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ENHANCING THE PERFORMANCE OF THE MEDICAL FACEMASK

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ABSTRACT
There is an increasing demand to develop the filtration efficiency of facemask materials and decrease their airflow resistance. The present work proposes a method of concentrating the electric field in front of the facemask to repel the viruses. This proposal may keep the airflow resistance constant. The present work aims to use the electrostatic charge (ESC) generated from the triboelectrification of the PP layers of the medical facemask to repel the negative charged viruses such as Covid-19 out of the facemask. The effect of the separation of the PP layers by PP and PE nets as well as paper sheet on the magnitude of the ESC generated from the friction of air flowing through the PP filter layers is investigated.

It was found that, the highest negative ESC was presented by PP layers separated by PP net followed by PE net due to the increase of the charged surface area, while the three layers of PP generated relatively lower values. Besides, inserting paper spacer between PP layers generated relatively higher values of ESC. The highest ESC values were observed for PP net inserted after the first internal PP layer followed by the arrangement that contained PP net as the first internal layer. When ESC increased, the intensity of the electric field increased and consequently the ability of the fibers to repel negative charged fibers increased due to the increase of the electric force. It is advised that electric field outside the fibers should be strong enough to repel viruses and prevent them from passing through the fibers.

KEYWORDS
Facemask, COVID-19, microfibers, polypropylene, polyethylene net.

INTRODUCTION
Medical facemasks are used to protect the wearer from airborne contaminants and viruses and increase safety. Recently, it was revealed that when the air from exhalation and inhalation passes through PP fibers of the facemask, it generates negative ESC supposed to repel viruses including COVID-19 of negative charge, [1]. That was one of the trials to get benefit of ESC to enhance the filtration efficiency of the PP facemask.

Electrostatic charged microfibers are widely used in facemasks, [2, 3], where facemask should protect the people specially who are working in medical care, [4]. Due to the spread of the coronavirus (COVID-19), the people are urged to use surgical masks to prevent the spread of the virus, [5, 6]. Non-woven PP was used to manufacture the masks, [7 - 9]. Due to the contact between the mask and the skin, ESC is generated in form of double layers of positive charge on the skin and negative charge on the PP mask, [10 - 12]. It was revealed that most viruses have a negative charge, [13], including COVID-19. Based on that, it is essentially to provide negative electric field in front of the facemask to repel the viruses away, [14].

It was recommended to manufacture the medical protective equipment such as facemask from materials that gain negative ESC when being in contact with other materials. According to that, PP should be selected, [15], while polyamide (PA), polymethyl methacrylate (PMMA), silk and cotton should be avoided. Eyeglasses and goggles should be made from PP, PE and PVC, because they gain negative ESC, [16]. ESC can ionize the air and offer zoon of negative electric field. The above mentioned precautions should be followed in hospitals, [17], where the materials of shoes and shoe covers should be from PP and PE respectively. PE gloves are recommended because they gain strong negative ESC able to repel the viruses of negative ESC, [18, 19]. PP and PMMA microfibers were proposed as materials for facemask, [20]. The function of PMMA as inner layer is to capture the negatively charged viruses like COVID-19, while the outer layer consisted of PP microfibers.

Nanofibers of polar materials exhibited higher removal efficiency, [21, 22], by nanofibers, [23] and electret nanofibers, [24] and increased the filtration efficiency. When the nanofibers were polarized by electric field, neutral solid contaminants passing through the nanofibers became polarized. The electrostatic attractive force, [25, 26], adhered the contaminants onto the nanofibers. The filtration performance is influenced by the electric field rather than the mesh size of the nanofibers.

It was found that the contact electrification is caused by the electron transfer between the two contacting materials, [27 - 30]. The transferred electron is slightly bound to the surface atoms after the separation of the two materials. The assumption of the dependency of filtration efficiency on the pore size of the filtering materials should be integrated with the ability of the materials to be triboelectrified. It was proved that the tested materials reported significant increase in filtration efficiency when tested after charging. Because ESC dissipates due to adsorption of water molecules in the air, it is essential to apply hydrophobic polymeric materials for medical facemask to make benefit of ESC to increase filtration properties. Because polypropylene is more hydrophobic than cotton, polyamide and silk, it is recommended and can be covered by external layer of polyester or polyurethane fabrics.

