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# SELECTION OF THE PROPER MATERIALS FOR MEDICAL FACEMASK

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## ABSTRACT
**Medical facemask is proposed to withstand COVID-19 virus concentration. It contains woven microfibers of polypropylene (PP) and polyamide (PA). PP forms the negatively charged external layer to repel viruses and maintain the health of the mask wearer. PA microfibers as internal layer has a positive charge and can capture the negatively charged viruses like COVID-19.**

**The present experiments revealed that when the air passes through PP fibers, it generates negative electrostatic charge (ESC) on their surfaces. Because viruses including COVID-19 have negative charge, it is recommended to use PP fibers as external layer to be able to repel the viruses away. Due to the contact and separation of PA with PP fibers caused by inhalation and exhalation, ESC can be generated. According to that, the inner layer should be made of PA fibers of positive ESC to capture viruses. Because protection from COVID-19 viruses needs filtration of particle size down to 0.01 µm, it is advised to use ESC as tool to enhance the filtration efficiency of the facemask. It was observed that the arrangement of the mask (PA PP PA PP) gave the best results, where ESC generated of negative charge extended to 17 mm in front of mask and provided negative electric field that able to repel the viruses away. In addition, the inner PA layer could attract the negative charged viruses and guarantee the safety of the people contacting the mask wearer.**

## KEYWORDS
**Facemask, coronavirus, microfibers, polypropylene, polyamide.**

## INTRODUCTION
**Medical facemask are used to remove airborne contaminants and viruses to provide increased safety. Electrostatically charged microfibers are extensively used in manufacturing facemasks, [1, 2]. The facemask should protect the patient and the people who are working in medical care, [3]. The spread of the novel coronavirus (COVID-19) urged the people to use surgical masks as a possible way to prevent the spread of COVID-**

**19, [4, 5]. These masks are made of non-woven PP, [6]. They are used to protect others that are not infected as well as the person who wears the mask from infection, [7, 8].**
**Because of the constant contact between the mask and the skin, triboelectrification generates charges on the skin of high positive charge and high negative charge on the PP mask, [9 - 11]. It was revealed that most viruses have a negative charge associated with them, [12], including COVID-19. It is necessary to have a negative electric field in front of the facemask to repel the viruses away, [13].**

**In recent studies, it was recommended to guarantee that the ESC generated on the surface of the protective equipment of medical care workers such as facemask, disposable cap, gloves, and gowns should gain negative charge to repel the viruses of negative ESC such as Covid-19. Based on that, actively negative charged polymers such as PP should be selected for masks, [14], while polyamide (PA), PMMA and cotton should be avoided. The material of eyeglasses and goggles should be made from PP, PE and PVC, because they gain negative ESC, [15]. The negative ESC may ionize the air around the charged surfaces and provide region of negative electric field. The same precautions should followed in hospitals, [16], that the materials of shoes and shoe covers should be from PP and PE respectively to repel viruses away. It was recommended to apply epoxy floor instead of PVC tiles to provide the floor with positive ESC to attract the viruses. It was suggested to use PE gloves because they gain strong negative ESC able to repel the viruses of negative ESC, [17, 18].**

**Polypropylene (PP) and polymethyl methacrylate (PMMA) were proposed as materials for face mask, [19]. It consists of two materials made of two layers. The first layer was made of PMMA microfibers as prefilter to capture the negatively charged viruses like COVID-19, while the second layer consisted of PP microfibers. The PMMA microfibers gains positive electrostatic charge (ESC). The mask was provided by polytetrafluoroethylene (PTFE) frame to develop the mask ability to repel viruses because of the electrostatic property of PTFE of gaining strong negative ESC.**

