EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 18, No. 3, July 2021, pp. 35 - 41 ISSN 2090 - 5882
(Received May 17. 2021, Accepted in final form June 22. 2021) jest.journals.ekb.eg

PROPSED MATERISALS FOR FACE MASKS

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ABSTRACT
In the present work, a face mask is proposed to withstand the severe conditions of increased virus concentration. It consists of two materials, polypropylene (PP) and polymethyl methacrylate (PMMA). Both materials are made of two layers. The first layer is made of fibers of 20 – 25 µm diameter and works as prefilter, while the second layer consists of microfibers of 2 – 5 µm diameter. The PMMA microfiber layer has a positive charge to capture the negatively charged viruses like COVID-19. The two layers are not completely bonded. Besides, it is recommended to provide the mask with a frame made of polytetrafluoroethylene (PTFE) to enhance the mask ability to repel viruses due to the electrostatic property of PTFE of gaining strong negative ESC.

KEYWORDS
Face mask, negative charged viruses, coronavirus, microfibers.

INTRODUCTION
Polymeric materials are used extensively in filters. They become electrically charged easily. The polymeric fiber carries ESC when it rubs another material, and the resulted electric field can attract the electrically charged particles by means of Coulomb forces, [1]. PP fiber is an actively charged material. Face mask filters are responsible for airborne contaminants and virus removal to offer increased safety. Most face masks are made of PP, [2]. Advanced fiber technology enabled manufacturing electrostatically charged microfibers, [3]. The drawbacks of the electrostatically charged filters is that when they become neutralized they lose efficiency.

Triboelectrification is the process of different surfaces acquiring different types and amounts of charge when they come into contact, [4 – 7]. Each material has a different tendency of obtaining positive or negative charge when it contacts or rubs another material. The triboelectric series was introduced to rank materials according to that parameter, where the higher a material is in the triboelectric series, the more likely it is to obtain positive charge when it comes in contact with another material, [8 – 10].

Surgical masks are generally used by surgeons to protect their faces from large droplets that may hit their faces. They protect the patient from small droplets that can come out of a surgeon's mouth or nose, [11]. As the spread of the novel coronavirus (COVID-19) continues, surgical masks are identified as a possible option to prevent the spread of COVID-19 as the initial investigations suggest that it can spread via airborne routes, [12 - 13]. These masks are generally made of non-woven PP, [14]. The use of surgical mask is generally recommended as a method for protecting others that are not infected rather than protecting the person who wears the mask from infection, keeping in mind that the evidence for its usefulness is not clear, [15 - 16].

Due to the constant contact between the mask and the skin, triboelectrification generates charges on both the skin and the PP mask. PP is at the lower end of the triboelectric series, [17], while the skin is located at the higher end, [18], that will result in a high positive charge on the skin and a high negative charge on the PP mask. Besides, it was found that air has a relatively high positive ESC, [19].

Most viruses have a negative charge associated with them, [20], including COVID-19. It can be a good idea to have a positively charged filter while dealing with viruses as it can result in a higher capture rate than neutrally charged filters. This is useful in air filtration systems, [21].

ESC generated on the surface of the protective equipment of medical care workers. Facemask, disposable cap, gloves, and gowns should gain negative charge to repel the viruses of negative ESC such as Covid-19. It was found that actively negative charged polymers such as PP should be selected for masks, [22]. Polyamide (PA), cotton, and PMMA should be avoided. The material of goggles and eye glasses should be made from PE, PP and PVC, because they gain g negative, [23]. Besides, negative ESC acquired by the surface of goggle may ionize the air around the goggle to be negatively charged and provide region of negative electric field. In hospitals, it was suggested, [24], that surface of shoes and shoe covers should be manufactured from PP and PE respectively to repel viruses away from the wearers. Epoxy floor instead of PVC tiles was recommended to provide the floor with positive ESC to attract the viruses. PP shoes are favorable rather than rubber outer soles of shoes. ESC generated on the gloves was studied to develop their protection of the wearer from viruses especially Covid-19. It was proposed to use PE gloves because they gain strong negative ESC able to repel the viruses of negative ESC out of the surface of the glove, [25, 26].

