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Potential application of biomass derived graphene for COVID-19 pandemic

N.F.T. Arifin [a,b], N. Yusof [a,b,*], N.A.H.M. Nordin [c], J. Jaafar [a,b], A.F. Ismail [a,b], F. Aziz [a,b], W.N.W. Salleh [a,b]

[a] Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia, Johor Bahru, Skudai 81310, Malaysia
[b] School of Chemical and Energy Engineering (SCEE), Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Skudai 81310, Malaysia
[c] Department of Chemical Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar Perak 32610, Malaysia

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ABSTRACT

Since the emergence of the novel coronavirus disease (COVID-19) pandemic, intense research has been carried out to find the effective vaccine. However, this issue remains as a global challenge. Graphene has captured various attention due to promising antimicrobial and antiviral applications, hydrophobic characteristic and superior electrical conductivity. Recently, biomass derived graphene also promises great opportunity to combat the spread COVID-19. In this paper, we demonstrated the ability and role of biomass derived graphene as superhydrophobic coating, biosensors and disinfectant in the fight against COVID-19.

Selection and peer-review under responsibility of the scientific committee of the Regional Congress on Membrane Technology 2020 (RCOM 2020) and Regional Conference Environmental Engineering (RCEnvE 2020).

1. Introduction

Coronavirus disease-2019 (COVID-19) has been a world pandemic since December 2019 caused by the severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) (Fig. 1) [1,2]. To date, the world is still fighting to halt the virus from spreading and the cure is still nowhere in sight [3]. As in July 2020, 13,042,340 has been infected with COVID-19 and 571,689 deaths are reported worldwide [4]. SARS-CoV-2 is a virus strain that possesses a similar characteristic with bat coronavirus. Generally, SARS-CoV-2 is made up of positive-sense single-stranded RNA virus with 50 – 200 nm in diameter [5].

COVID-19 is transmitted by respiratory droplets through mouth and nose [7]. Typically, SAR-CoV-2 has different lifetime on various surfaces. It is reported that SAR-CoV-2 able to survive longer on a smooth surface compared to rough surface. For instance, SAR-CoV-2 can survive up to three days on plastic, two days on stainless steel materials and one day on cardboard. In contrast on surfaces like tissue papers, wood and clothes the SAR-CoV-2 only able to last for about 3 – 2 h [8]. Currently, viral nucleic acid real-time PCR (RT-PCR) method is an effective way to identify active carriers. However, RT-PCR is a slow method that requires an expensive equipment and trained technicians for nasopharyngeal swab analysis [9]. Thus, the current pandemic caused by COVID-19 has urged researchers to find a solution in order to combat the virus from worsen. Graphene and its derivatives were found as promising materials to help deal with the daily challenges posed by COVID-19 and related future diseases [10]. Graphene is the thinnest two-dimensional (2D) atomic material that has immerged as a revolutionary material due to its high specific surface area, superior mechanical, electrical, optical and thermal properties. Due to its unique properties, graphene has been applied in many applications including sensors, biomedical aids and membranes [11]. On top of that, graphene is acknowledged as having superior anti-bacterial and antiviral properties due to the movement of electron towards bacteria which induces cytoplasmic efflux, decreases metabolism, affects lipid membrane, causes oxidative stress, produces reactive oxygen species (ROS) and finally destroys the bacteria [12]. It is claimed that lipid bilayer of feline corona virus is adsorbed on the surface of graphene via hydrogen bonding and electrostatic interactions [13]. Of all the graphene derivatives, graphene oxide (GO) is the most negatively charged material which has higher affinity for positively charged viruses. Eventually, the binding of graphene destroyed the viral membrane and confirmed the effectiveness of graphene against viruses [12,14].

* Corresponding author.
E-mail address: norhaniza@petroleum.utm.my (N. Yusof).