**It was revealed that nanofibers made of polar materials exhibited higher removal efficiency, [20, 21], by nanostructured nanofibers, [22] and electret nanofibers, [23] to increase the filtration efficiency. It was revealed that when a voltage was applied across the metal layers that sandwiched polyacrylonitrile (PAN) based nanofibers, the nanofibers were polarized by the electric field, where neutral particulates passing through the nanofibers became polarized. As a result of that, electrostatic attractive force, [24, 25], effectively adhered the particulates onto the nanofibers. The expected enhancement developed from the electric field, where the electric field across the metal layers polarized the PAN-based nanofibers and formed ESC that attracted the incoming particulates. In this condition, the filtration performance depends on the electric field rather than the mesh density of the nanofibers.**

**The present work investigates the effect of the order of the layers of the materials of the facemask on the sign and magnitude of the ESC generated in the front of the facemask. It is proposed that the filter contains PP and PA, where PP generates the negatively charged**

**layer to repel viruses, while PA has positive charge that capture the negatively charged viruses like COVID-19.**

## EXPERIMENTAL

**Experiments were carried out to measure the ESC generated after five times of exhaling and inhaling air through the tested materials. The electrostatic field (voltage) measuring device (ULTRA STABLE SURFACE DC VOLTMETER) was applied to measure ESC, Fig. 1. The procedure of the measurement is shown in Fig. 2. PP and PA were tested as filtering materials for the facemask. The order of the two materials was changed as shown in Fig. 3 to search for the proper design.**


**Fig. 1 Electrostatic field measuring device.**

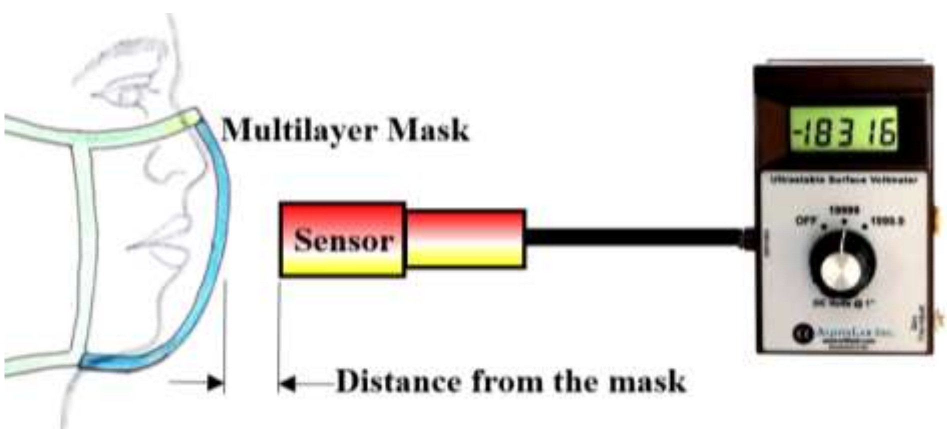


**Fig. 2 Measurement of ESC.**

**The proposal depends on using ESC generated on the polymeric materials of surgical facemask to enhance their performance. The use of PP and PA of different signs of ESC can give the flexibility to repel and attract the negative charged viruses such as Covid-19. It is essential to know the order and the number of the layers of both PP and PA. Several arrangement were proposed, Fig. 3, where the ESC was measured to select the best arrangement suitable to be applied in the medical facemask. The suitability should guarantee the best performance of the mask with a negatively charged external layer to**

repel the viruses and a positively charged inner layer to capture the viruses to decrease the risk of having an infection.