It is known that the mesh size of textile is too coarse to capture submicron sized viruses entering the respiratory system. Generating ESC on the surfaces of fibers, good respiratory protection is guaranteed. When the polymeric fibers are charged by the friction of air, ESC can generate E-fields in front of the filter. The present work discusses

the effect of separating PP layers by PP and PE nets as well paper sheet on the magnitude of the generated ESC on the surface of PP filter textile.

EXPERIMENTAL

Exhaling and inhaling have been repeated five times to measure ESC generated in front of the tested materials. Experiments were carried out to measure the ESC generated on the tested facemask. The Ultra stable surface DC voltmeter was applied to measure ESC. The procedure of the measurement is represented in Fig. 1. PP textile, Fig. 2, PP net and PE net were tested as filtering materials for the facemask. The order of the tested materials is shown in Fig. 3 to search for the proper design.

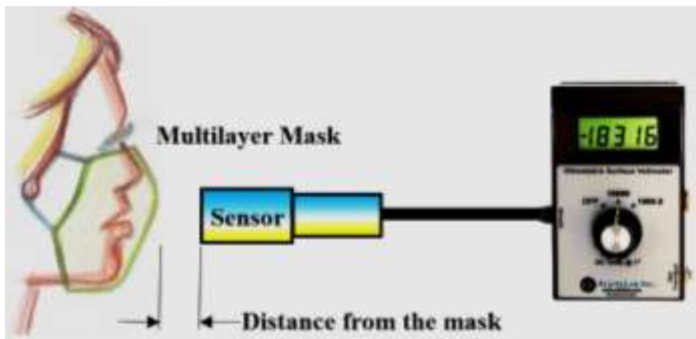


Fig. 1 Measurement of ESC.

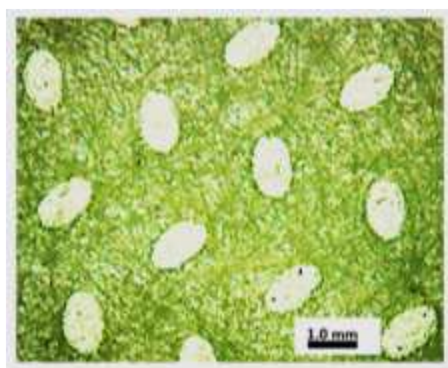


Fig. 2 Microphotogragh of the PP filter.

Fig. 3 The details of PE Net.