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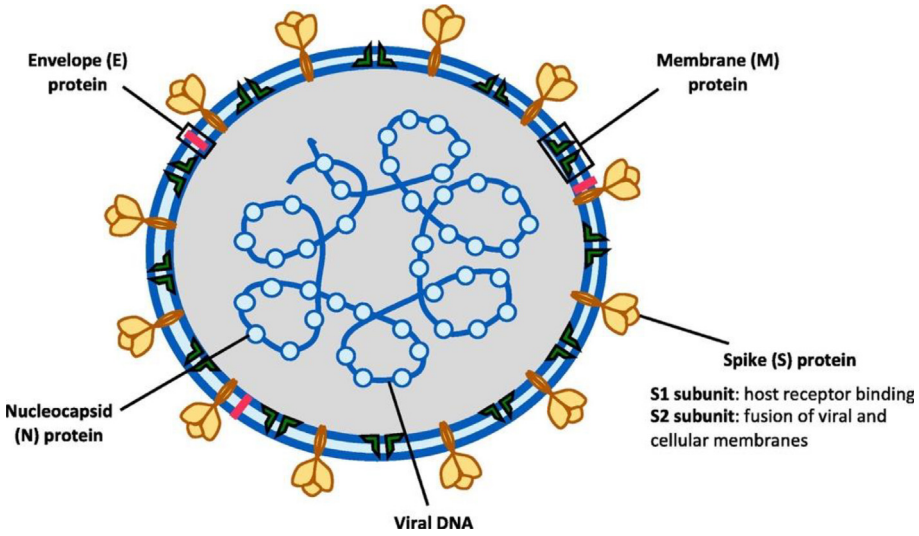

Fig. 1. Illustrations of SARS-CoV-2 (). Adapted from [5]

Currently, a study reported by Palmieri and Papi [14] have shown that graphene can be one of the best materials to combat COVID-19 as it can be used as filters and coatings. However, the synthesize method of graphene is rather complex and expensive. Furthermore, the use of toxic materials and solutions will harm the environment [15]. Nowadays, biomass materials has been used to prepare graphene-like material [16] which include rice husk [17,18], olive stone [19], chitosan [20] and sugarcane bagasse [21]. The biomass derived graphene exhibits similar characteristics with conventional prepared graphene [22] thus, making it as promising material that can also be used to prevent the spread of COVID-19. To further enhance the effectiveness of biomass derived graphene towards corona virus, it can be modified. Instantly, the modification of reduced graphene oxide (rGO) with sulfate derivatives able to destroy herpesvirus strains, swine fever and orthopoxvirus [23]. As illustrated in Fig. 2, it shows that thermally reduced graphene oxide (TRGO) is functionalized with dendritic polyglycerol (dPG) and it was further modified by sulfation to allow a multivalent interaction with viruses. The sulfonation degree and polymer density will affect the interactions between the rGO sulfated derivatives and viruses. The higher the degree of sulfation and the smaller the size, the effectiveness on the herpesvirus is greater [14,24]. Based on this hypothesis, it is clear that the potential use of biomass derived graphene in the application for COVID-19 is promising.

2. Biomass derived graphene as promising material to combat the spread of COVID-19

Kulal and team [25] reported that, graphene derived from sugarcane waste powder exhibits a hydrophobic characteristics. Therefore, graphene is also able to form a superhydrophobic coatings with appropriate nanostructures [26]. Superhydrophobic can be defined as a material that strongly repel aqueous liquids [27]. Superhydrophobic materials can be used on surgical masks to prevent respiration droplets from entering the lungs. Hence, if the potential of biomass derived graphene to form superhydrophobic coating is maximized, it can be beneficial for community in the war against this pandemic. A study conducted by Zhong and coworkers [26] also reported that the graphene-coated masks can be sterilized by exposing them to sunlight for 40–100 s as graphene absorbs more than 95% of light across the solar spectrum of