This article aims at investigating the effect of the ESC generated on the surfaces of the surgical masks and the human skin on their performance, proposing a new design for a surgical mask that can perform better based on the triboelectric perspective than typical PP surgical masks and analyzing the different options of achieving that.

SURGICAL MASK STRUCTURE

Selection of the proper materials of the face mask necessitates concentrating on the size of the virus, [15, 16], where higher levels of efficiency are critical in order to meet health regulations. COVID-19 requires filtration of smaller particle size down to 0.01 µm. The

face mask should be able to deal with different viruses and bacteria suspended in the air. The proposed mask consists of two materials PP and PMMA, where the layers are illustrated in Figs. 1, 2.

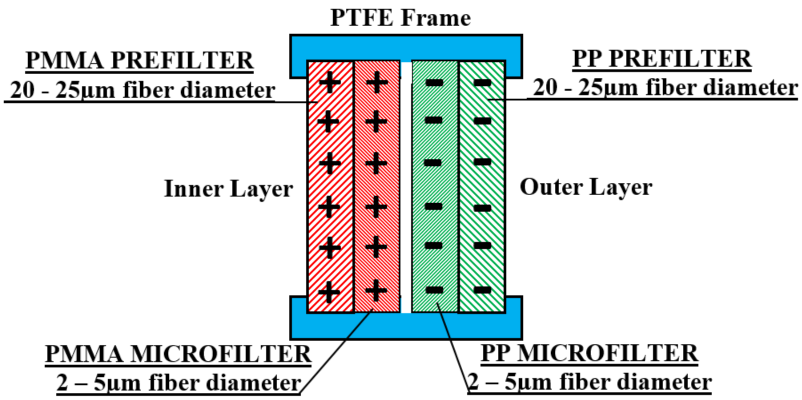

Fig. 1 Cross section of the proposed surgical mask.

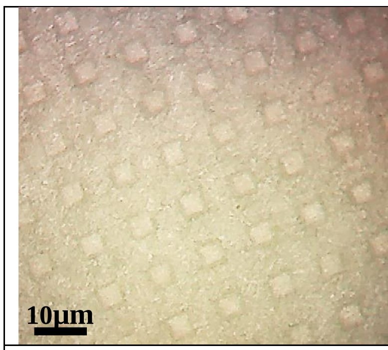	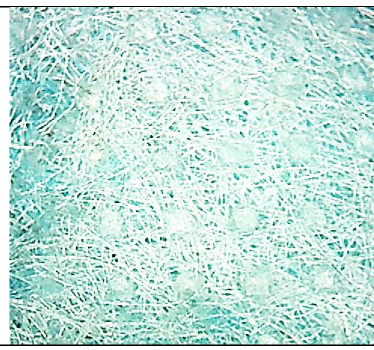	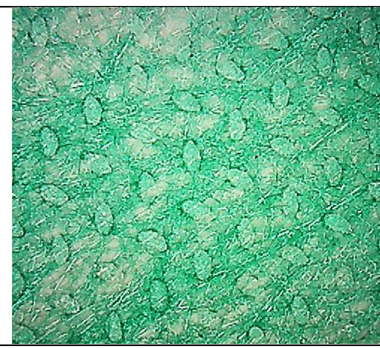
Inner layer of PMMA.	**Inner layer of PP microfibers of 2.0 µm fiber diameter.**	**Outer layer of PP prefilter of 20 – 25 fiber diameter.**

Fig. 2 Optical microscopes of the proposed material for the face mask.