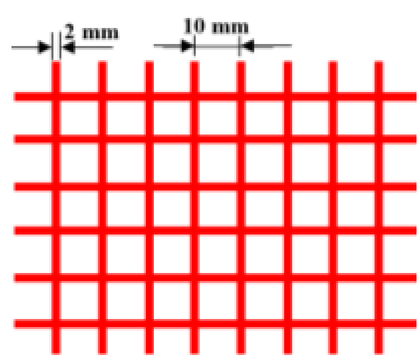
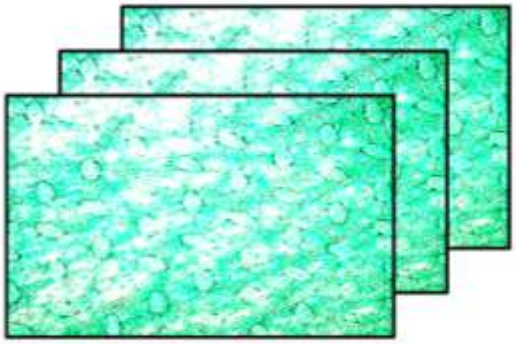
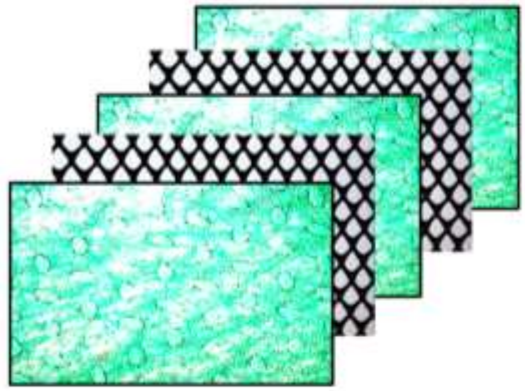
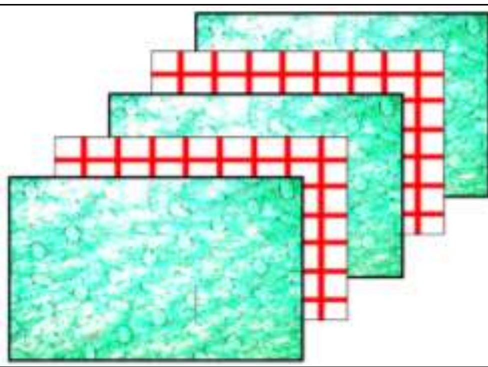
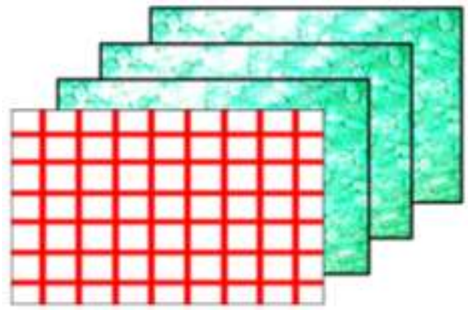
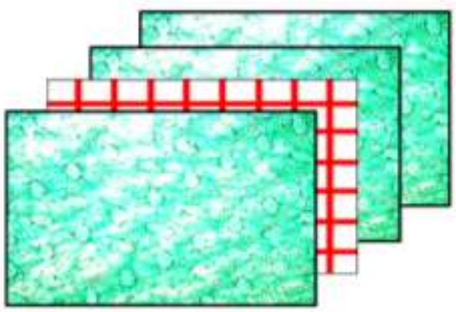
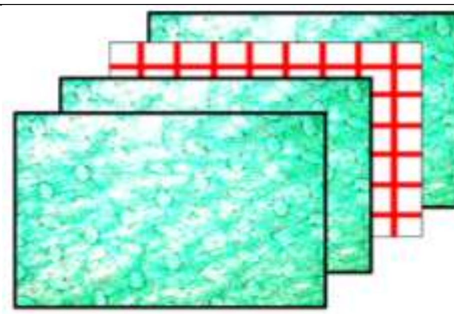
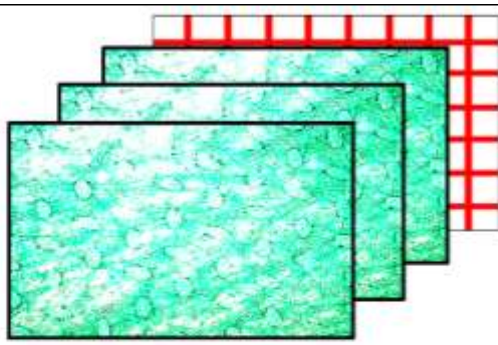
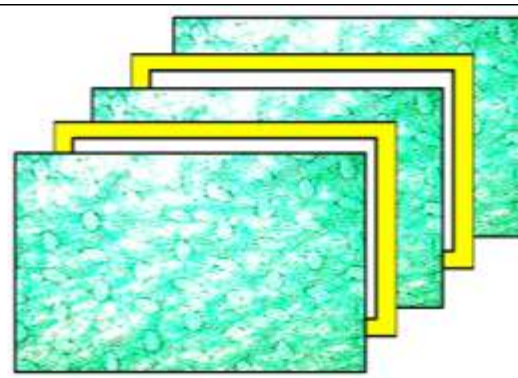


Fig. 4 The details of PP Net.

