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Functionality of nanomaterials and its technological aspects – Used in preventing, diagnosing and treating COVID-19

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ABSTRACT

COVID-19 (Coronavirus) has severely affected the life of human beings since December 2019. Many difficulties are faced by human beings to prevent the spread of the corona virus. However, this unexpected evolution of COVID-19 has also thrown many challenges to scientists and researchers so as to develop technologies that can be used to combat COVID-19. In the effort to combat COVID-19, many research universities and academic laboratories are also contributing by developing many technologies like Facing masks, hand sanitizers, hand washing machines, etc., to control and prevent the spread of COVID-19 disease. The use of Nano-materials is proving to be very effective in prevention, detection and diagnosis of COVID-19. In this paper many such technologies that are used to combat COVID-19 are also discussed. Some of the technologies like the germ trap technology used in face masks and hoods are also discussed. The use of nano-coatings, nano materials like graphene and carbon nano materials is playing a key role in preventing the spread of the virus. Antimicrobial nano-materials like silver nanoparticles are also effectively contributing to preventing the spread of the virus. Nano bio-sensors and gold nanoparticles are used in RT-PCR (Reverse transcription polymerase chain reaction) testing devices which are used for detection of coronavirus. The use of many nano chemicals and compounds has helped in making vaccines and anti-viral drugs that are today showing a way to safeguard human beings against the attack of this deadly virus.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Materials and System Engineering.

1. Introduction

In an effort to combat COVID-19, many functional textiles and Nano-materials are being introduced so that the human-to-human transmission of COVID-19 virus is controlled. Some important technologies are also being developed like the Virustatic shield or the snood with germ trap technology, which can protect the wearer against airborne transmission of the virus. The virustatic shield guarantees 96% and 360° protections to the wearer. Many technologies are also used for developing different kinds of surgical masks, including the use of high-performance fibers and textiles to ensure protection of the wearer from highly infectious corona virus disease. N95 respirators are also being sold on the market. However, due to increased demand from the public, face masks made from functional textile materials are proven to be a good replacement to N95 masks. Most of the personal protective equipment's are made using functional textiles and Nano-materials to provide enhanced comfort and durability to the wearer. The use of light-sensitive semiconductors and protective compounds working on the principle of photo catalysis is also found to be a very effective technology used for controlling the spread of COVID-19 disease. A few of the photosensitive compounds like copper oxide nanocluster, and titanium dioxide when used as a coating compounds are found to be very effective in neutralizing the virus on contaminated surfaces. Apart from hand washing using soap and surfactants, the use of hand sanitizers is practiced regularly to keep oneself safe from the attack of COVID-19 disease. Much alcohol and non-alcohol-based sanitizers are also found to be very effective in killing the COVID-19 virus. Nanotechnology has contributed widely to the control of COVID-19 disease today. The nanotechnologies like the Nano-biosensors, Nano-medicines and other Nano-compounds are very effective in detection, control, treatment and preventing the transmission of the virus. These antiviral polymer coatings are used in many medical appliances, medical instruments, hygienic implement and per-

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sonal protective equipment's. Finally, the contribution of synthetic biology research has started showing effective results by successfully developing m-RNA (Messenger Ribonucleic acid) based vaccines coupled with developing rapid testing devices based on technologies tracing the gene sequence and helping in faster detection, control and preventing the spread of COVID-19 disease ever since it was identified. Table 1 gives the overview of the applications of Nano-materials and their functionality.

2. Utility of functional textiles and nano-materials

2.1. Snood with germ trap technology

The Carrington textile company has developed a snood that can help and prevent the transmission of airborne virus like influenza, SARS (Severe Acute respiratory syndrome) and MERS (Middle East Respiratory Syndrome. The coating provides 96% and 360° protection against the virus. The coating can also prevent airborne droplets which are 15 times smaller in size as compared to human hair. The anti-viral coating material is affected by making the virus inactive as and when the viral droplets come into contact with the fabric. Pincroft the manufacturer also confirms the soft handle properties coupled with its reusability and touching while wearing are characteristic features which distinguish this mask from common face masks available on the market. Fig. 1 shows the snood with germ trap technology face mask developed by Carrington textiles [1,2].