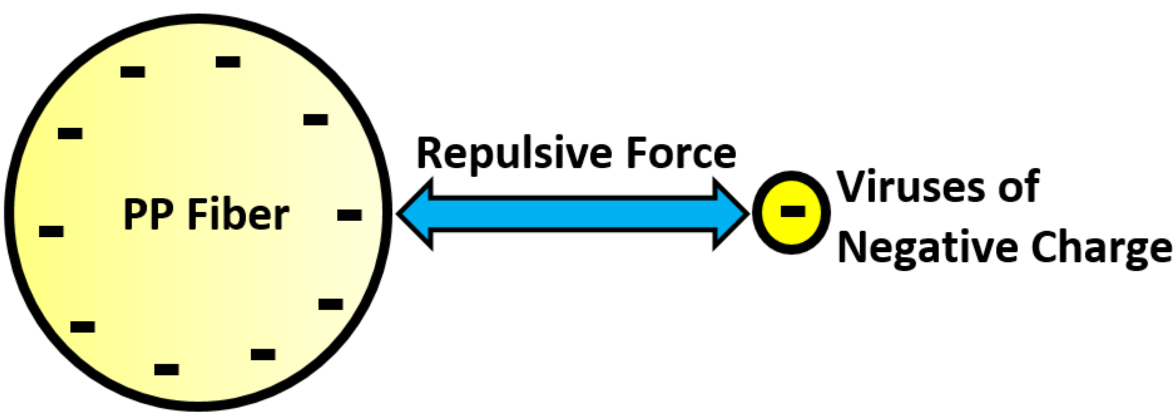

Fig. 3 Illustration of protection of PP layer.

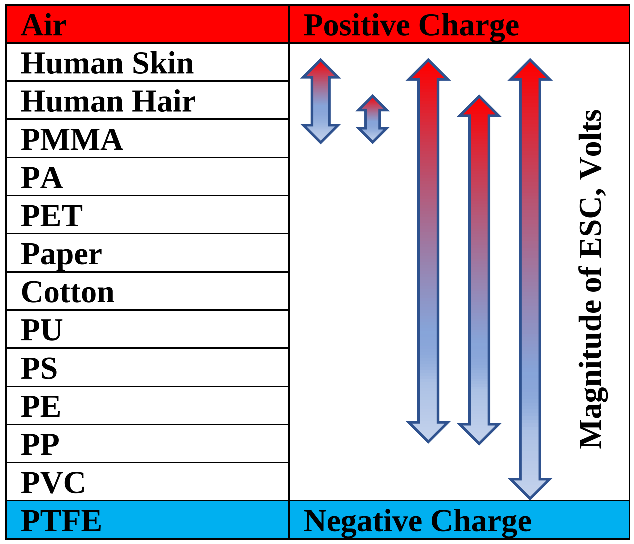

Fig. 4 Triboelectric series of the proposed materials.

The external layer is proposed to be made of PP. When the air passes through PP fibers, it increases the negative charge generated on the surface of those fibers. Because viruses have negative charge associated with them, [19, 20], including COVID-19, the PP layer will be able to repel the viruses and prevent them from passing through the layer, Fig. 3. The inner layer is made of PMMA fibers. The prefilter layer will be negatively charged due to the contact and separation with human skin and hair. Due to the clearance between PMMA and PP microfilters, PMMA will gain strong positive charge that will be able to capture viruses, Fig. 3. The contact and separation is caused by inhalation and exhalation. The proposal depends on the idea of having a positively charged filter that can deal with viruses with higher capture rate than neutrally charged filters. The prefilter and microfiber layers provide gradient filtration with submicron efficiency to capture solid airborne contaminants.

In addition to that, it is recommended to provide the mask with frame made of polytetrafluorethylene (PTFE) to avoid the drawbacks of the mask and purify the air from viruses before entering into the mouth and nose as illustrated in Figs. 5 and 6. Due to the electrostatic property of PTFE of gaining a negative charge when it contacts human skin and hair, framing the mask will enhance the ability of the mask to repel viruses. The positive charge generated on the skin and hair will be released because the human body is considered as good conductor, [21]. The negative charge generated on the mask will stay due to the good insulation property of its materials.