Table 1 The order of the tested materials.

	
3 PP	**PP PE Net PP PE Net PP**
	
PP PP Net PP PP Net PP	**PP Net 3 PP**
	
PP PP Net 2 PP	**2 PP PP Net PP**
	
3 PP Net PP	**PP Spacer PP Spacer PP**

The objective of the present work is use the ESC generated from the triboelectrification of the PP layers of the medical facemask to enhance its performance. The use of PP can repel the negative charged viruses such as Covid-19. It is aimed to investigate the effect of the separation of the PP layers on the magnitude of the ESC generated from the friction of air flowing through the PP filter layers. PP layers have been separated by PP net, PE net and paper sheet of 0.25, 0.75 and 0.4 mm thickness respectively, Table 1. ESC has been measured to select the best arrangement that generates the highest negative ESC to repel the viruses in front of the facemask.

RESULTS AND DISCUSSION

The comparative performance of the three layers of PP textile and that separated by PP net and PE net is shown in Fig. 5. ESC as function of the distance in front of the facemask during exhaling showed that inserting PP net generated the highest value of ESC followed by PE net. When the layers were put together, the intensity of ESC was lower than that generated from the separated layers because the surface area activated by ESC was smaller, Fig. 6. Separation of the layers increased the magnitude of ESC because the surface area increases. As result of that, the e-field intensity in front of the facemask may increase. It seems that the double layer of ESC generated on the sliding surfaces generated an E-field inside the gap. Illustration of the increase of ESC caused by the separation of PP layers is shown in Fig. 7.

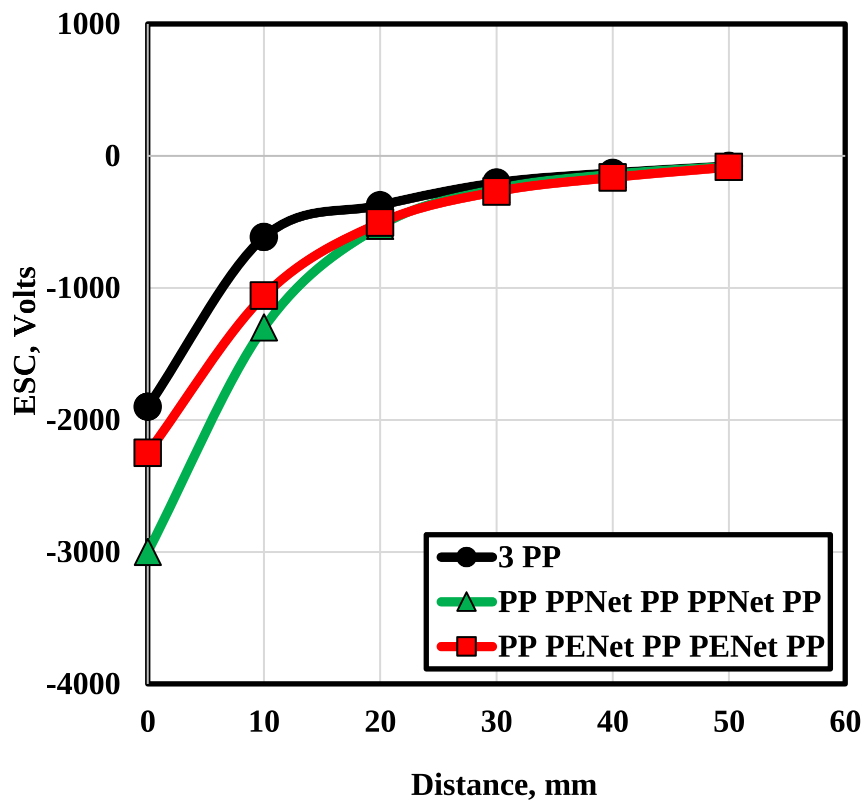


Fig. 5 ESC as function of the distance in front of the facemask during exhaling.