2.2. N95 and other protective face masks

Face Masks are made mandatory to be worn by people in public places as regulated by USFDA (United States Food and Drug Administration) and WHO (World Health Organisation) in many countries. There are many types of face mask available on the market. The filtering face masks are the ones that are preferred by the National Institute for Occupational Safety and Health. This standard face mask is identified by the term N95 (Fig. 2). Here the letter 'N' means "Non-oil" explaining the fact about the absence of oil-based particles. The numerical word 95 indicates the filtration efficiency when exposed to germs. The masks with 99.97 and 100% indicate better quality of face mask which are equivalent to the HEPA (High efficiency particulate air) ones. The masks are also capable of filtering contaminations of 0.3 μm, the viral droplets are larger than 0.3 μm and are recommended by centres for disease control and prevention (CDC) for commercial usage. Electrostatic non-woven polypropylene which is highly hydrophobic is used for making the filter material used in the mask. Many masks also come with exhalation valves to make the users breathe easier. Even surgical masks or masks made from clothes are also quite effective in controlling the transmission of the corona virus even though they have low filtration efficiency as compared to N95 masks. The shortage of supply of N95 masks is met by surgical masks and masks made from fabrics (Figs. 2 and 3) [3–6].

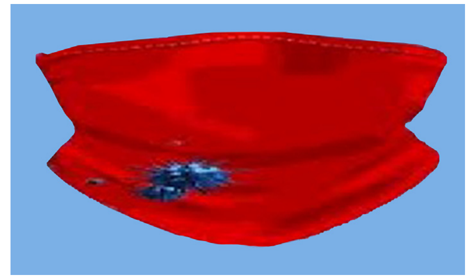

Fig. 1. Snood with germ trap technology.

Fig. 2. N95-Face Mask.

Table 1
Overview of Nano-materials and its functionality.

SL No	Description of Nano-Material	Functionality
1	Silver Nano-particles	Anti-bacterial finishing
2	Fe (Iron) Nano-particles	Conductive magnetic properties, remote heating
3	Zinc Oxide (ZnO) and Titanium di-oxide (Tio_2)	UV protection, fire protection, Oxidative catalysis
4	Titanium di-oxide (Tio_2) and Magnesium oxide (Mgo)	Chemical and biological protective performance, provide self-sterilizing function
5	Silicon di-oxide (Sio_2) and Aluminum oxide (Al_2O_3) Nano particles with Polypropylene (PP) or Polyethylene (PE) coating	Super water repellent finishing
6	Indium-tin oxide Nano-particles	Electromagnetic/Infra-red protective clothing
7	Ceramic Nano-particles	Increasing resistance to abrasion
8	Carbon black Nano-particles	Increasing resistance to abarasion, chemical resistance and impart electrical conductivity, coloration of some textiles
9	Clay Nano-particles	High electrical, Heat and chemical resistance
10	Cellulose Nano-whiskers	Wrinkle resistance and water repellency

2.2.1. Different types of face masks

A face mask is used to control the spread of coronavirus in the public domain. Many countries have made the use of face masks mandatory in public places. Face masks do come with its own advantages and disadvantages. Now-a-days people have adapted a taste to wear face masks that may look good and provide comfort while they are wearing. However, the primary purpose of wearing a face mask is to prevent the entry of viral particles into the human respiratory system. So, the face masks functional properties are an important issue that has to be addressed while selecting and wearing the right kind of face mask. Filtration efficiency, durability aspects, comfort characteristics, skin-friendly properties are a few important issues that a face mask manufacturer should consider before manufacturing the face mask.

2.2.2. Filtration efficiency of different face masks

Filtration efficiency is defined as the ratio of the concentration of particles filtered to the concentration of particles recorded in a particular environment. In face masks many technical parameters play a key role in improving the filtration efficiency. COVID-19 viral particles travel in droplets, and there is a need for further study to explore stream of movement and the kinetic energy that these viral particles possess. However, Adanur et al. in their research on face masks has listed a few important technical parameters like particle size, intercepting fiber surface, Initial deposition behaviour, diffusion (dracys law), electrostatic forces in the particles, gravitational forces, air porosity and the pore characteristics of the fabrics influence the viral particle movement. Even though many universities and technical laboratories are conducting community-based projects and testing them to determine its filtration and breathability levels, one notable research that is reported [17] is the work carried out by Kennedy et al. using TSI particle size testing instruments. They have released the test data on the filtration efficiency as shown in Table 2. The data clearly show that N95 is the most affordable and acceptable type of face mask of daily usage in this pandemic period due to its 95% filtration efficiency. However, the dust mask and cloth face masks show only 55% and 38% filtration efficiency. The number of layers and type of fabric being used for making the face mask plays a crucial role in determining its filtration efficiency. Surgical masks offer a filtration efficiency of 85%. When a face mask is designed using one layer filter and one layer 6.5 gm cotton rip stop fabric, the filtration efficiency of a cloth mask increases to 84%. From the above discussion, it is possible to develop face masks with higher filtration efficiency using a combination of cloth and filter materials. Air purifying-based respirators offer higher filtration levels that are equivalent to N95 face masks. However, the difficulty to carry these face masks and their price may be the main reason for its less popularity in the public domain.