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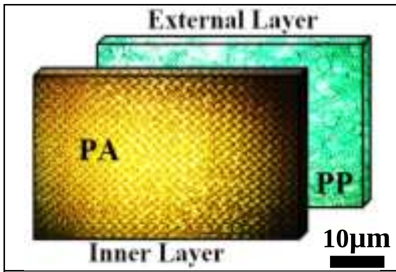
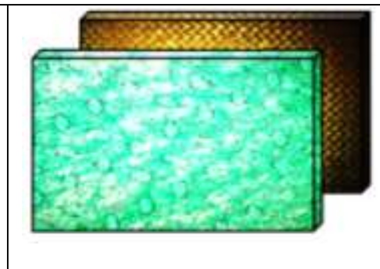
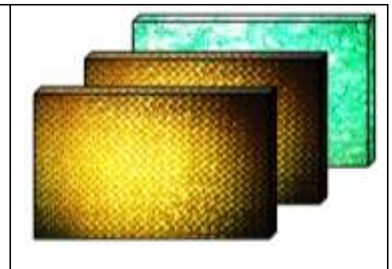
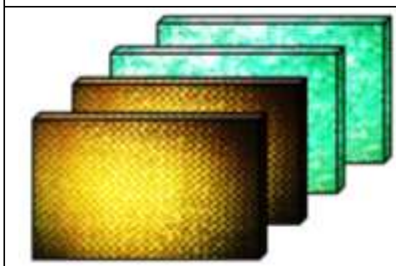
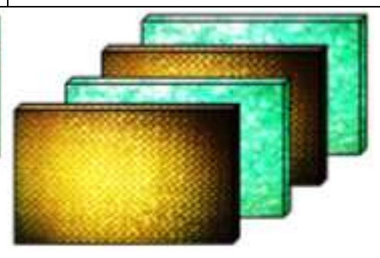
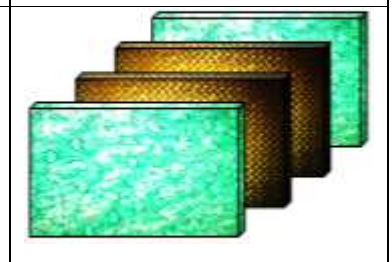
|   |  |  |
| **PA PP** | **PP PA** | **2PA PP** |
|  |  |  |
| **2PA 2PP** | **PA PP PA PP** | **PP 2PA PP** |

**Fig. 3 The order of the tested materials.**

**RESULTS AND DISCUSSION**

**ESC generated on the outer layer of the mask that contained one layer of PA is shown in Fig. 4. The ESC generated in the outer surface showed positive trend. This type of the mask has the ability to capture the negatively charged viruses. It is advised to use that mask for the people who has been infected. When the inner layer was PP and the outer one was PA, Fig. 5, positive ESC was measured on the surface of the facemask, where the magnitude was 2700 and 900 volts for exhalation and inhalation respectively. The presence of such positive ESC is not recommended for the medical facemask because the mask attracts the viruses instead of repelling them.**

**The arrangement (2PP 2PA) generated positive ESC on the surface of the facemask, Fig. 6. The values of ESC were 600 and 67 volts for exhalation and inhalation respectively. It is known that polymeric fibers develop ESC from the friction of air with their surface. The airflow causes their triboelectrification. When the surface charge accumulates on the fiber surface, air will have an electric field for a distance, where the greater the charge gained by the fiber, the greater will be the electric field. When the fibers gained charge of the same sign, the field outside the fibers should be very high. The efficiency of the fibers to resist viruses increases the electric field that extends to relatively long distance in front of the charged fibers. The electric field decreases with increasing distance.**