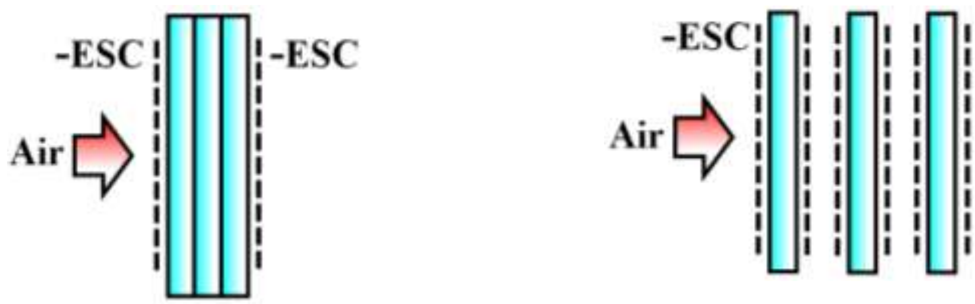


Fig. 6 ESC distribution for the tested PP layers.

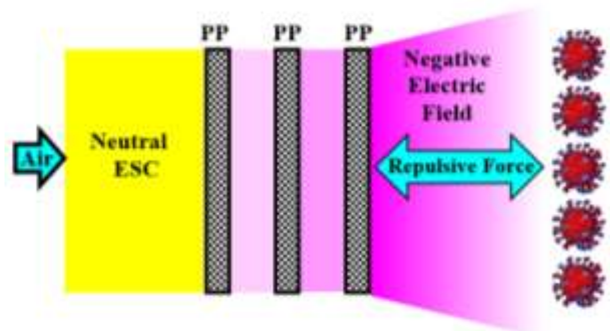


Fig. 7 Illustration of the increase of ESC caused by the separation of The PP layers.

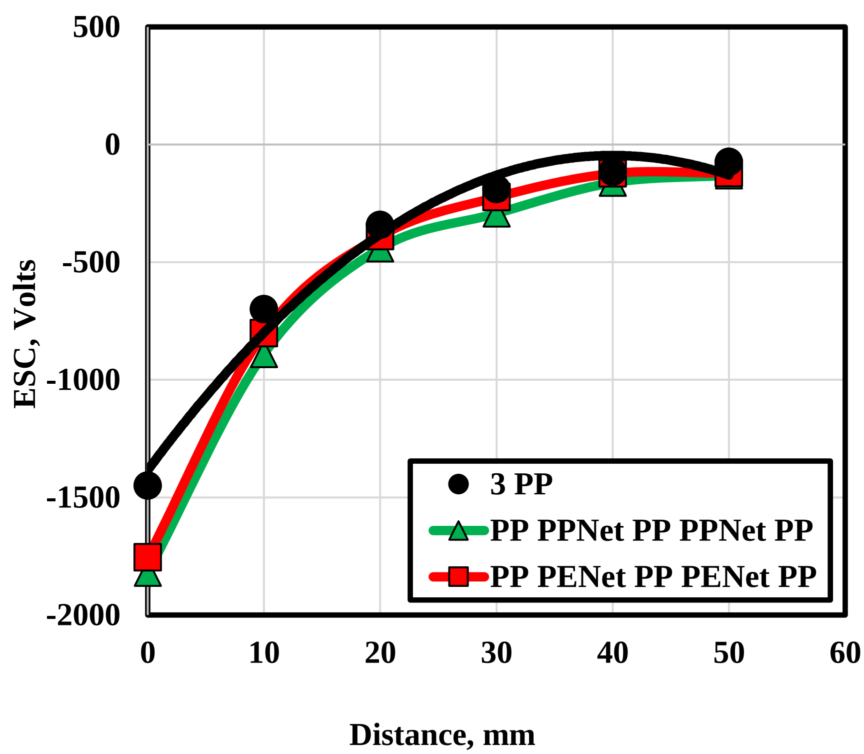


Fig. 8 ESC as function of the distance in front of the facemask during inhaling.

