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Face Masks Using Nanotechnology

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***Abstract*— In today's times, coronavirus has been one of the biggest challenges to the healthcare community predominantly due to its high infection rate. Researchers have been successful to a great extent in the development of vaccines and understanding the evolution of the harmful virus and its mechanism of action. However, there is always a threat of new variants of the virus coming up. Therefore, it is absolutely essential for us to maintain social distancing along with the mandatory use of face protection. The use of masks is very important in preventing the transmission of the coronavirus. In recent times, nanoparticles having biocidal properties are finding increasing applications in the development of face masks. Nanomaterials have been introduced in to mask-making and various face mask designs have been extensively studied to check the filtration efficiency and breathability in addition to antiviral protection. Apart from that, the possibility of side effects on the skin and lungs as well as the environment is also being analysed. This paper presents an overview of some important properties of nanomaterials and their utilisation in making more efficient facemasks along with presenting the guidelines for using these nanomaterials for making protective equipment for fighting SARS COV-2.**

***Keywords*—**nanotechnology, corona virus, facemask, nanomaterial, SARS- CoV-2.

I. Introduction

Nanotechnology is the study and use of materials in the nano scale. Owing to their small size, these materials exhibit unique physical and chemical properties compared to bulk and can be adapted for use in medicine, environmental remediation, and aerospace. During the pandemic times, face masks became an essential part of our normal living. Nanomaterials are being increasingly used nowadays in developing more efficient face masks. Although face masks are generally intended to protect us from airborne particles, the primary function of face masks during the COVID-19 pandemic was to protect others from droplets and particles inhaled, cough, or sneeze by the wearer of the mask[1-4]. The filter material in masks is always not suitable for all pollutants and pathogens because contaminants in air vary in size. For example, the SARS-CoV-2 virus measures from 60 to 140nm, smaller than bacteria, dust, pollen and other large viruses [5,6].

Nanomaterials have the same size as viral particles and due to their large surface to volume ratio, exhibit physical, chemical, and biological properties that are different from materials of larger sizes. Surface area, melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity are examples of properties that change as a function of particle size [7]. This phenomenon causes selective interactions with biological systems especially with nanosized organisms such as viruses and bacteria [8,9].

Based on filtering efficiency, protective masks can be classified into single-use face mask, respirator mask and surgical mask. Single-use face mask and cloth mask are usually made of a single thin layer which cannot filter out very small particles but they can still block the release of large droplets [10,11].

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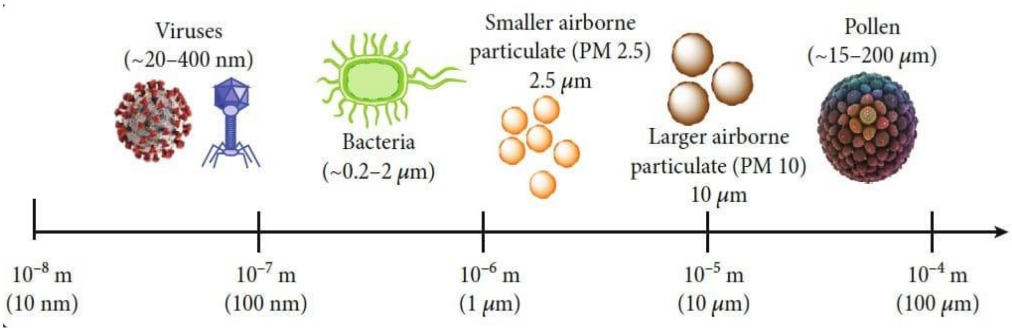

Fig- 1-Relative size chart of common airborne contaminants and pathogens [4].

Respirator masks (N95) that fit properly over the wearer's face has the highest filtering capacity of at least 95% of particles. Respirator masks usually has four layers – a non-woven layer which filters 0.5 µm of particles, an activated carbon layer that filter chemicals and a cotton layer filtering 0.3 µm particles [12].

In the case of a 3-layer surgical mask, the outermost layer is waterproof and repels fluids such as mucosalivary drops. The middle layer prevents particles or pathogens higher than a certain size from penetrating inside[13-15]. The innermost layer is made of materials that can absorb mucosalivary droplets from the user.

II. Nanomaterials for Face Masks

A. Nano Fibres

Electrospun nanofibers (with diameters in the range 50–100 nm) are the most widely used materials for nanoscale filtration. Filtering using nanofiber membranes is essentially done through five mechanisms: interception, inertial impaction, diffusion, gravitational settling and electrostatic attraction [16].

B. Metal Nanoparticles

Metal nanoparticles and their compounds have gained considerable attention as a powerful antimicrobial agent due to their high surface-to-volume ratios compared to their large counterparts. Nanoparticles of silver compounds, copper, titanium dioxide, zinc oxide, and aluminium and aluminium oxide were incorporated into various filters due to their antimicrobial properties [17-18]. The large surface area of nanoparticles allows increased exposure of the active metal or metal oxide surface to bacteria, where the metal ions can penetrate and kill the bacteria.

The four main stages of interaction of these metal nanoparticles showing anti-viral properties include [19]:

1) Nanoparticles get attached to the virus and does not allow it to attach itself to a potential host cell.

2) Air flow will result in partial ionization of the metal nanoparticle layer on the surface. The nanoparticles, on coming in contact with bacteria or viruses, causes the generation of oxygen reactive species by oxidizing the primary material of bacteria or viruses.

