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Self-sanitizing reusable glove via 3D-printing and common mold making method

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ABSTRACT

In health care and public health practice, it is critical to settings control practices that are critical to reducing the transmission of infections through cross-contamination. To provide protection from cross-contamination, use and throw gloves are routinely used. However, single-time use and inconsistent sanitization of used gloves remain a large problem and elevate the risk of catching viruses, germs, pathogens, and contaminants. The study reports reusable self-sanitizing gloves via 3D-printing and common hand molding methods. The major contribution is frequent self-sanitization of gloves without any manual intervention. The elastomeric material is used for fabricating gloves and continuous channels are embedded within the elastomeric material that runs through the entire glove surface, covering the front, back, and fingers. Elastomeric material allows the engagement of fingers for gripping objects. While the embedded channel is provided with uniformly spaced openings to eject the sanitizing solution. The glove surface is textured with a porous morphology that acts as mini and micro reservoirs for sterilizing solution ejected through embedded channel opening. The embedded channel is connected to a sanitizing solution storage tank. The incorporation of sanitizing solution storage tank enables its usage over a longer period. This uniquely constructed design of the gloves even assists in the effective sterilization of infected surface that comes in contact with the gloves. The gloves can be customized to improve comfortability by fabricating them from the 3D-printed mound developed based on the palm size of the user. The developed technology can be used by individuals working in hospitals, the transport sector, delivery units, schools, offices, industries, etc. We strongly believe that this technology will be highly useful in minimizing the risk of getting infected through cross-contamination and will help in maintaining hygienic as well as safe surroundings.

1. Introduction

The wide spread of infectious diseases can result in health emergencies like a pandemic. An infectious disease can be caused by viruses, bacteria, pathogens, etc., which spread through transmission from an infected person or a contaminated object to a susceptible host. Infectious diseases are responsible for an immense global burden of disease that impacts public health systems and economies worldwide [1,2]. According to WHO, the best solution to curtail its widespread is by adopting precautionary measures at the early stage [1–3]. Thus there is an extended need to develop new strategies and innovations to disinfect daily-use objects and curtail the spread of the infection through cross-contamination [1–2]. While breathing and talking, the resultant aerosol dispersion and infected surfaces/objects are the prime routes of transmission. The quality of the air we breathe and the cleanliness of the surfaces we touch have a profound affect on our health and well-being. We're all at risk of contracting and spreading infection, especially in busy public areas. Under these circumstances, as we prepare

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to step outside for work and restore normalcy around us, the cross-contamination problem is one of the most common threats imposed by touching an infected surface. In order to minimize the spread of infection through cross-contamination, it is recommended to wear gloves, use mask, disinfecting methods and sanitize hands frequently. The market is flooded with various disinfecting technology [4–10]. Table 1 lists the few disinfecting technologies reported in the literature and existing in the market.

Further, to provide protection from cross-contamination use and throw gloves are routinely used in the medical sector, delivery staff, transport sector, malls, security staff, etc. The practice of continuously removing and donning gloves is both expensive and time-consuming. Even individuals working in these sectors are adopting manual sanitization of gloves. However, inconsistent sanitization of gloves still remains a large problem and elevates the risk of catching viruses, germs, pathogens, and contaminants. Further, unless manual sanitization is done carefully, a potentially serious spread of cross-contamination remains an issue. Moreover, the rapid increase in the use of protective items has introduced an urge for their reuse. Thus, there is a need for a reusable self-sanitizing glove that eliminates the necessity of removing/discarding the gloves and prevents cross-contamination.

In the present work, we report reusable self-sanitizing gloves via 3D-printing and the common hand molding method. The major contribution behind this is the frequent self-sanitization of gloves without any manual intervention. The technology uses continuous channels embedded in the gloves that run through the entire surface. The gloves surface is made highly porous and this porous morphology act as mini and micro reservoirs for sanitizing solution coming out of the embedded channel. The technology is provided with a sanitizing solution storage tank that enables its usage over a longer period. Further, the product can be developed as a personalized glove. The user's hand size and dimensions will be taken, and the glove will be fabricated based on it, which gives the best fit and comfort. The current developed technology offers cost-effective products to minimize the risk of getting infected through cross-contamination.