2.2.3. Face masks advantages and disadvantages

Face masks prevent the spread of a coronavirus from one individual to another by preventing the viral particles from entering the human respiratory system. Since many cases are found to be present in people who do not show any kind of symptoms of infection, the use of face masks helps with preventing the spread of the virus from unknown sources. Face mask wearing has now become a sense of social responsibility of the citizen to reduce the risk of infection for everybody. Face masks break the chain of transmission and help in the greater decline of the COVID-19 infection rates. The proper use of a face mask will enable the reduction of lock down periods and thus help people to carry out normal day-to-day activities and enable economic recovery. Vaccination programs can be effective if wearing a face mask, using hand sanitizers and practicing social distancing is followed by people everywhere. Likewise, there are numerous advantages rather than disadvantages of wearing a face mask. Even though wearing a face mask is the cheapest and easiest method of preventing the spread of COVID-19 at public places, there are many face masks lacking the basic qualities and failing to meet the minimum requirements. Wearing low quality face mask with low filtration efficiency will not serve the purpose of breaking the chain of transmission. Improper habits and lacking discipline in the use of a face mask will increase the infection rate rather than reducing it. There are also numerous skin-related problems and breathing obstructions faced by people wearing face masks due to pre-existing co-morbidities present in the wearer. Further, health hazards faced with wearing face masks are discussed in the next topic.

Table 2
Different face masks and filtration efficiency.

SL No	Type of Mask	Filtration Efficiency %
1	N95 Face Mask	95
2	Dust Mask	55
3	Surgical Mask	83–85
4	Cloth Face Mask (Depending on the number of layers)	38
5	Half face respirator	95–99
6	Powered Air purifying respirator	94–95
7	One layer filter + one layer 6.5 g cotton rip stop fabric	84.03
8	Two layers 100% cotton + one layer filter furnace paper	80.85

2.2.4. Health hazards due to prolonged use of face masks

Face masks like N95 are very closely and tightly worn on the face. This usually results in scars at the place of wearing, create respiratory problems and body temperature varies. In many instances, skin rashes, acne, headaches and cognition impairment are also reported. At work places, wearing face masks has resulted in reduced productivity and work efficiency. Due to increased accumulation of Co_2 due to low level of oxygen circulation, in many cases the symptoms of hypoxemia are also seen.

2.3. PPE enabled by nanotechnology and filter systems

SARS-CoV-2 is found to infect the surroundings through aerosols and circulation within a distance of 2 m. The use of face-masks has considerably reduced the infection rate in many countries. PPE (Personal Protective equipment) made using fabric is commonly used in hospitals and other sterile work places. The use of natural materials like cotton, silk and chiffon has enhanced the prospects for making a biodegradable PPE, material that can replace the use of huge plastic resources. The cellulosic fibers can be coated or treated with Nano-materials to make them functional and act as an anti-microbial barrier. Many have also reviewed the application of graphene (Fig. 4) as a coating material which can enhance the mechanical property as well as the antimicrobial property of the PPE. Graphene has also fired resistant, UV (Ultra violet) protective and conductive to textiles. Graphene is light weight and can be applied over both woven and non-woven fabric structures which are primarily used for making PPEs (Fig. 4) [2,3].

In public places the ventilation systems are widely used. In ambulances, aircraft cabins, commercial buildings, hospitals, homes and cars, the usage of ventilation systems is mandatory. However, these ventilation systems pose a serious threat to users due to the accumulation and spreading of the virus whose size is about 50–130 nm, eventually leading to respiratory disorders. The use of graphene based and activated carbon granulated powder or fibers as air filters can ensure the adsorption of bacterial and virus particles coupled with the biocidal silver (Ag) and CuO (Copper oxide) Nano particles will increase the filtration efficiency and ensure safety of the users against these viral attacks. Some of the metal nanoparticles and their oxides (such as Cu, Cu, Ag, Zn, ZnO, etc.) Are also quite advantages when used in filter systems.

2.4. Antiviral semi-conductors and protective compounds

The photosensitising (PS) and inorganic semi-conducting nanoparticles are compounds that are used to fight against viral infections as they are capable of producing virucidal radicals when they are activated in the presence of light. This process is known as Photodynamic inhibition (PDI). The light interaction kills the viral components like proteins, membrane and, in some case, damages the DNA/RNA component of the virus. The use of organic photosensitizers like Methylene blue (MB) and other coloured organic dyes coupled with inorganic nanoparticles like Gold (Au), silica and titanium di-oxide are found to be very effective in killing the virus, germs, fungi and bacteria. Fig. 5 shows the working principle of a doped semiconductor action in killing the germs when used in an indoor light device. VOC stands for volatile organic compound, VB stands for Valance band, ICFT stands for interfacial charge transfer, and CB stands for conduction band (Fig. 5) [4,5,16].