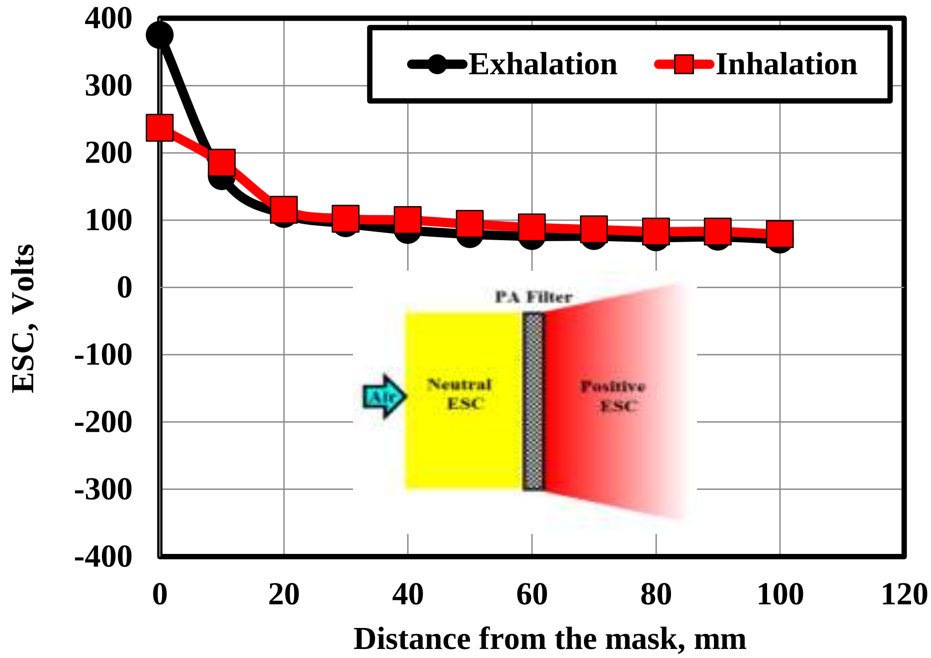



Fig. 4 ESC generated on the outer layer of the mask (PA).

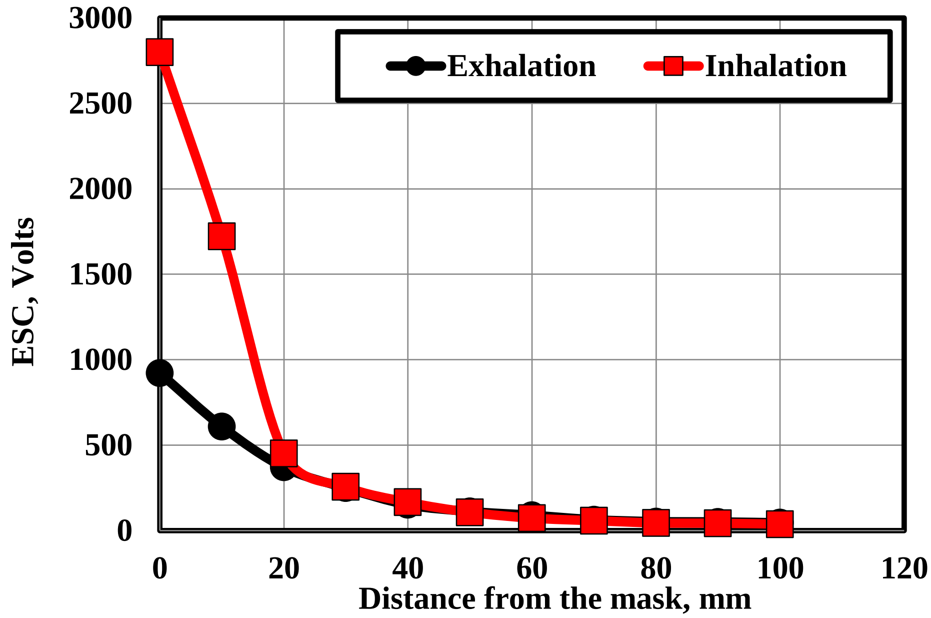



Fig. 5 ESC generated on the outer layer of the mask (PP PA).

