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DEVELOPING THE PERFORMANCE OF THE MEDICAL FACEMASK TO RESIST COVID-19

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ABSTRACT
The present work aims to develop the electrostatic charge (ESC) generated from the triboelectrified fibers of polypropylene (PP) layers of the medical facemask caused by the air of inhalation and exhalation to repel the negative charged viruses such as Covid-19 out of the facemask. The effect of separating PP layers by different materials on ESC is investigated. The tested materials are copper and iron coils wrapped on cartoon spacer of 0.5 mm thickness and inserted between the PP layers. PP and PE nets as well polytetrafluoroethylene (PTFE) strings were tested as separating materials. In addition to that, carbon fibers and copper textile were tested. Fibrous polyester (PET) strings of 2.0 and 3.0 mm diameter weaved in PP middle layer were inspected.

It was revealed that the surface area activated by ESC increased in condition of the separation of PP layers. As result of that, the electric field induced inside the gap in front of the facemask increased, where the effect of the electric field induced by copper and iron wires was significant. Besides, presence of the wires and strings inserted between PP layers increased the gap between PP layers and therefore increased ESC. Inserting PP and PE nets between PP layers increased ESC due to the increase of area rubbed by air. Conductive materials such as copper textile and carbon fibers generated relatively lower ESC than that generated in the presence of polymeric spacers due to the leakage of ESC from the charged PP layers. Insulated copper wires showed higher ESC than uninsulated ones. Fibrous PET strings weaved in PP layers showed the highest values of ESC due to increase of their surface area.

KEYWORDS
Facemask, COVID-19, microfibers, polypropylene.

INTRODUCTION
Medical facemasks should protect the wearer from viruses. Few attempts were carried out to develop ESC generated from the air passing through PP fibers of the facemask. When the fibers are made of PP, it generates negative ESC supposed to repel viruses including

COVID-19 of negative charge, [1, 2]. PP fibers were recommended as external layer for the facemask to repel the viruses of negative charge such as COVID-19. Protection from COVID-19 viruses suggests filtration fineness of 0.01 μm particle size or less. It is advised to use ESC to develop the filtration efficiency of the facemask. When PP layers were separated by PP and PE nets the magnitude of ESC increased.

Electrostatically charged microfibers are used in facemasks, [3 - 5]. Surgical facemasks are extensively used to prevent the spread of the coronavirus (COVID-19), [6, 7], where non-woven PP was used, [8 - 10]. Because of the contact between the mask and the skin, double layers of ESC are generated of positive and negative charge on the skin and PP mask respectively, [11 - 13]. It was mentioned that most viruses have a negative charge, [14], including COVID-19. According to that, it is necessary to develop the negative electric field generated in front of the facemask to repel the viruses away, [15].

It was recommended to manufacture the medical protective equipment such as facemask, eyeglasses and goggles from PP, polyethylene (PE) and polyvinyl chloride (PVC) that gain negative ESC, [16 - 18], while polyamide (PA), polymethyl methacrylate (PMMA), silk and cotton should be rejected. The function of ESC is to ionize the air and provide zoon of negative electric field. The materials of shoes and shoe covers used in hospitals should be from PP and PE respectively. PE gloves are favorable because they gain strong negative ESC, [19, 20]. It was proposed PP and PMMA microfibers as materials for facemask, [21]. PMMA was used as inner layer to capture the negatively charged viruses like COVID-19, while PP microfibers were used as outer layer.

Polar nanofibers exhibited higher removal efficiency and increased the filtration efficiency, [22 - 25], by nanofibers and electret nanofibers. The polarized nanofibers by electric field can polarize the neutral solid particles passing through the nanofibers. The electric force, [26, 27], adhered the particles onto the nanofibers.

It was proved that small air ions are necessary for life, [28]. Because they are microbiocidal, they reduce infection and contamination. They are found in low levels. When air is bipolar ionized, the ability of the body to fight disease may be significantly improved. Surface charge modification was carried out by providing the surface of the implants by negative charge to promote the osseointegration of titanium biomaterials. It was found that the negative charge significantly enhanced their osseointegration to the living bone due to the selective osteoblasts activation and fibroblasts inhibition, [29 – 31]. Those observations should be carefully investigated to explore the role of the negative ESC in defeating viruses.