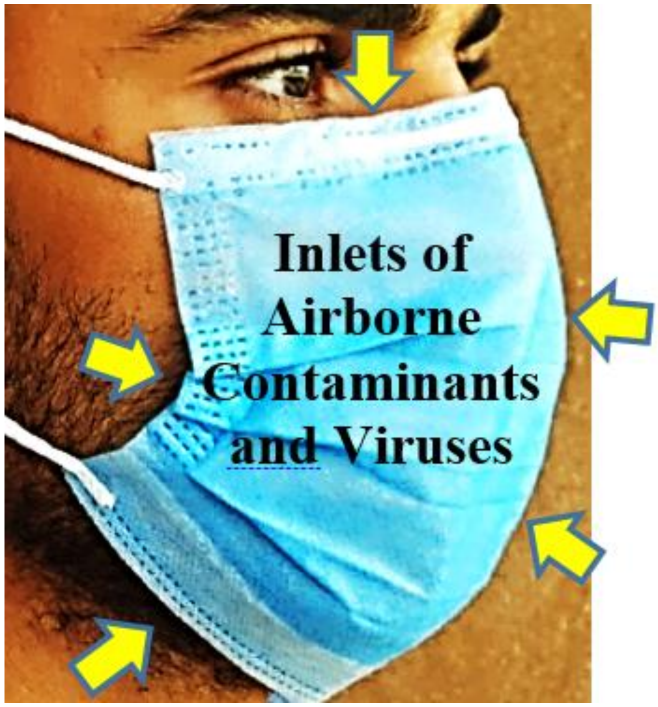

Fig. 5 Inlets of airborne contaminants and viruses.

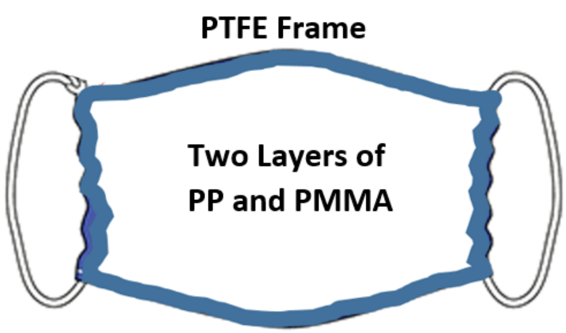

Fig. 6 Framing the mask by PTFE.

Having a negative charge on the face of the mask was seen as a viable approach as it will exert a repulsive force on the viruses in the air. There is an argument to be made for a positively charged mask external layer, as it can help capture the virus particles more easily when they contact the mask. In this condition, it is not guaranteed that the viruses will not contaminate the face of the wearer. Besides, a positively charged external layer makes the external surface of the face mask more dangerous to be touched than usual. Keeping in mind that masks are used by lot of people during the COVID-19 pandemic, that means the general public can be in danger.

Eye safety can also be a concern with this approach, considering that viruses can be deflected towards the eyes of the wearer. It is recommended to wear face shield. It is

important to recommend transparent polymer of negative charge such as PP or polystyrene (PS) instead of polycarbonate (PC).

For the inner layer of the mask, a positively charged layer can be useful to capture the viruses better in the case when the wearer already being infected.

CONCLUSIONS

The proposal discusses the possibility of making use of the electrostatic charge (ESC) generated on the surfaces of the polymeric materials of surgical face masks to enhance their performance. The approach of having a surgical mask with a negatively charged external layer and a positively charged inner layer can cause the mask to become more effective in repelling viruses and maintaining the health of the mask wearer by not introducing any potentially harmful electrostatic fields. Further studies on the effect and control of the ESC of surgical masks should help create a better way to design and use surgical masks. The interactions between the environment and surgical masks is also a topic that will be important to study in the future to help clarify the risks of having negatively or positively charged external layer on potentially increasing the risk of having an infection by other means than the mouth or nose.

REFERENCES

1. Brown R. C., "Effect of Electric Charge in Filter Materials", Filtration and Separation, January/February 1989, pp. 46 –- 51, (1989).
2. Dickenson C., "Filters and Filtration Handbook", Elsevier Advanced Technology, Oxford, UK, pp. 447 - 463, (1996).
3. Gustavsson J., "Can We Trust Air Filters?", Filtration + Separation, March 2000, pp. 16 – 22, (2000).
4. Al-Qaham, Y., Mohamed M. K., and Ali. W. Y., "Electric Static Charge Generated From the Friction of Textiles", Journal of the Egyptian Society of Tribology, EGTRIB, Vol. 10, No. 2, pp. 45 - 56, (2013).
5. Shivangi N., Mukherjee R., and Chaudhuri B., "Triboelectrification: A review of experimental and mechanistic modeling approaches with a special focus on pharmaceutical powders", International journal of pharmaceutics, Vol. 510, No. 1, pp. 375 - 385, (2016).
6. Ali A. S., "Triboelectrification of Synthetic Strings", Journal of the Egyptian Society of Tribology, EGTRIB, Vol. 16, No. 2, pp. 26 - 36, (2019).
7. Pan S. and Zhang Z., "Fundamental theories and basic principles of triboelectric effect: a review." Friction, Vol. 7, No. 1, pp. 2 - 17, (2019).
8. Zou H., "Quantifying the triboelectric series", Nature communications, Vol. 10, No. 1, pp. 14 - 27, (2019).
9. Burgo T. A. L., Galembeck F., and Pollack G. H., "Where is water in the triboelectric series?", Journal of Electrostatics, Vol. 80, pp. 30 - 33, (2016).
10. Gooding D. M., and Kaufman G. K., "Tribocharging and the triboelectric series." Encyclopedia of Inorganic and Bioinorganic Chemistry, pp. 1 - 14, (2011).
11. Benson S. M., Novak D. A. and Mary J. O., "Proper use of surgical N95 respirators and surgical masks in the OR", AORN journal, Vol. 97, No. 4, pp. 457 - 470, (2013).