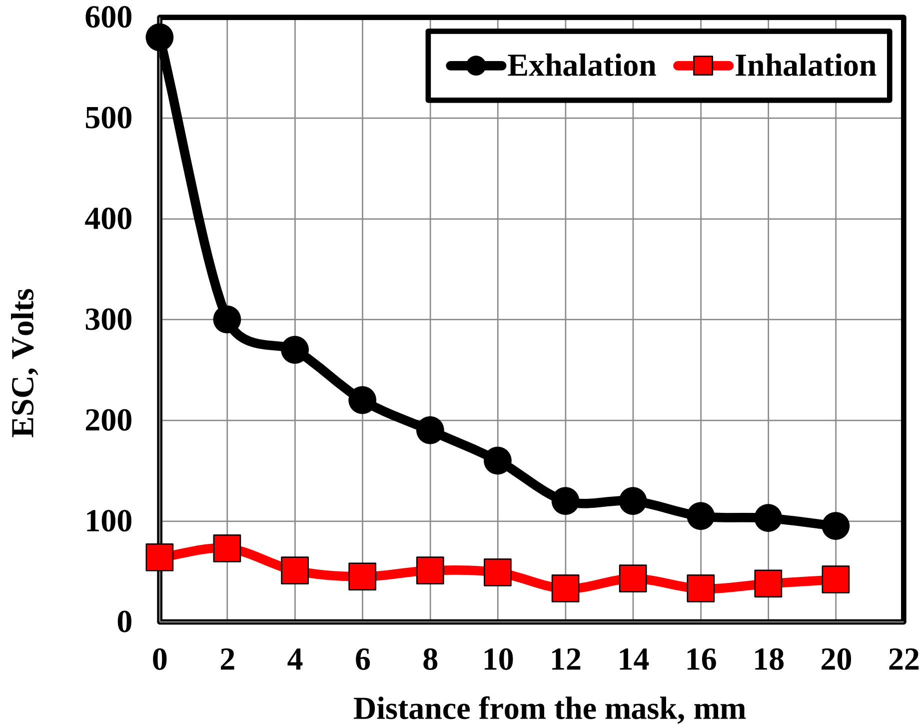



**Fig. 6 ESC generated on the outer layer of the mask (2PP 2PA).**

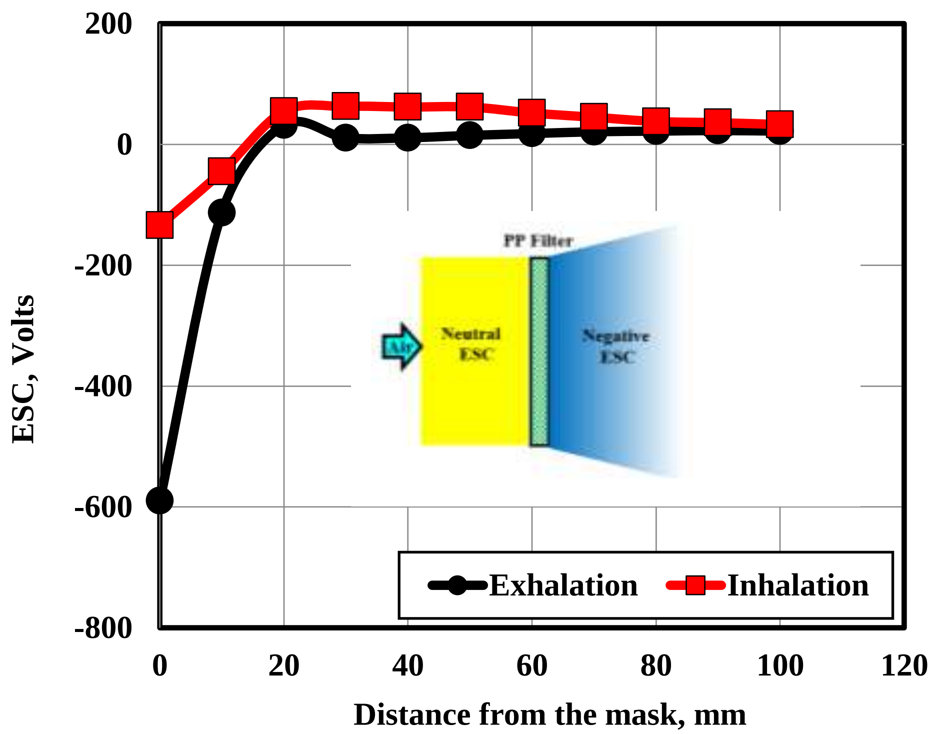



**Fig. 7 ESC generated on the outer layer of the mask (PA PP).