Table 1
Various disinfection technologies are reported in the literature and exist in the market.

Technology	Description	Reference
Methods and compositions for cleaning and disinfecting surfaces	Relates to the problem of cleaning and disinfecting unclean surfaces that are contaminated, typically with bacteria, viruses, yeast, and molds.	[11]
Disinfecting device	A sanitizing system uses ultraviolet light within a housing having an interior chamber	[12]
Maya sticker	3D-printed unique film called 'Maya sticker' can be attached to a face mask to increase its protective capabilities	[13]
University of Arizona	A washable mask that would kill 99% of bacteria and viruses	[14]
Central Salt & Marine Chemicals Research Institute	A special self-disinfecting mask that can give enhanced protection against the virus	[15]
CleanDefense Clean box	UV treatment-based hygiene product. The technology is based on UV treatment for disinfecting point-of-use protective products that are not feasible to clean by a solution-based process.	[16]
Schwartz A et al.	Decontamination and reuse of N95 respirators with hydrogen peroxide vapor to address worldwide personal protective equipment shortages during the SARS-CoV-2 (COVID-19) pandemic	[17]

2. Methods and materials

Arduino pro mini microcontroller kit and mini pump were purchased from Voltaat Elastomer resin was purchased from Alfa Aesar. Creality Ender 3 S1 3D-Printer was used for fabricating the hand mold and was purchased from Amazon.

3. Results and discussion

The glove is uniquely constructed using a hand replica fabricated through 3D-printing and a common molding method technique. The elastomeric material is used for fabricating gloves and continuous channels are embedded within the elastomeric material that runs through the entire glove surface, covering the front, back, and fingers. These channels are provided with uniformly spaced openings to eject the sanitizing solution. To ensure the uniform spread of the sanitizing solution over the entire region, the glove is made highly porous. These porous morphologies act as mini and micro reservoirs for sterilizing solution ejected through embedded channel opening. The embedded channel is connected to a sanitizing solution storage tank, which is equipped with an automatic assembly that periodically injects the solution into the channel. The schematic representation of self-sanitizing gloves is shown in Fig. 1.

3.1. Hand mold and channel fabrication

The replica of the hand is made by two different methods (i) common hand mold-making technique. (ii) 3D-printing technique. The technology uses continuous channels that run through the entire surface, covering the front, back, and fingers. This channel is provided with uniformly spaced openings to eject the sanitizing solution.

Fig. 1. Schematic representation of reusable self-sanitizing gloves.

3.1.1. Common mold-making technique and channel formation

For replicating the hand by common mold-making technique, initially, the hand shape is cast by inserting the human hand into a polymeric resin solution. Once the resin gets dry, the hand is removed leaving behind a hollow hand replica in the resin. Further, this hollow space is filled with gypsum or different mold-making material. After leaving it overnight for drying, the casted hand replica is carefully removed from the system. Thereafter, a flexible tube is manually attached to the surface for the hand mold forming a continuous channel that runs throughout the glove surface, covering the front, back, and fingers. Fig. 2a shows the fabricated hand replica from gypsum and the channel formed on the surface.

3.1.2. 3D-printing method

Fused deposition modeling (FDM) 3D-printing technology is adopted for fabricating hand replicas having a channel route embedded within the printed hand. Initially, the CAD design of the hand replica is designed which incorporates the channels for placing tubes. This helps in more systematic and uniform coverage of the gloves surface. The CAD design is saved in the 3D-printer for printing. PLA material is used for making 3D-printed hand molds. Thereafter a flexible tube is manually placed in the channel route carved onto the printed hand forming a continuous channel that runs throughout the glove surface, covering the front, back, and fingers. Fig. 2b shows the fabricated hand replica from the 3D-printed method and channels formed on the surface.

3.2. Fabricating channel embedded elastic gloves and texturing glove surface with porous morphology

The elastomeric material is used for fabricating gloves. Fig. 3 shows the process of glove fabrication and texturing the surface with porous morphology using a common mold-making method and 3D-printing technique.