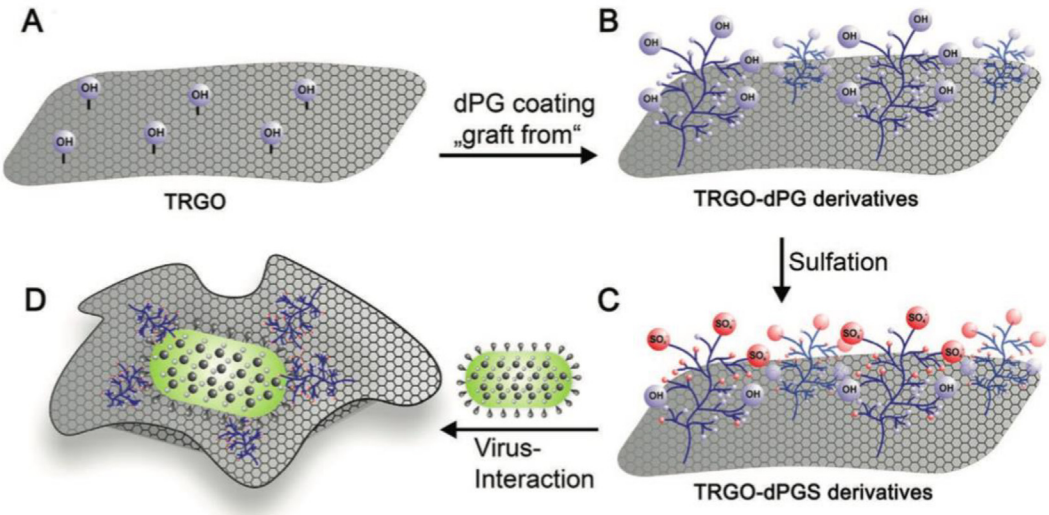

Fig. 2. Schematic representation of (a) thermally reduced graphene oxide (TRGO); (b) polyglycerol functionalized TRGO derivatives (TRGO-dPG) by "grafting from" method; (c) polysulfated dPG-functionalized TRGO derivatives (TRGO-dPGS); (d) interaction of an orthopoxvirus particle with a TRGO-dPGS sheet. (). Adapted from [19]

300–2500 nm. Thus, the coated masks can adsorb heat very fast (reaching 70 °C after 40 s of solar illumination and more than 80 °C after 100 s) [26]. This shows that the graphene-coated masks able to inactivate most type of viruses. As a result, the graphene-coated masks are reusable and reducing waste. Recently, it has been claimed that graphene-based coatings able to destroy the COVID-19. This coating is specifically designed to be used in almost any surface. For instance, it can be coated on doorknob and clinical apparatus. The effectiveness of this graphene-coatings can last up to 60 days where the graphene can destroy the virus as soon as it contacts the coatings [28]. Hence, with the right technique biomass material can be a great source to produce graphene and help in preventing the spread of COVID-19.

Graphene is an established lightweight, chemically stable and conductive material that can be employed for the detection of numerous virus strains. The sensitivity and selectivity of graphene can be emphasized by its functionalization as well as combination with other materials. Acceptable functional groups in the hybrid structure allows tuning of optical and electrical properties, that is appealing for rapid and easy-to-use virus detection [29]. To monitor vitals, diagnose patients and improve the critical care of patients, sensors is widely used in medicine field. The urge for early detection, diagnosis of diseases and minimally invasive detection approaches, various novel sensors have been evolved [30]. For instance, Palmieri and Papi [14] reported that a textile screen-printed biosensor based on a graphene oxide (GO) transduction film is developed in 2018 for the detection of environmental exposure to influenza A virus H1N1. The biosensor is sensitive to influenza proteins. The sensors can be interfaced within clothing, gloves and other textiles to detect if a user has been in contact with the virus [31]. Hence, it is hoped that future research can foresee the development of SARS-CoV-2 sensors for epidemiological control of virus spreading through protective clothing. Besides that, graphene has been used as biosensor chip to detect zika virus in 2018. The results shows that graphene biosensor chip was sensitive towards zika viral nonstructural protein 1 (ZIKV NS1) [32]. The data readout is conducted via the Agile Plus software, which is run on a PC attached to the system via USB (Fig. 3). Since biomass-derived graphene has also been applied widely in electronic, electrical and optical sensors [33], this can be a great opportunity for the materials to be used as a virus detection.