**

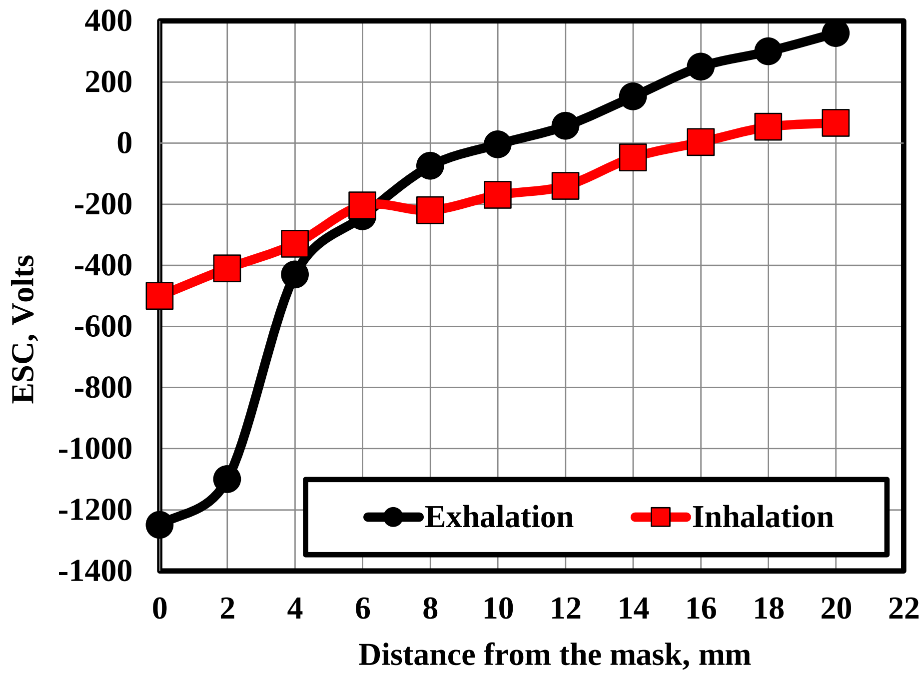



**Fig. 8 ESC generated on the outer layer of the mask (2PA PP).**

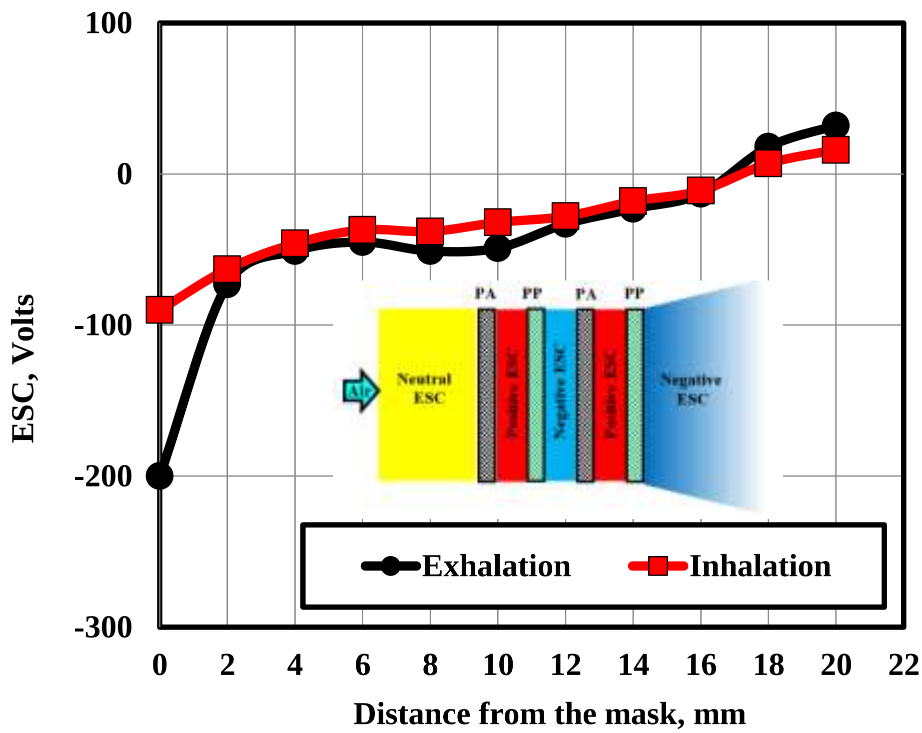


**Fig. 9 ESC generated on the outer layer of the mask (PA PP PA PP).