Fig 3. Different types of face masks.

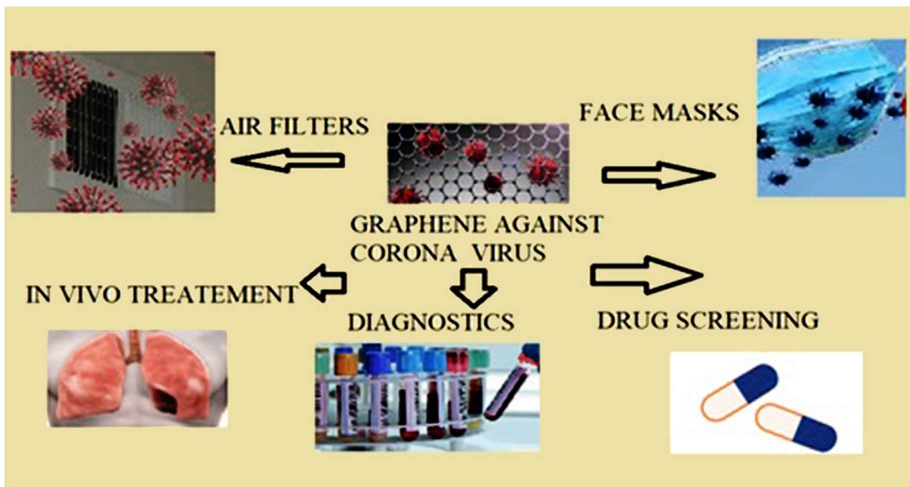

Fig 4. Application of graphene Nano-Materials in Personal Protective Equipment and Filter systems.

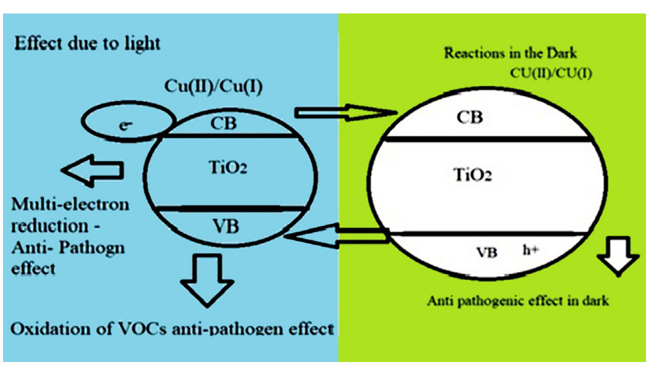

Fig 5. Application of Semi-conductors and photoactive compounds in Indoor light device.

2.5. Interaction of viral particles with carbon-based materials

Carbon-based nanoparticles are very effective in removal of germs and viral particles in water, air and on surfaces where coronavirus is found to be present. When the viral particles interact with the surface charges of carbon nano materials, the viral particles are inhibited from its further activity and results in protection against viral attack. These carbon nanoparticles like carbon dots are modified to increase their action against their viral attack. The functionalities in metal nanoparticles are due to the presence of functional groups like carboxylic acid, location and hydroxyls on the polymer surface aid the inactivation process of the viral particles. Some of the carbon nanoparticles like carbon dots, single walled and multi-wall carbon nanotubes, and Nano diamonds are found to have shown virucidal activity. Activated carbon nano materials, due to their Nano pores and hydrophobic interaction on the viral surface, show an elevated capacity to entrap the viral particles. Due to this, the activated carbon materials are used in water purification, adsorption process and filtration of liquids and air for screening and elimination of deadly pathogens including viruses. The use of carbon dots is found to be very useful in preventing the multiplication of viral particles on the surfaces. The carbon dots interfere and damage the replication cycle of the virus at both DNA (Deoxy ribonucleic acid) and RNA levels. The use of Nano diamonds is also found to introduce functional groups like boron, which can inhibit the replication of SARS-CoV-2 virus (Fig. 6).

