Title: Customized and Reusable Antimicrobial/Antiviral 3D Printed Respirator
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Brief Description:

Surgical masks and N95 respirators are examples of Personal Protective Equipment (PPE) that are used to protect the individual wearing it from airborne particles and from liquid contaminating the airways. While a surgical mask may be effective in blocking splashes and large-particle droplets, a surgical mask does not filter or block very small particles in the air that may be transmitted by coughs, sneezes, or certain medical procedures. Surgical masks also do not provide complete protection from germs and other contaminants because of the loose fit between the surface of the mask and face reduce the wearer's exposure to airborne particles, from small particle to large droplets.

Furthermore, to safely discard used masks the Centers for Disease Control and Prevention (CDC) recommends placing these items in a plastic bag and put it in the trash, then wash your hands after handling the used mask. Facemasks are a single used item with no inherit antimicrobial properties. N95 respirators, on the other hand, are tight-fitting respirators that filter out at least 95% of particles in the air, including large and small particles. N95 respirators are respiratory protective device designed to achieve a very close facial fit and very efficient filtration of airborne particles. The "N95" designation means that when subjected to testing, the respirator blocks at least 95 percent of very small (0.3 micron) test particles. If properly fitted, the filtration capabilities of N95 respirators exceed those of surgical masks. However, even a properly fitted N95 respirator does not completely eliminate the risk of illness due to face and respiration contamination by manual adjustments to the respirator.

Furthermore, single-use respirators are expensive, pollute the environment, can make breathing difficult reducing lung capacity. Due to the low customization and manual adjustments for adjustments increasing the risk of contamination of current respirators, these devices are not recommended for everyone, including children. We propose a customizable, reusable, recyclable, modular, antimicrobial and antiviral 3D printed respirator. To accomplish this goal, our respirator will include

1. The use of a material containing a copper nanocomposite that has antimicrobial activity and is capable of deactivate viruses,

2. A flat pattern for easy transport,
3. Thermoforming capabilities (glass transition) at 55° C to allow the use of hair dryers or warm water,
4. Customizable using an adjustable nose and chin folding,
5. Reusable after washing it with running water,
6. A recyclable material,
7. A modular fine particle filtration and viral deactivation system,
8. A modular filtration disc that can modulate the level of filtration and air intake.

Background

Surgical masks and N95 respirators are examples of Personal Protective Equipment (PPE) that are used to protect the individual wearing it from airborne particles and from liquid contaminating the airways. While a surgical mask may be effective in blocking splashes and large-particle droplets, a surgical mask does not filter or block very small particles in the air that may be transmitted by coughs, sneezes, or certain medical procedures. Surgical masks also do not provide complete protection from germs and other contaminants because of the loose fit between the surface of the mask and face reduce the wearer's exposure to airborne particles, from small particle to large droplets.

Furthermore, to safely discard used masks the Centers for Disease Control and Prevention (CDC) recommends placing these items it in a plastic bag and put it in the trash, then wash your hands after handling the used mask. Facemasks are a single-use item with no inherit antimicrobial properties. N95 respirators, on the other hand, are tight-fitting respirators that filter out at least 95% of particles in the air, including large and small particles. N95 respirators are respiratory protective device designed to achieve a very close facial fit and very efficient filtration of airborne particles. The "N95" designation means that when subjected to testing, the respirator blocks at least 95 percent of very small (0.3 micron) test particles. If properly fitted, the filtration capabilities of N95 respirators exceed those of surgical masks. However, even a properly fitted N95 respirator does not completely eliminate the risk of illness due to face and respiration contamination by manual adjustments to the respirator.

Furthermore, single-use respirators are expensive, can make breathing difficult, and have shown to reduce lung capacity. Due to the low customization and manual adjustments for increasing the risk of contamination of current respirators, these devices are not recommended for children.

According to the World Health Organization (WHO), the 2019 pandemic until March 2020 have killed 7,019 people with cases reported in 152 countries. Extraordinary public health measures have been implemented around the globe to help reduce virus spreading and reduce the rate of transmission. Nevertheless, recent investigations have found novel and effective ways of decreasing the risk of infection, such as the use of copper. Copper has been used in clinical settings to reduce the risk of bacterial and viral contamination, complementing traditional protocols. Furthermore, the addition of copper nanoparticles to polymer/plastic matrices can also produce highly effective antimicrobial materials. Studies have shown that copper destroys the replication and propagation abilities of SARS-CoV, MERS-CoV and other respiratory viruses, having a high potential of air-disinfection in hospitals, communities, and households. Copper and copper alloy can also eliminate pathogenic organisms such as bacterial strains, coronavirus, influenza virus, HIV, and fungi after a short period of exposure. Thus, the addition of copper nanocomposites to a polymer base has been proposed as an effective and low-cost complementary strategy to help reducing transmission of several infectious diseases such as the coronavirus by limiting nosocomial infectious transmission, as well as reducing surface transmission in non-clinical settings. Additionally, copper oxide or nano-compounds may be used as filters, face masks, clothing and hospital common use devices to reduce viruses and bacterial incubation. Thus, we propose a customizable, reusable, recyclable, modular, antimicrobial and antiviral 3D printed respirator.

In summary, our Customized and Reusable Antimicrobial/Antiviral 3D Printed Respirator will incorporate:

1. The use of a material containing a copper nanocomposite that is antimicrobial and capable of deactivate viruses,
2. A flat pattern for easy and efficient transport,
3. Thermoforming capabilities (glass transition) at 55° C to allow the use of hair dryers or warm water,
4. Customizable using an adjustable nose and chin folding,
5. Reusable after washing it with running water,
6. A recyclable material,

7. A modular fine particle filtration and viral deactivation system,
8. A modular filtration disc that can modulate the level of filtration and air intake.