**

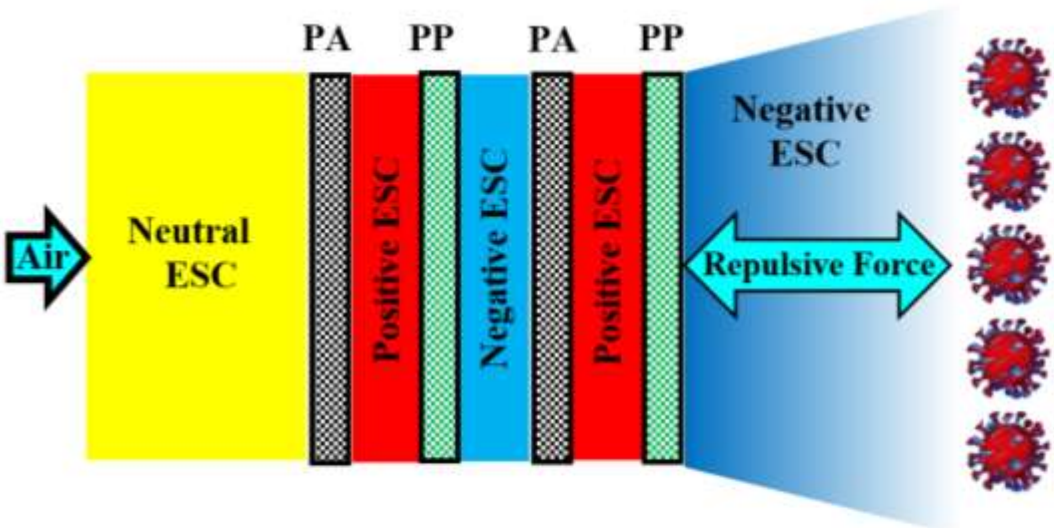



**Fig. 10 Illustration of the function of the proposed mask (PA PP PA PP) to resist the virus of Covid-19 by the use of ESC.**