2.6. Hand sanitizers

A supplement to hand washing is the use of hand sanitizers at regular intervals to control the transmission of the virus when touched any unknown object or surfaces. Hand sanitizers can also be made using natural medicinal plants like turmeric, garlic, wild spinach with the addition of organic compounds like camphor by grinding them and doing ethanolic extracts in the laboratories. These extracts are then combined with absolute ethanol and glycerine to obtain the final hand sanitizer. The mixture of wild spinach and camphor is found to be successful in making a good hand sanitizer. Hand sanitizers are very effective in controlling the spread of virus and bacteria. Their effective range depends on the strength of alcohol being used. The strength of the alcohol varies from 62% to 95%, which is primarily responsible for elimination of bacteria and

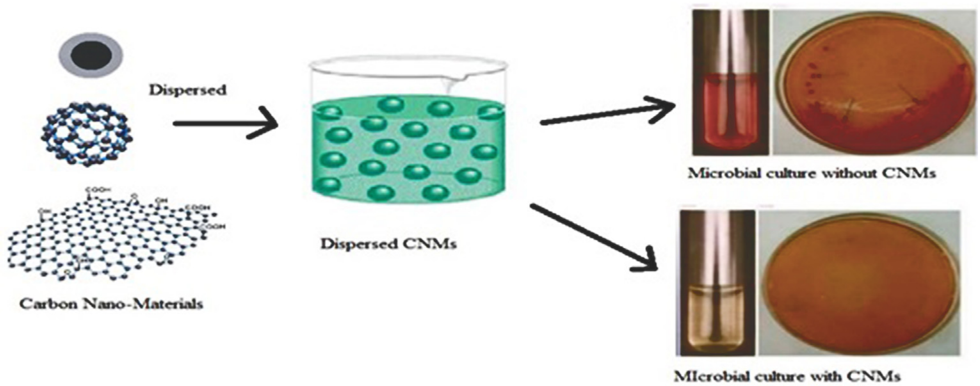

Fig. 6. Viral particles interaction with Carbon Nano Materials (CNMs).

virus. Hand sanitizers come in different ranges like the non-alcohol ones, which are made from benzalkonium chloride or an aromatic chlorinated compound like triclosan [8–12].

Hand sanitizers are classified into two categories like the alcohol-based or the alcohol-free ones. Alcohol based sanitizers have a composition of 60%–70% concentration of Isopropyl alcohol as per USFDA standards. The effectiveness of these hand sanitizers doesn't only depend on the alcohol concentration, but also the use of antimicrobial agents, which act on the microbes. Metal oxide compounds are used as non-bio-based antimicrobial agents. Some of the metal-oxides based compounds are Neosporin, tetracycline and muprocin that are used along with alcohol at the time of making the sanitizer. In bio-based based antimicrobial agents, compounds with low molecular weight like turbines, bacteriocins, fatty acids (lipids) peptides and other organic acids are used for making hand sanitizers. Chitosan is one of the most prominently used bio-based antimicrobial agents due to its nontoxicity and biodegradability properties. Ethanol or Isopropyl alcohol is found to be very effective in killing the virus when the concentration is above 50%, with a 1-minute time to act on the germs.

Alcohol-based hand sanitizers are effective today due to improper hand washing practice in public and low compliance with the use of handwash in public places by people. Many regulatory boards and advisory agencies are now insisting on using both hand sanitizers and hand washing devices at their work places. However, alcohol-based hand sanitizers have a residual activity of 1–2 min due to its quick drying rate. In most of the cases, the virus may again take shelter after 2 min of hand wash. Organic acids like males and citric acid increases the residual activity for 4 h (Fig. 7) [7–12].

2.7. Nano materials used for diagnosis and prevention of COVID-19

Nano materials have today been integrated in the development of many modern technologies that are used to develop diagnostic and prevention devices used for combating COVID-19. Nanomaterials are also used in research connected with Nano-biosensors, Nano medicines, Nano compounds used to develop detection devices, drugs and prevention medicines like vaccines used in treating and controlling the spread of corona virus disease. The SARS-Cov-2 virus is characterized by a Nano-sized stranded ribonucleic acid, which is encapsulated in a nucleocapsid shell made of protein and covered by a 3-structural protein namely and envelop protein, glycoprotein membrane and a nucleocapsid protein. The outer layer is covered by a lipid membrane which is highly susceptible to soap molecules. The nucleocapsid protein is damaged by subjecting to UV exposure, desiccation and chemical treatments with acids, alcohols and surfactants. The spike protein present on the outer surface is easily attached by nanoparticles,