3.2.1. Common mold-making technique and channel formation

The flexible tube channelled mold is coated layer by layer with an elastomeric material. When the desired thickness of the coated elastomeric material is reached, the final layer is uniformly sprayed with micron size water-soluble crystals. Once the elastomeric material gets cured, the glove is removed from the mold and dipped in water for a period of time. The crystals sprayed on the glove surface get dissolved in the water, resulting in the formation of a highly porous morphology. The schematic of the process is shown in Fig. 3a.

3.2.2. 3D-printing method

For making gloves and texturing the surface with uniform porous morphology, another hand-casting hollow mold (part B) is fabricated by the 3D-printing method. The hollow casting mold's inner surface is textured with uniform vertical extruding structures. The flexible tube embedded 3D-printed mold (part A) is sandwiched between the casting hollow 3D-printed molds (part B). The assembly is clamped tightly, and elastomeric material is poured into the assembly through a hole provided in part B. The system is left for elastomeric material to get cured. Once the material gets cured, the elastomeric glove with uniform textured porous

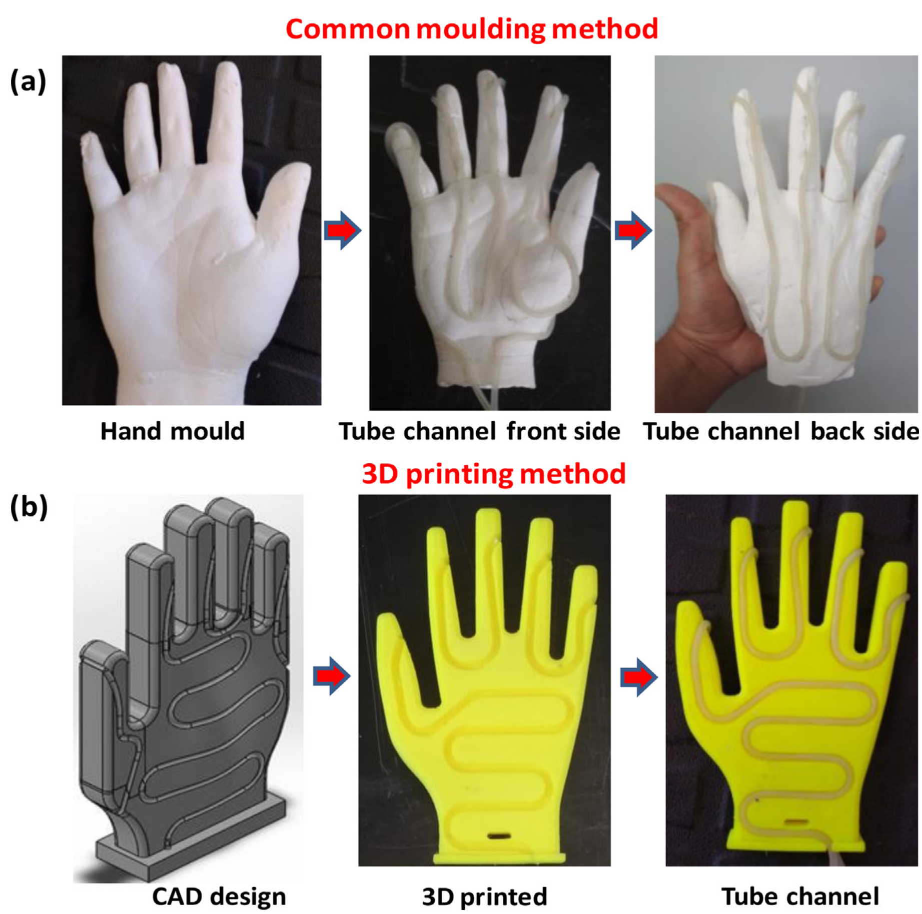

Fig. 2. Hand mold and channel fabrication. (a) Common mold-making method. (b) 3D-printing method.

Fig. 3. Fabricating channel embedded elastic gloves and texturing glove surface with porous morphology. (a) Common mold-making method. (b) 3D-printing method.

morphology is removed from the mold. The schematic of the process is shown in Fig. 3b.