Detail Description

(Claim 1)

- Use of a material containing a copper nanocomposite that is antimicrobial and capable of deactivate viruses

1.1. The development of the polymer coverage will be formulated using a special combination and ratio of copper nanostructures (10nm) and other metals using the exterior of some specific forms of zeolites as a carrier with high capacity of copper ions release to accomplish a potent biocidal behavior. The carrier (inner substrate) can also be silicates, sepiolite, dolomite, wollastonite, mica, ceramics, carbon, activated charcoal, clay, hydroxyapatite, kaolin, talc, calcium carbonate, pumice stone, natural and synthetic fibers, coir.

The specific combination of copper and other nanostructures and carriers will result in a potent antimicrobial polymer with antimicrobial action against microorganisms such as bacteria, virus, protozoa, algae, fungi, and yeast. Specifically, a carrier will contain a specific formulation consisting in copper, silver, zinc, gold, bismuth, mercury, tin, antimony, cadmium, chromium, tantalum, iron, manganese and lead, their oxides, hydroxides, acetates, carbonates, chlorides, nitrates, phosphates, sulfates, sulfides, and mixtures.

Modifying the carrier with an agent with biocidal properties is performed through ionic exchange and ionic adsorption in the bulk of the supporting material or only as nanostructures on its surface. Due to the enhanced biocidal characteristic, our antimicrobial polymer coverage will also present higher efficacy in killing bacteria at higher copper content, temperature and relative humidity, decreasing the effect of bacterial biofilm. However, when compared to other thermoplastics with additives of silver, our new material will be more effective under typical indoor environments, such as dry conditions and low temperatures. The main viral deactivation mechanism of copper consists in producing damage to the cell membrane, structural proteins, DNA, RNA, and other biomolecules. In addition, copper and associated hydroxyl radicals promote DNA denaturalization damaging helical structures inside the cell. Copper also damage and alter proteins acting as a

protein inactivator via RNA, useful to deactivate virus such as herpes, HIV-1, West Nile, and SARS-CoV-2 the causative agent of the COVID-19 disease. Advance in nanotechnology research have shown that the antimicrobial and viral deactivation mechanisms of action of copper is enhanced by using copper nanoparticles on thermoplastic matrices. The small size of copper nanoparticles potentiates the antimicrobial behavior of copper by facilitating endocytosis producing a higher increase of ionic species due to higher oxygen concentration as compared to the cell media resulting in a massive oxidative stress accelerating cell death. Studies have found a dose-dependent response of copper to inactivate the virus's protease, a protein that plays a crucial role in the replication of the virus. The specific known mechanism of copper is believed to cause nonspecific damage to the virus by damaging the envelope phospholipids and denaturing the virus nucleic acids.
Copper oxide affected free viruses, virions being formed within the cytoplasm of cells during the cell exposure to copper, and virions prior to their budding from the cells.

(Claim 2)

- Flat pattern for easy manufacturing and transport

2.1. The flat pattern has been designed to fit the human face anatomy after thermoforming.
This flat pattern will facilitate manufacturing and massive transportation to rural settings. Furthermore, the use of acute, obtuse, right, and straight angles in the design of the external frame of the respirator will facilitate production using fused deposition modeling 3D printers.

(Claim 3)

- Thermoforming

3.1. Thermoforming capabilities (glass transition) at 55° C to allow the use of hair dryers or warm water. The respirator is designed to be thermoformed at temperatures as low as 55°C to prevent burns and the use of home appliances, such as the use of a hair dryer. The thermoforming capabilities will also be helpful for a tight fit between the respirator and face.

(Claim 4)

- Customizable using an adjustable nose and chin folding.

4.1. The design of the respirator includes strategically place foldings at the nose and chin to facilitate customization and minimize the any gaps between the respirator and face.

(Claim 5)

- Reusable after washing it with running water.

5.1. The single-use nature of current respirators makes them expensive and limit the massive distribution during outbreak periods. Thus, having a reusable and washable respirator can facilitate the use and effectiveness of these devices. The antimicrobial nature along with the viral deactivation system of the material used to manufacture the current respirator will offer a practical and effective solution to end users around the globe.

(Claim 6)

- Recyclable.

6.1. There are several reports of a large mass of surgical masks and N95 respirators disposed in the oceans and local rivers and parks. The increasing use of single-used surgical masks and N95 respirators will have a detrimental effect in the ecosystem. To prevent this detrimental effect in our environment, the current respirator will be recyclable.

(Claim 7)

- Modular fine particle filtration and viral deactivation system

7.1. The current respirator will incorporate a novel modular fine particle filtration system manufactured with a material using copper nanocomposite proven to deactivate viruses.

This novel filtration system includes a several layers with different geometries (square, circular, and honeycomb) to provide an effective fine particle filtration. Furthermore, this system can house third party filtration materials, such as non-woven propylene, clothing, sponges, or textiles.

(Claim 8)

- Modular filtration disc that can modulate the level of filtration and air intake

8.1. A modular filtration disc that can modulate the level of filtration and air intake. Prolong use of N95 respirators have shown to reduce lung capacity. These single-use respirators do not allow the regulation of air intake or particle size. Our current invention incorporates a modular filtration disc that can effectively regulate the air intake and the particle size. Furthermore, claim 7 and 8 are integrated and represent a novel filtration system that can be customized by using third party filtration non-woven propylene, clothes, sponges, and different textiles to reduce the level of filtration.

Conclusions

Although the subject matter has been described in language specific to structural features and/or process operations, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims. Thus, we propose a customizable, reusable, recyclable, modular, antimicrobial and antiviral 3D printed respirator. To accomplish this goal, our respirator will include

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