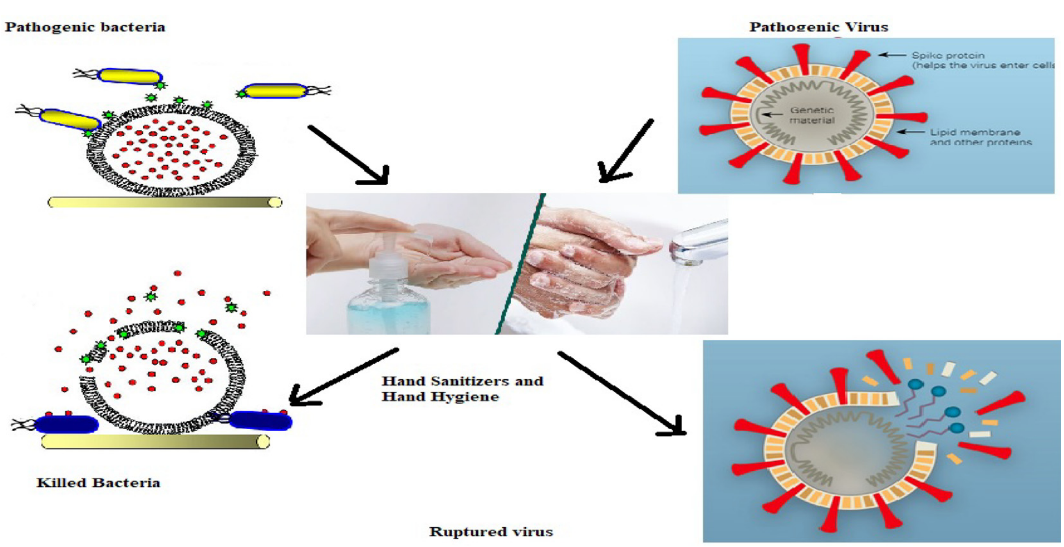

Fig 7. Action of Hand Sanitizers in killing the virus and other pathogens.

which are used in the form of drugs, coatings for protection and Nano medicines in the form of vaccines [13].

Initially, when COVID-19 virus was detected, scientists used identification techniques like computed tomography, electron imaging and genome sequencing procedures which were time-consuming and took long periods to report the infected patients. Subsequently, with the introduction of nanotechnology, many diagnostic tools and RT-PCR passed testing devices were developed which could detect the infected ones by drawing samples of their nasal swab, blood, stool and serum of the infected people. We made these diagnostic devices on the working principle of Nano-biosensors and nanotechnology. These RDT (Rapid diagnostic tests) reported the results within 30 min and helped to prevent further spread of the disease through undetected people. The RDT devices worked on the principle of detecting either the antibody presence in the blood or by measuring the response of the respiratory tract to the antigen. Due to these limitations of identification at a specific stage of infection, the results were inaccurate and the test sensitivity values ranged from 30 to 80%.

The more accurate and direct detection devices came up using the principle of detecting the protein or RNA of the COVID-19 virus. The Rapid diagnostic kit made use of an RNA from an infected patient and the device with the use of iron oxide and gold nanoparticles has contributed in controlling the spread of the disease. The test kit identifies the presence of immunoglobulin G and M (IgG and IgM) antibodies in the infected samples, where the device uses the concept of surface Plasmon resonance property of God nanoparticles which change when they interact with DNA and RNA of the infected person. The RDT devices also use the plasmonic photo thermal effect to identify the infected DNA and RNA. The advanced version device was developed by the Massachusetts Institute of Technology (MIT) using heat produced by the thermo-plasmonic heat and the surface plasmonic resonance property of gold nanoparticles [5]. Magnetic nanoparticles like iron oxides are also being developed and used for rapid detection of COVID-19 virus. Iron-oxide nanoparticles are also used with a coating with silica, which breaks the virus and attaches RNA to the magnetic nanoparticles, thus enabling a faster and efficient way of analysing and infected sample. A graphene-based 2-D detection kit has also been reported which can detect the virus in less than one minute. The graphene-based bio-sensor attaches to the antibody of COVID-19 by detecting the variations in electrical current in the samples.

2.8. Antiviral polymer coatings

N, N-dodecyl methyl-polyethylenimine (PEI) when coated on textile substrates has shown to kill the bacteria by damaging the cell membranes of the virus. The poly-cationic chains are responsible for deactivation of the viral protein and rupturing the lipid membrane. The anti-viral coating materials are classified into different groups based on their composition and function. Antiviral polymers, functional nano-materials and metal oxide/ions are, the more commonly used materials used in textile and other material surface coatings. These coatings find multipurpose applications like medical instrument and appliance coating, coating the PPE, hygienic implements, etc. Antiviral coatings are applied by modifying the substrate surface and depositing a thin film over the substrate surface and induce the antiviral activity (Fig. 8) [4,13].