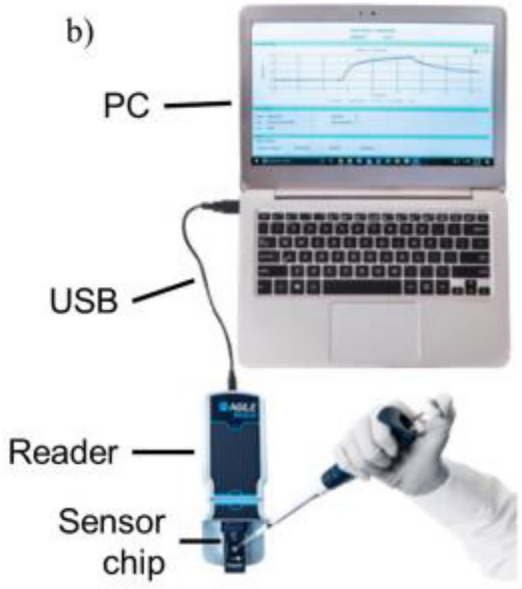

Fig. 3. Illustration of the entire sensor chip system (). Adapted from [27]

In the midst of pandemic, it is vital for the people to take a good care of personal hygiene. Therefore, biomass derived graphene can also be used in disinfectant solutions or detergents. This is due to the fact that graphene has shown positive results as disinfectants in previous study [34]–[36]. For example, GO can destroy bacterial membranes by direct inorganic-biomolecule interactions where the attached proteins on GO always result in altering intrinsic structures and denature effects [37]. To further support the statement, Song and team [38] have shown that the viruses can bind with GO via hydrogen bonding, electrostatic interactions and redox reaction. Furthermore, the presence of oxygenated groups on GO's surface makes the binding of the viruses easier. This interaction is vital for the destruction of viruses particles [38]. Therefore, GO based materials shows a physical toxicity associated with the interaction with cells or tissues [39].With a proper modification technique, biomass materials able to form GO [40] and aid to halt the spread of COVID-19. On top of that, based on aforementioned properties graphene and its derivatives can serve to kill bacteria and viruses. Hence, biomass derived graphene able to serve as an efficient detergents and disinfection of viruses.

Apart from that, graphene can also be applied in textile to fight against COVID-19. Due to the hydrophobic [12] properties possesses by graphene, this material shows a promising characteristic that is good for fabrication of personal protective equipment (PPE). It has been reported that graphene-based material has the ability to destroy viruses when introduced in face mask or PPE. For instance, face mask incorporated graphene able to self-sterilizing, kills the virus and reusable. It is noteworthy that the effectiveness of face mask incorporated graphene against viruses is 99% as compared to N95 face mask [41]. On top of that, a PPE that is layered with biomass-derived graphene able to prevent the transmission of COVID-19 since the material is hydrophobic [12].

3. Limitation and challenges

Although the antiviral properties of graphene has been proven, the immediate use of graphene for treatment of COVID-19 is impractical [14]. This is due to the fact that, the effectiveness of biomass derived graphene towards COVID-19 is yet to be tested. This is crucial to ensure the idealness of biomass derived graphene for various applications in the war against COVID-19 and beneficial for the community.

4. Conclusions

Graphene is a versatile nanomaterial. Thus, the use of biomass derived graphene in preventing COVID-19 should be taken seriously. The biomass derived graphene can be used as superhydrophobic coatings on face masks to prevent any droplets from entering our body. Since graphene has been widely used is sensors, the biomass derived graphene can also be applied in biosensors to detect the presence of COVID-19 in human. On the other hand, biomass derived graphene has a great potential to be used as disinfectant to prevent the spread of the COVID-19.

CRediT authorship contribution statement

N.F.T. Arifin: Conceptualization, Writing - original draft, Resources, Visualization. **N. Yusof:** Supervision, Funding acquisition, Project administration, Writing - review & editing. **N.A.H.M. Nordin:** Supervision. **J. Jaafar:** Funding acquisition. **A.F. Ismail:** Funding acquisition. **F. Aziz:** Funding acquisition. **W.N.W. Salleh:** Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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