3.3. Storage tank and electronic assembly for periodic automatic ejection of sanitizing solution into the channels

The glove of the present invention uses a sanitizer agent in liquid form, and the glove is attached to the storage tank that can be easily refilled with the sanitizing solution. The storage tank is provided with a motor that pumps the sanitizing solution into the channels. The automatic periodic pumping of the solution into the channels is governed by the Arduino-programmed unit. Both the motor and the programmed unit are powered by a portable battery. The storage tank, Arduino unit, and battery are attached to a band that can be easily tied to the hand. The schematic of the wearable band equipped with all the assembly and the picture of the fabricated gloves is shown in Fig. 4a, and b, respectively.

The developed product can be provided in the form of a self-sanitizing glove fabricating kit, as shown in Fig. 5a. The product in the kit includes a 3D-printed hand with channels and tubing, elastomeric material for coating 3D-printed hand and producing gloves, sanitizing solution storage tank and assembly for automatic self-sanitizing functionality. Using these supplied products in the kit and instruction manual, the user can fabricate the self-disinfecting gloves at home. The current developed technology offers cost-effective products to minimize the risk of getting infected through cross-contamination. The developed technology can be used by individuals working in hospitals, transport sector, delivery units, schools, offices, industries, etc., as shown in Fig. 5b. The skills used in this art makes the product to be more susceptible to incorporate modifications and changes relatively based on the specific requirements or users. The incorporated changes will not affect the scope and spirit of the invention. The implementation of the reported technology also promotes the clean and hygienic surrounding.

4. Conclusion

In summary, a self-sanitizing reusable glove was successfully developed by common mold-making techniques, and 3D-printing fabricated mold methods. The elastomeric material is used for fabricating gloves, and continuous channels are embedded within the elastomeric material that runs through the entire glove surface. Elastomeric material allows the engagement of fingers for gripping objects. While the embedded channel is provided with uniformly spaced openings to eject the sanitizing solution. To ensure the uniform spread of the sanitizing solution over the entire region, a glove is made highly porous. The autonomous periodic flow of the sanitizing solution into the channels was accomplished by a flow-controlled microcontroller unit. The flow rate and time interval of sterilizing solution injection into the channels can be easily controlled by simple modification in the program. The fabrication of personalized gloves was demonstrated by glove fabrication using customized 3D-printed hand molds. The developed prototype exhibited a high degree of disinfection. We strongly believe this equipment can help in curtailing the spreading of infectious diseases through cross-contamination. The developed technology can be used by individuals working in hospitals, the transport sector, delivery units, schools, offices, industries, etc. Implementing the above technology also promotes the clean, environmentally friendly, and healthy factor with application in areas such as parks, tourist places, streets, buildings, remote places, etc.

CRediT authorship contribution statement

Kishor Kumar Sadasivuni: Methodology, Conceptualization, Supervision, Writing – review & editing, Conceptualization, Supervision, Writing – review & editing, Funding acquisition. **Muni Raj Maurya:** Methodology, Investigation, Writing - review & editing. **Mohammad Talal Houkan:** Methodology, Formal analysis. **John-John Cabibihan:** Methodology, Formal analysis, Conceptualization, Supervision, Writing – review & editing. **Mithra Geetha:** . **Somaya**