Submicron sized viruses entering the respiratory system cannot be captured by the mesh size of textile. Developing ESC on the surfaces of fibers, high respiratory protection can be guaranteed. As the polymeric fibers are charged by the friction of air ESC generates E-fields in front of the filter. In the present work, the influence of separating PP layers by different materials on generation of ESC is investigated.

EXPERIMENTAL

The proposed materials were tested by exhaling and inhaling ten times and ESC generated at different distances in front of the tested materials was measured by ultra stable surface DC voltmeter. The procedure of the test is shown in Fig. 1.

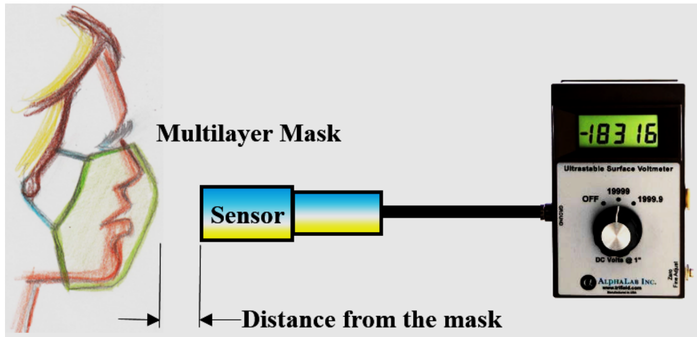
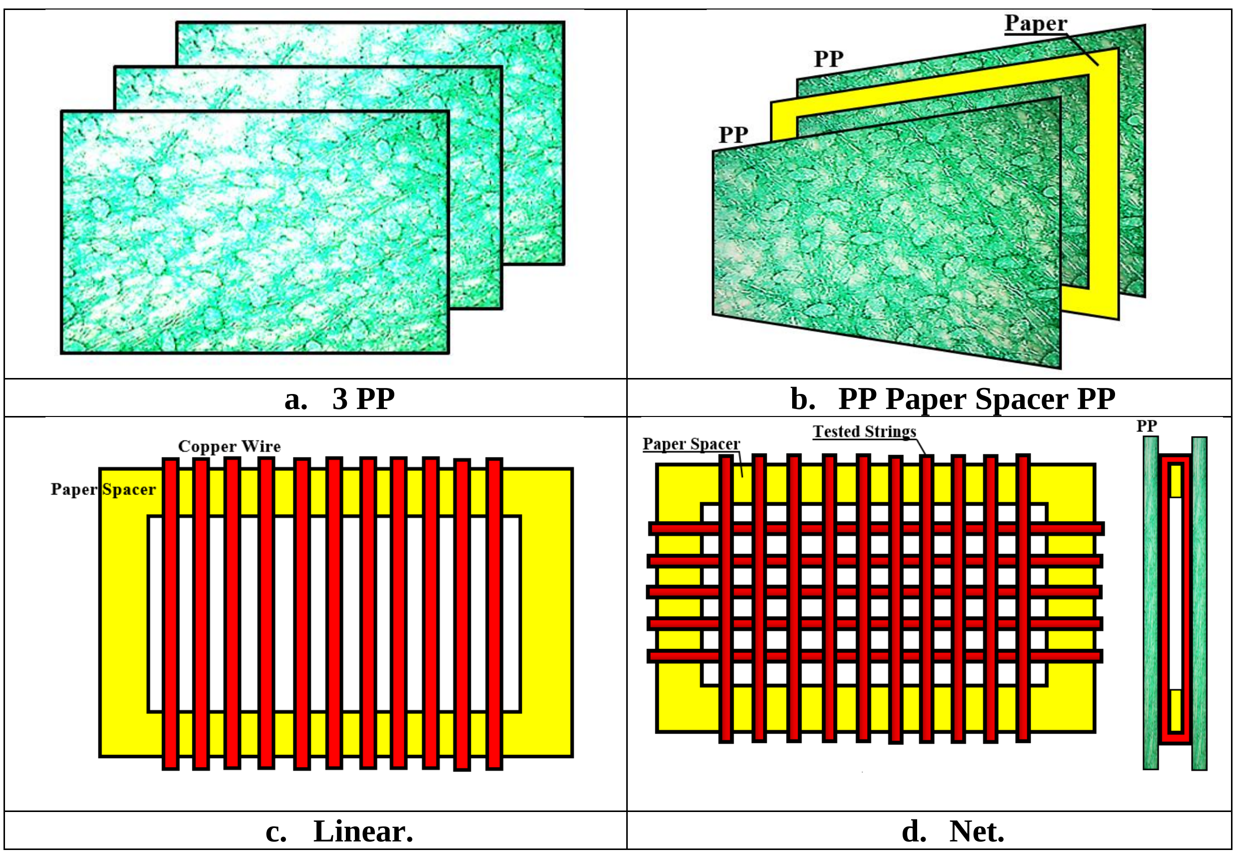
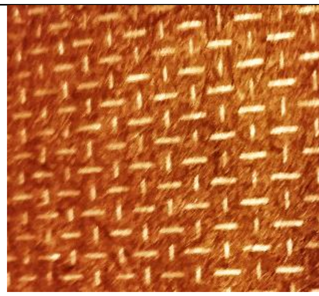