12. Zhang R., Li Y., Zhang A. L., Wang Y. and Molina M. J., "Identifying airborne transmission as the dominant route for the spread of COVID-19", Proceedings of the National Academy of Sciences, (2020).
13. World Health Organization., "Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations: scientific brief, 27 March 2020", No. WHO/2019-nCoV/Sci_Brief/Transmission_modes/2020.1., World Health Organization, (2020).
14. Chellamani K. P., Veerasubramanian D., and Balaji R. S. V., "Surgical face masks: manufacturing methods and classification.", Journal of Academia and Industrial Research, Vol. 2, No. 6, pp. 320 - 324, (2013).
15. Lipp A., and Peggy E., "Disposable surgical face masks for preventing surgical wound infection in clean surgery", Cochrane Database of Systematic Reviews, No. 1, (2002).
16. Greenhalgh T., Schmid M. B., Czypionka T., Bassler D., Gruer L., "Face masks for the public during the covid-19 crisis" Bmj, 369, (2020).
17. Hiratsuka K., Hosotani, K., "Effects of friction type and humidity on triboelectrification and triboluminescence among eight kinds of polymers", Tribology International 55, pp. 87 – 99, (2012).
18. Mohamed R. A., Samy A. M., Ali W. Y., "Electric Static Charge and Friction Coefficient of Head Scarf Textiles Sliding Against Hair and Skin", International Journal of Advanced Materials Research, Vol.2, No. 3 (April), pp. 45 – 51, (2016).
19. Hernando-Pérez M., "Quantitative nanoscale electrostatics of viruses", Nanoscale, Vol. 7, No. 41, pp. 17289 - 17298, (2015).
20. Leung W., Woon F., and Qiangqiang S., "Electrostatic Charged Nanofiber Filter for Filtering Airborne Novel Coronavirus (COVID-19) and Nano-aerosols.", Separation and Purification Technology, (2020).
21. Gary J. R., Frith C. H., and Parker D. J., "Cancer Growth Acceleration by External Electrostatic Fields", proceedings of the electrostatics society of America Annual Conference, (2004).
22. Ali A. S., Al-Kabbany A. M., Ali W. Y. and Badran A. H., "Triboelectrified Materials of Facemask to Resist Covid-19", Journal of the Egyptian Society of Tribology, Vol. 18, No. 1, January 2021, pp. 51 – 62, (2021).
23. Ali A. S., Al-Kabbany A. M., Ali W. Y. and Ibrahem R. A., "Proper Material Selection of Medical Safety Goggles", Journal of the Egyptian Society of Tribology, Vol. 18, No. 2, April 2021, pp. 1 – 15, (2021).
24. Ali A. S., El-Sherbiny Y. M., Ali W. Y. and Ibrahem R. A., "Selection of Floor Materials in Hospitals to Resist Covid-19", Journal of the Egyptian Society of Tribology, Vol. 1, No. 18, January 2021, pp. 40 – 50, (2021).
25. Ali A. S. and Ali W. Y., "Proper Material Selection of Medical Gloves", Journal of the Egyptian Society of Tribology, Vol. 17, No. 4, October 2020, pp. 1 - 11, (2020).
26. Abdelwahab S. F., Mohamed M. K., Ali W. Y. and Ali A. S., "Role of Polymeric Materials in Preventing COVID-19 Infection", Archives of Virology, Springer-Verlag GmbH Austria, part of Springer Nature 2021, July (2021).