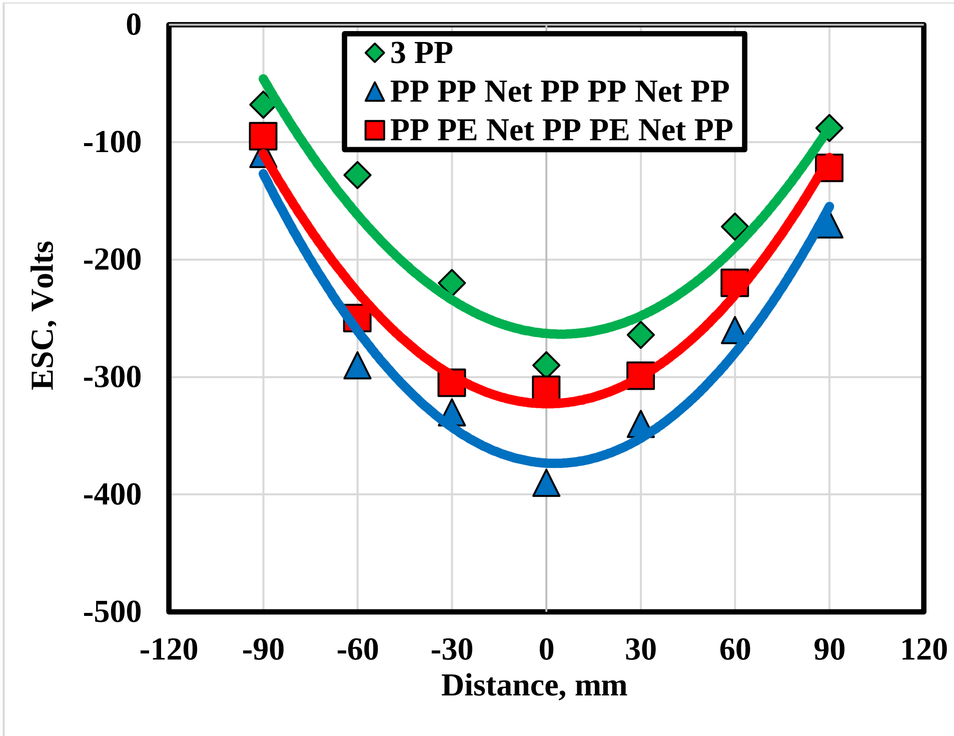


Fig. 9 Distribution of ESC as function of the distance in front of the facemask during exhaling in the transverse direction.

During inhaling, ESC recorded lower values than that observed in exhalation, Fig. 8. Distribution of ESC as function of the distance in front of the facemask during exhaling in the transverse direction is shown in Fig. 9. ESC recorded the highest values in the center and the value decreased as the distance increased to the two sides. The effect of ESC extends to 100 mm on both sides. The highest negative ESC was presented by PP layers separated by PP net. This can be interpreted on the bases that air triboelectrifies PP net and generates higher values of ESC than that generated from the friction of air with PE net.

Inserting paper spacer caused relatively higher values of ESC, Fig. 10, where the value reached -3500 volts at the surface of the PP outer layer. As the distance from the surface increased, ESC decreased. The location of inserting PP net into the three layers of PP is illustrated in Fig. 11. When PP net was inserted after the first internal PP layer, ESC recorded the highest values followed by the arrangement that contained PP net as the first internal layer. It seems that the separation of the first two PP layers by PP net is the reason for that behavior. Besides, because PP is strongly triboelectrified by air due to its position in the tribelectric series, ESC significantly increased. The same trend was observed for PE net inserted into the PP layers, Fig. 12. The value of ESC was lower than that observed for PP net.