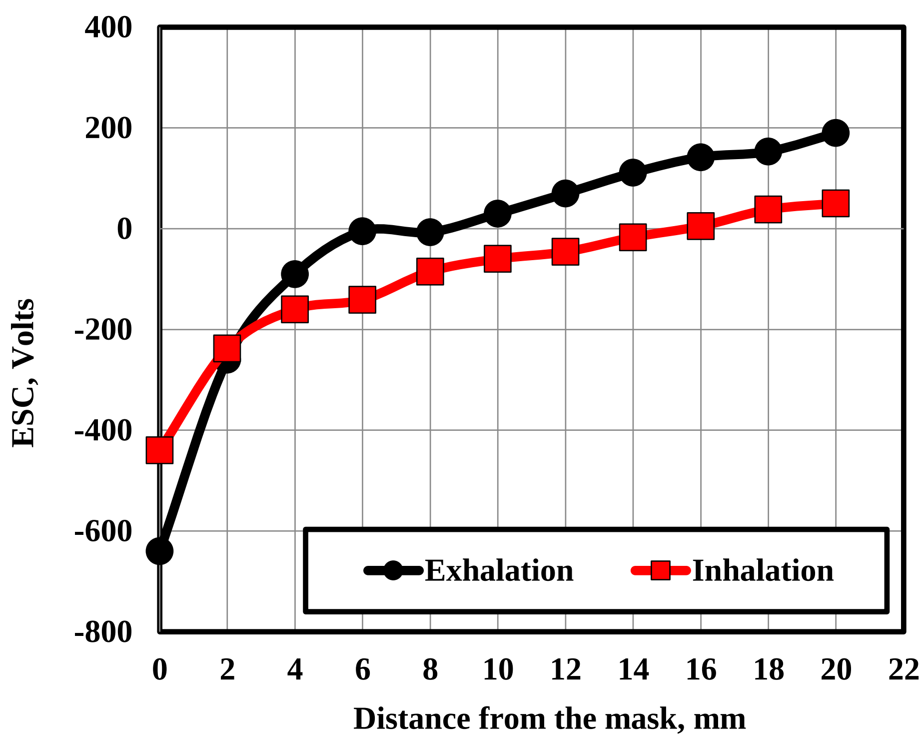



**Fig. 11 ESC generated on the outer layer of the mask (PP 2PA PP).**

**The ESC generated at the front of the tested arrangement that contained internal PA layer and PP external layer is shown in Fig. 7. It was observed that during exhalation, ESC recorded negative value reached -600 volts at the surface of the mask, where the negative charges extended to 16 mm in front of the mask. Inhalation showed relatively lower ESC values that extended to 13 mm. It seems that when the air passes through PP fibers, it increases the negative charge generated on their surfaces. Because viruses including COVID-19 have negative charge, PP fibers will be able to repel the viruses away. The inner layer made of PA fibers that would be positively charged due to their contact and separation with PP fibers caused by inhalation and exhalation so that their ability to capture viruses increased.**

**Figure 8 shows ESC measured on the mask external layer for the (2PA PP) arrangement, where exhalation and inhalation recorded -1250 and -500 volts respectively. The negative charge extended to 10 mm for exhalation and 16 mm for inhalation. That observation is promising in constructing the layers of both PP and PA.**

**ESC generated on the outer layer of the mask (PA PP PA PP) is illustrated in Fig. 9. Although the magnitude of ESC was relatively low, the negative charge extended to 17 mm for both exhalation and inhalation. The inner layer was made of PA of positive charge due to its contact and separation with PP. In this condition, it is expected that inner PA layer could attract the negative charged viruses so that the safety of other people close to mask wearer can be enhanced. The outer PP layer provided the zone in front of the mask by negative electric field that might be able to repel the viruses away. Illustration of the function of the proposed mask (PA PP PA PP) to resist the virus of Covid-19 by the use of ESC is shown in Fig. 10.**

**The mask (PP 2PA PP) gained relatively higher ESC in the front surface, Fig. 11. The negative charge extended to 6 mm for exhalation, but for inhalation it extended to 16 mm. The magnitude of ESC was -650 and -430 volts for exhalation and inhalation respectively. Presence of negative charge on the face of the mask can be considered as a solution to exert a repulsive force against the viruses. The positively charged external layer increases the risk of the external surface of the facemask to be touched. Negative or positive ESC generated on the skin and hair due to the contact and separation with the facemask will be released because the human body is considered as good conductor. While, the ESC generated on the mask will stay due to the good insulation property of its polymeric materials. Further studies should be carried out to investigate the role of ESC generated on the fibers of surgical facemask in defeating the viruses.**

## CONCLUSIONS

**1. ESC generated on the outer surface of the PA mask showed positive values. The mask has the ability to capture the negatively charged viruses. It is advised to use that mask for the people who has infected.**
**2. When the inner layer was PP and the outer one was PA, positive ESC was measured on the outer surface of the facemask. This arrangement is not recommended for the medical facemask because the mask attracts the viruses instead of repelling them.**

**3. ESC generated at the front of the tested arrangement (PA and PP) recorded negative value, where the negative charges extended to 16 mm in front of the mask.**
**4. The mask (PA PP PA PP) generated ESC of negative charge extended to 17 mm in front of mask. It is expected that inner PA layer could attract the negative charged viruses in a manner that the safety of other people close to mask wearer could be enhanced. The outer PP layer provided the zone in front of the mask by negative electric field that was able to repel the viruses away.**

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