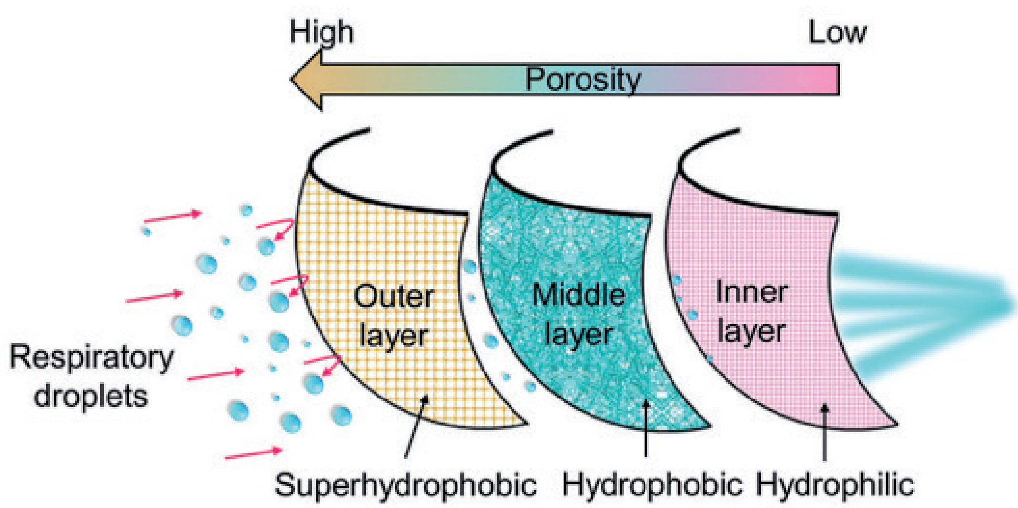

Figure 5.
Multi-layered masks with varying porosity from hydrophilicity to superhydrophobicity. Reprinted with the permission from [32].

4. Cytotoxicity of graphene

Cytotoxicity valuation of nanomaterials is important and beneficial for real understanding of their biological action. The *in-vitro* labeling of therapeutic cells with nanoparticles is becoming more and more common and the possible effects of the nanoparticles on the esthetic cells are increasing. In general, carbon based nanomaterials show specific antiviral activities and low cytotoxicity. It was found that the graphene based nanomedicines made for antiviral treatment have been tested for against a specific virus and these types of antiviral nanomedicines can also enhances the biocompatibility and reduces the cytotoxicity of the drug. The two-dimensional structure and negatively charged surfaces of graphene sheets can easily interact with bacteria and viruses and destroy them by disrupting their plasma membrane. Graphene sheets can also interact with living cells depending on its concentration [33]. Experimental evidences show that the graphene sheets inactivate the virus before it enters the cells and the sharp edges of graphene layers inactivate the infection by actual interruption of the construction through direct association. The antiviral movement of the graphene sheet can be powerful on both DNA and RNA infections, and reliant on fixation and incubation time. The *in-vitro* study shows that the carbon based materials disturb the membrane potential, membrane integrity, metabolic activity and cellular reproduction and they are blamed for DNA damage [34]. Ye et al. [24] reported the antimicrobial and antiviral activity of graphene and its derivatives and its cytotoxicity. In this study, he detailed the antiviral action of graphene oxide against pseudorabies infection and porcine pandemic the runs infection with non-cytotoxic concentration. In this experiment, antiviral activity along with the toxic effect of graphene was measured and it was found that at low concentration level, graphene show non-toxic effect with good antiviral behavior but at higher concentration level, graphene show low toxic effect. These results show that the graphene and its derivatives have low toxicity level compared to other carbon materials and it can be the promising candidate for the next generation antiviral materials.

5. Conclusion

Graphene and graphene derived materials have excellent antimicrobial, antiviral and self-cleaning properties and found application in various industries. Graphene and graphene-based material have recently received enormous attention due to their applicability in tacking lethal SAR-CoV-2 infection. The study suggests that the graphene-based coating on different surfaces tend to neutralize viruses and bacteria, to a varying degree, due to their antiviral and antimicrobial activity. The graphene coated surgical masks could control the transmission of virus and protection from the lethal covid-19 virus. It is to strengthen the research in this field to evaluate the effectiveness of graphene and graphene-based material for their applicability in fighting the Covid-19 virus.

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