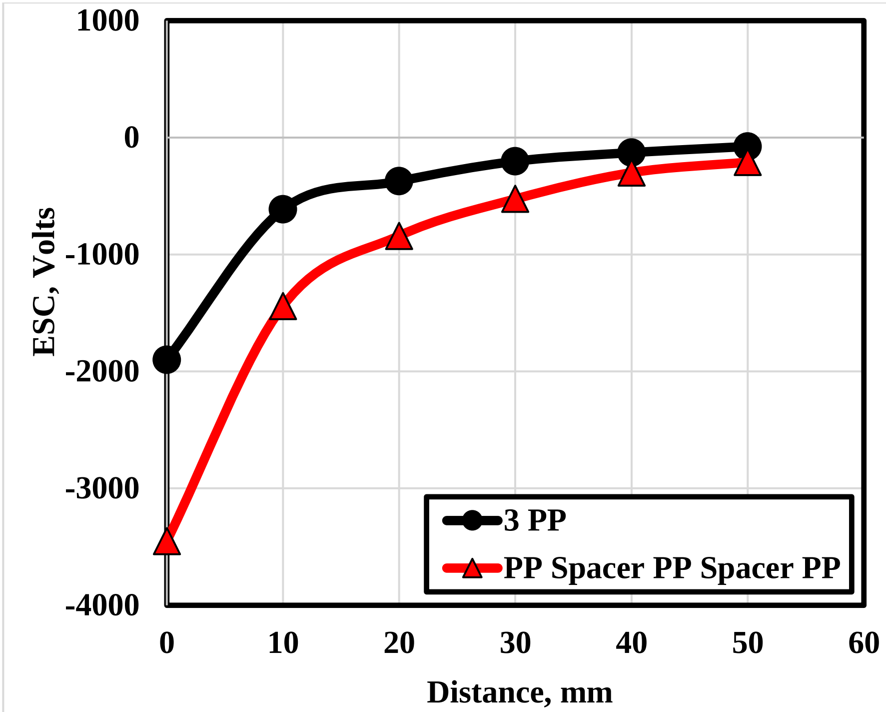


Fig. 10 ESC as function of the distance in front of the facemask during exhaling.

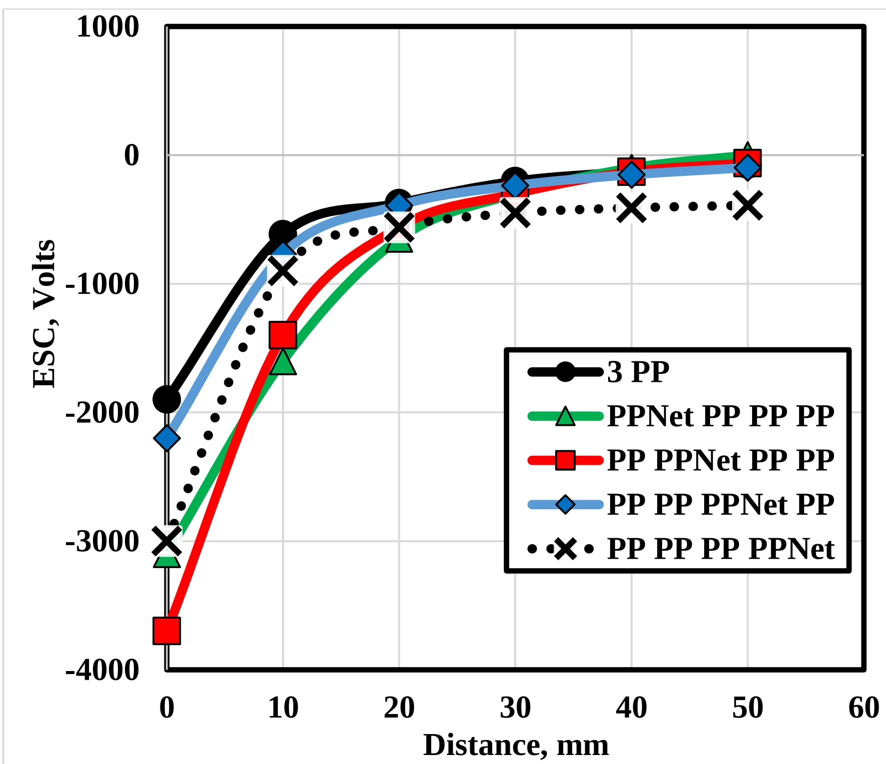


Fig. 11 ESC as function of the distance in front of the facemask during exhaling.