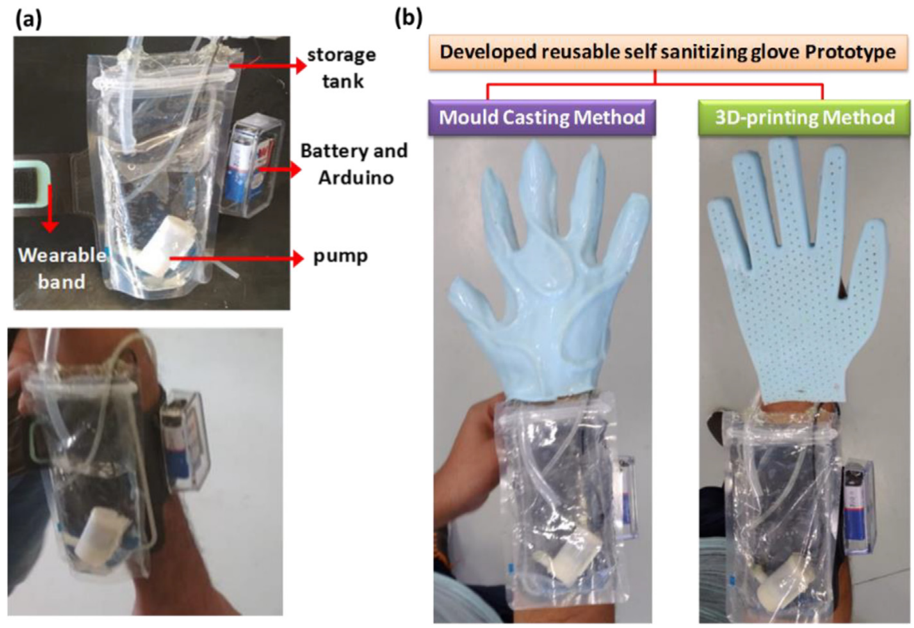

Fig 4. (a) Storage tank and electronic assembly attached to a wearable band. (b) Photograph of the fabricated self-sanitizing gloves.

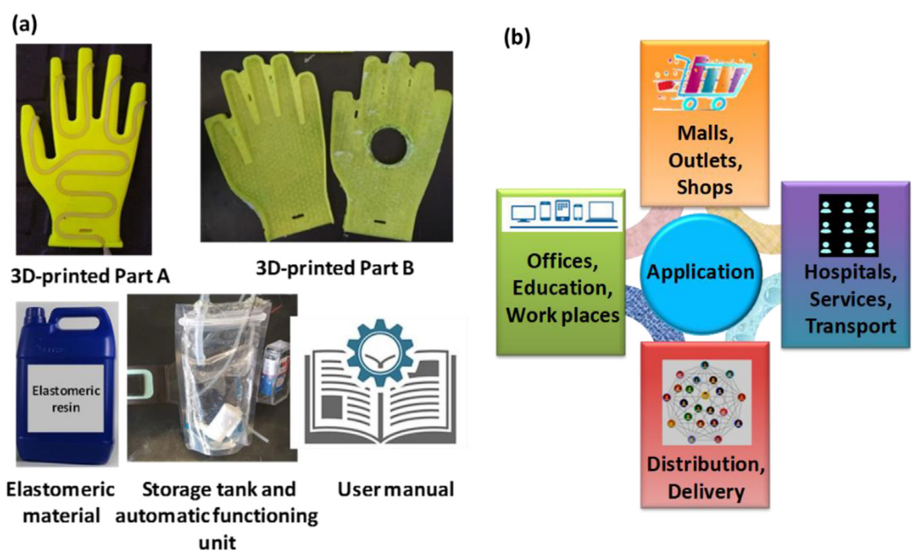

Fig. 5. (a) Self-sanitizing glove fabricating kit. (b) Potential application area of the developed technology.

Al-Maadeed: . **Hafsa Omar:** Data curation. **Noor Asnida Asli:** Data curation.

Data availability

Data will be made available on request.

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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References

[1] Coronavirus disease (COVID-19) Weekly epidemiological update and monthly operational update. Accessed 18-12-2022. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports.

[2] M.R. Maurya, H. Onthath, H. Morsy, N.-U.-S. Riyaz, M. Ibrahim, A.E. Ahmed, R. Abuznad, A. Alruwaili, F. Alsaedi, P. Kasak, K.K. Sadasivuni, Colorimetry-based detection of nitric oxide from exhaled breath for quantification of oxidative stress in human body, Healthcare 9 (8) (2021) 1055, https://doi.org/10.3390/healthcare9081055.

[3] H. Khan, K.K. Kushwah, S. Singh, H. Urkude, M.R. Maurya, K.K. Sadasivuni, Smart technologies driven approaches to tackle COVID-19 pandemic: a review. 3, Biotech 11 (2) (2021) 50, https://doi.org/10.1007/s13205-020-02581-y.