2.8.1. The antiviral activity of gold sphere nanoparticles used as polymer coating

Metals like Au, Ag, Cu are a few nano-materials that are used in coating textile substrates and other metal substrates to impart antiviral activity on the surface. In surgery or examination gloves the inner coating is made anti-infective using chlorohexidine and other lubricating agents. Povidone-iodine (PVP-I) and nonoxynol-9 (N-9) is also used as an anti-pathogenic agent. Hydrophilic polymers containing hydrocarbon chains and quaternary ammonium groups are used as anti-viral agents. In most of the cases, the coating substances with superior water repelling properties are used as anti-viral coating agents. The concept of super hydrophobicity works well in these circumstances. Polymer coating solutions are used along with nanoparticles to functionalise the substrate surface. The virus, when it comes in contact with the surface undergoes chemical reactions between the viral molecules and functional molecules. V Lysenko et al (2018) has reported their results of anti-viral activity (Table 3). Their main idea was to evaluate the anti-adenoviral activity of gold nanoparticles.

The mechanism involves the adsorption of gold nanoparticles to the viral surface (Fig. 9). A few problems of toxicity of the cells are also discussed in their paper. In their study, they use 2 types of Au nanoparticles. Type 'a' is a sample of Au nanoparticle covered with Sio_2 shell and Type 'b' is an Au nanoparticle on sio_2 nanoparticle. Adenovirus was used in their study to determine the viral activity. Human adenovirus was developed in their lab, which is a double-stranded DNA genome. They synthesized nanoparticles using different methods like soil-gel transformation process for Type (a) and Type (b) by a polycondensation process (Fig. 9).

More details of the synthesis process can be obtained from their experimental work [4]. The Table 3 shows anti-adenoviral activity of gold nanoparticles that was developed by two methods. The Fig. 10 shows the change in anti-viral activity and comparison of the anti-adenoviral activity. In their study, they report that type-b samples showed higher level of anti-viral activity, even though both the samples showed satisfactory anti-adenoviral activity.

2.9. Technologies used in fighting COVID-19

Many organizations have started developing and transferring technologies in order to combat COVID-19. Many technologies, namely, face mask making machines, hand washing devices, sanitizers, bed, etc. Are being developed continuously to meet the demand of the public. In this section we discuss the working prin-

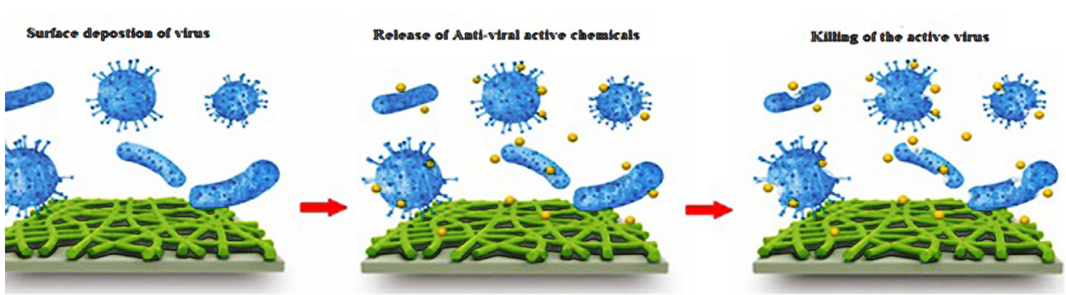

Fig. 8. Action of Anti-viral polymer coating.

Table 3
Anti-Adenoviral activity of gold nanoparticles.

Concentration of Nano-particles	Anti-Adenoviral activity(%)	
	A-type	B-Type
1×10^{-2}	85	100
1×10^{-3}	96	100
1×10^{-4}	82	100
1×10^{-5}	65	95
1×10^{-6}	55	90

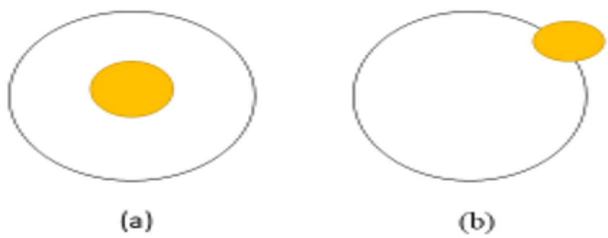

Fig 9. Placement positions of gold nanoparticles.

ciple and mechanisms of a few technologies used in combating COVID-19 [14,15].

2.9.1. Face-mask manufacturing machines

Face Mask Manufacturing machines are usually of continuous range having one feeder unit. The capacity of the machines ranges above 100 masks per minute. The machine has a titanium head-stock which prevents electrical accidents and is also composed of pneumatic components to aid the hands-free manufacturing process. The machine is robust and contains stainless steel part which helps in improving durability and preventing machine stoppages. There is also integrated camera control and a packing unit. Some of the machinery units are also equipped with an automatic inspection system.