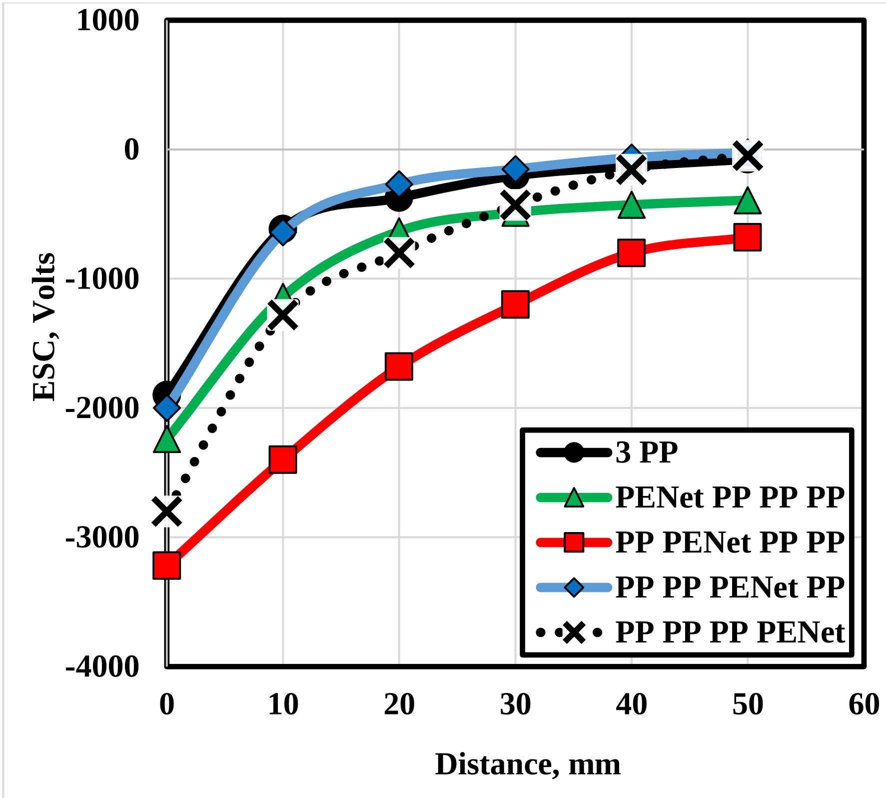


Fig. 12 ESC as function of the distance in front of the facemask during exhaling.

It was found that when the layers were separated, ESC increased, where the strength of the electric field (E-field) was proportional to the value of the generated ESC, [31 – 33]. It is known that the polymeric fibers develop ESC from air passing through them, where they get charged. The contact of fibers with each other caused by the air stream may generate ESC on the surface of the fiber.

As the magnitude of ESC increases, the intensity of the electric field increases and consequently the ability of the negatively charged fibers to repel negative charged viruses increases due to the increase of the electric force. When the fibers are charged by the same sign, the electric field outside the fibers may be relatively high. In the other side, the electric field between the charged fibers may be low. It is preferable that electric field outside the fibers should be strong enough to repel viruses and prevent them from passing through the fibers. The electric field will polarize the neutral particles by inducing dipole, where the magnitude of the dipole will be proportional to strength of the electric field. In this condition the neutral particle will be attracted to fibers regardless their sign of ESC.

CONCLUSIONS

1. Separating the three layers of PP textile by PP net generated the highest value of ESC followed by PE net due to the increase of the charged surface area. The three layers of PP without separation generated relatively lower values of ESC.
2. Inhaling generated lower ESC values than that observed in exhalation.

3. The effect of ESC extended 200 mm in in the transverse direction, where the highest values were measured in the center.
4. Inserting paper spacer between PP layers caused relatively higher values of ESC.
5. The highest ESC values were observed when PP net was inserted after the first inernal PP layer followed by the arrangement that contained PP net as the first internal layer.
6. The same trend was observed for PE with relatively lower values of ESC.

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