[4] W.A. Rutala, D.J. Weber, Uses of inorganic hypochlorite (bleach) in health-care facilities, Clin Microbiol Rev 10 (4) (1997) 597–610, https://doi.org/10.1128/CMR.10.4.597.

[5] J. Koivunen, H. Heinonen-Tanski, Inactivation of enteric microorganisms with chemical disinfectants, UV irradiation and combined chemical/UV treatments, Water Res. 39 (2005) 1519–1526, https://doi.org/10.1016/j.watres.2005.01.021.

[6] P. Setlow, Spores of Bacillus subtilis: their resistance to and killing by radiation, heat and chemicals, J Appl Microbiol. 101 (2006) 514–525, https://doi.org/10.1111/j.1365-2672.2005.02736.x.

[7] K. Bergmann, UV-C irradiation: A new viral inactivation method for biopharmaceuticals, Am. Pharm. Rev. (2014). https://www.americanpharmaceuticalreview.com/Featured-Articles/169257-UV-C-Irradiation-A-New-Viral-Inactivation-Method-for-Biopharmaceuticals/.

[8] B. Casini, B. Tuvo, M.L. Cristina, A.M. Spagnolo, M. Totaro, A. Baggiani, G.P. Privitera, Evaluation of an ultraviolet C (UVC) light-emitting device for disinfection of high touch surfaces in hospital critical areas, Int. J. Environ. Res. Public Health 16 (19) (2019) 3572, https://doi.org/10.3390/ijerph16193572.

[9] Health Quality Ontario, Portable Ultraviolet Light Surface-Disinfecting Devices for Prevention of Hospital-Acquired Infections: A Health Technology Assessment, Ont. Health Technol. Assess. Ser. 18 (1) (2018) 1–73. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5824029/.

[10] D.J. Weber, H. Kanamori, W.A. Rutala, 'No touch' technologies for environmental decontamination: focus on ultraviolet devices and hydrogen peroxide systems, Curr. Opin. Infect. Dis. 29 (4) (2016) 424–431, https://doi.org/10.1097/QCO.0000000000000284.

[11] Inventor: Maria UD, Beug-Deeb, Thomas MD, Assignee: Maria Beug-Deeb Inc dba T&M Associates. Methods and compositions for cleaning and disinfecting surfaces. Patent no. AU2017100988B4, Australia. https://patents.google.com/patent/AU2017100988B4/en?q=disinfecting&oq=disinfecting.

[12] Inventor: Richard GF, Assignee: HAYS DORIS M MRS, Hays Doris M, Hays WJ. Disinfecting device, Patent no. US9198990B2. https://patents.google.com/patent/US9198990B2/en?q=disinfecting&oq=disinfecting.

[13] Breaking Defense (2020) COVID-19: Israel deploys new mask & C2 technologies. Accessed 18-12-2022. https://breakingdefense.com/2020/04/covid-19-israel-deploys-new-mask-c2-technologies/.

[14] The National (2020) Coronavirus: reusable face masks to ease UAE eco concerns. Accessed 18-12-2022. https://www.thenational.ae/uae/health/coronavirus-reusable-face-masks-to-ease-uae-eco-concerns-1.1024300.

[15] The Times of India (2020) These face masks that use new technology could actually kill virus. Accessed 18-12-2022. https://timesofindia.indiatimes.com/city/rajkot/these-face-masks-that-use-new-tech-could-actually-kill-virus/articleshow/75130514.cms.

[16] CLEAN BOX. Accessed 18-12-2022. https://cleanboxtech.com/.

[17] A. Schwartz, M. Stiegel, N. Greeson, A. Vogel, W. Thomann, M. Brown, G.D. Sempowski, T.S. Alderman, J.P. Condreay, J. Burch, et al., Decontamination and reuse of N95 respirators with hydrogen peroxide vapor to address worldwide personal protective equipment shortages during the SARS-CoV-2 (COVID-19) pandemic, Appl. Biosaf. 25 (2) (2020) 67–70, https://doi.org/10.1177/1535676020919932.