3) When contact occurs, metal nanoparticles can adhere to the membrane walls of microorganisms, causing denaturation and deactivation of specific surface proteins by bacteria or viruses, which is subsequently followed by apoptosis.

4) The immune response of the infected cells is activated thereby preventing the spread of the virus.

C. Enhanced Mask Performance Using Nanotechnology

Nanomaterials in face masks that are already available in the market include copper oxide, carbon, graphene, nano silver and titanium oxide. When embedding in textile products, nanomaterials can modify mask fibers and improve filtration efficiency. Polymers used in masks include polypropylene, which does not absorb moisture [20].

Polyester fabrics are made to better maintain a static charge compared to natural fiber or cotton, because polyester woven fabrics are less water resistant or hygroscopic. Copper and silver nanoparticles have been known to have good antibacterial properties however, they can cause significant toxic health and environmental effects, such as immunotoxicity. Zinc oxide is an attractive alternative to these pollutant materials due to its low toxicity and ease of manufacture. Although it is less efficient than silver or copper, zinc oxide nanoparticles still retain antibacterial properties as Zn^{2+} ions released from the surface can penetrate the cell and change its metabolic processes [21].

The physical properties of masks can be varied by using nanomaterials to improve performance. Thermal comfort of face masks is required for healthcare professionals as there is a need for long term use by them. Moist and warm Fig-2- illustrates the function of each individual layer of a 3-layer surgical mask. Conditions will help in the survival of microorganisms and hence optimization of these thermal parameters is essential [22]. The thickness of fibers is an important factor that controls the thermal properties of the face masks. The particle removal efficiency depends on the thickness (better with thick fibers) and air permeability (better with thin fibers). Nanofibers incorporated on to nano porous polyethylene provides a cooling effect and good particle filtration to the mask [22]. Also, adding a silver layer to these materials provides a high infrared reflectance and a warming effect. [23,24].

Filtration efficiency of face masks can be improved if fibers are charged into electrets with quasi- permanent dipoles without adding any mass or density to the structure. Subsequently, high air permeability can be achieved [21]. Barium titanate (BaTiO3) nanomaterials have ability for long-term charge storage and have been used as the ferroelectric inorganic electret to construct filter membranes for electrospinning process [24].

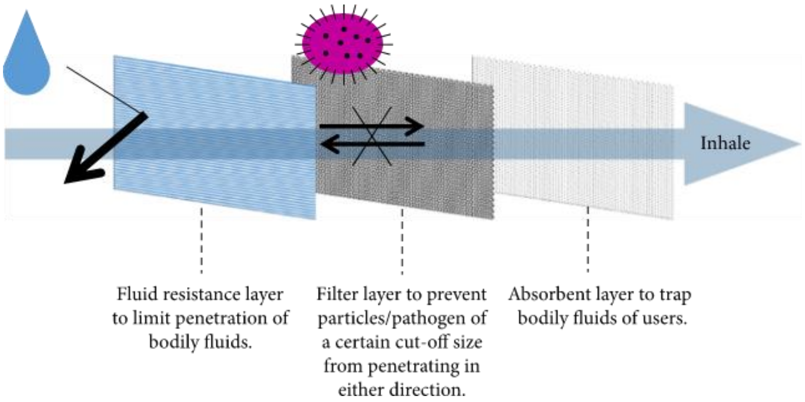

Fig-2- Illustration showing the function of each individual layer of a 3-layer surgical mask.

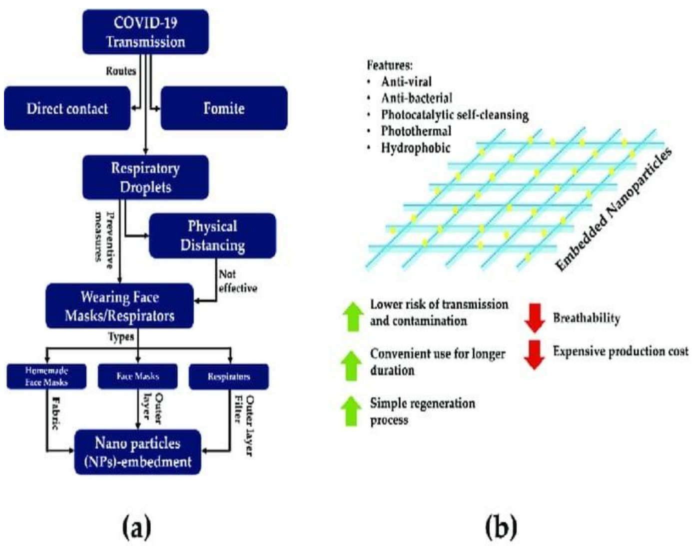

Fig-3- (a) Schematic diagram of the prevention of COVID-19 transmission through nanoparticle technology [17].
(b) Features, strengths (green arrow), and weaknesses (red arrow) of NPs-based face masks or respirators.

Fig-4- A step–by-step guide for interventions and behaviour related to the use of protective equipment based on nanomaterials[17].

III. CONCLUSION

A short review on the use of nanomaterials in enhancing the efficiency of face masks in fighting the Covid 19 virus has been presented in this paper. Several nanofibers, metal and metal oxide nanoparticles as well as polymers have been found to show better particle filtration. The advantages and disadvantages of nanomaterials in prevention of Covid 19 virus has been discussed.

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