2.9.2. Hand washing devices

Experts have suggested wearing a face mask is not only the only option to break the chain of transmission of COVID-19. So, hand washing with soap is also suggested, coupled with social distancing is the norm and protocol of COVID-19 today. Hand washing along with soap will reduce the spread of the disease and infect the respiratory infections. Many hands-washing stations are installed in public places to reduce the spread rate of COVID-19. These places are technically called handwashing stations. These handwashing stations contain water supply, soap solution, and a tap for fresh water. Different types of hand washing devices are available for public usage. Mechanically operated and sensor-based hand washing devices are also available today. There are also other technologies like sanitizer sprayers, UV light disinfectants, robotic automation at many public places, telehealth systems, contact tracing software, etc. Which are very effectively helping to flatten the COVID-19 curve. The working principle and technical concepts involved in these technologies require a different approach and are limited at this point of discussion. In many countries' health bodies are promoting the concept of proper hygiene of the hand, and they are assisted by health workers who are educated to help people and provide hand washing devices at public entry points so as to change the behavior and create awareness of cutting the chain of transmission

2.10. Role of synthetic biology

Synthetic biology deals with the bio-engineering and design of solutions and biological systems based on molecular and genetic oriented biological data. The research in synthetic biology makes use of automated and computer-assisted design and tools to model the biochemical synthesis and behaviour of biological molecules. Synthetic biology has also contributed to the development of anti-viral drugs and vaccines, which are also based on nano-material. The research on the DNA and RNA sequence of synthetic biology experts has shown the way to develop vaccines based on DNA and mRNA, which are proven to be safe and easy to produce in the labs. These vaccines are made from strands of synthetic nucleotide which triggers the production of proteins in the cells. Many companies like Moderna, Inbovio, etc. Are benefited by the viral sequence that was tapped by synthetic biologists all around the world. Certain antigen-carrying nanoparticles are also being made by antigen-carrying nanoparticles. These nanoparticles help in successfully triggering the immunity in human beings [15].

3. Conclusion

In the efforts to combat covid-19, the efforts are being put to develop innovative and newer functional materials which can detect, treat and prevent the transmission of coronavirus. The development of snood with germ trap technology is highly successful and many variations in masks and N95 protective gear have already been introduced by technologists. The developments in nanotechnology and its contribution to control the spread of COVID-19 is highly commendable. Protective personal equipment

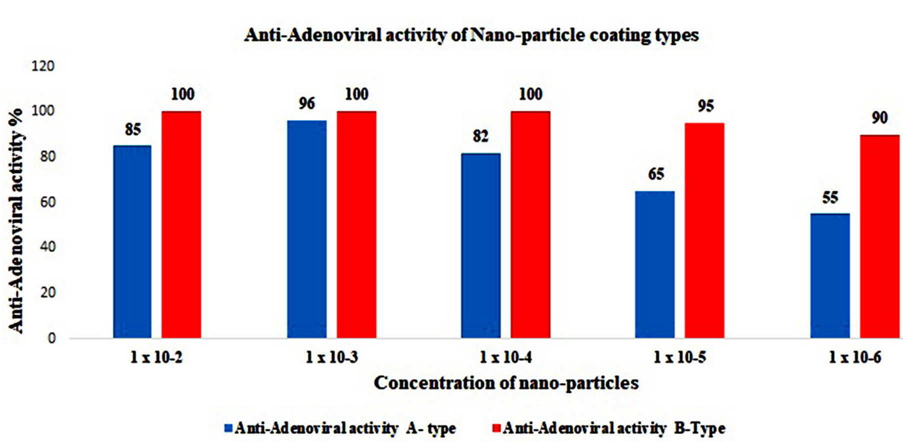

Fig. 10. Graphical plot of anti-adenoviral activity of Au Nanoparticles.

made using nanotechnology are very useful and have contributed widely in preventing the spread of COVID-19 disease. Use of high-end materials like anti-viral semiconductors, photo-active compounds and carbon-based materials has contributed to develop detection and prevention of COVID-19 virus. The role of anti-viral polymer coatings and the Nano-bio-sensor based detection devices has considerably reduced the risk and time in controlling and identifying the coronavirus using DNA and RNA extract of the infected specimens. The discussion of technical parameters of face mask, technology devices like hand washing devices forms a very important tool to control the spread of COVID-19.

CRediT authorship contribution statement

Gurumurthy B. Ramaiah: Conceptualization, Methodology, Software, Data curation, Writing - original draft, Visualization, Investigation, Supervision, Software, Validation, Writing - review & editing. **Asmamaw Tegegne:** . **Bahiru Melese:** .

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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