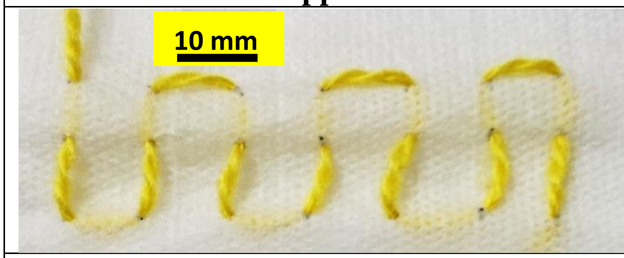
Fig. 1 Measurement of ESC.



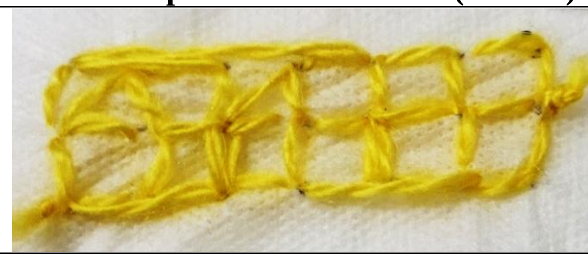


e. Copper textile.

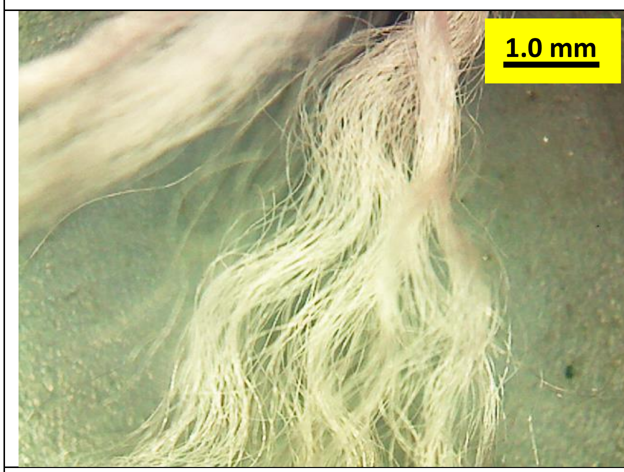
f. Simple Weaves of PET I (3.0 mm).



g. Simple Weaves of PET II (2.0 mm).

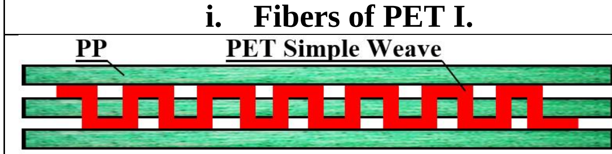


h. Increased Area of Simple Weaves of PET II.

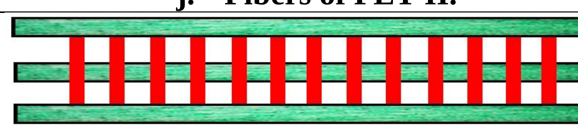


i. Fibers of PET I.

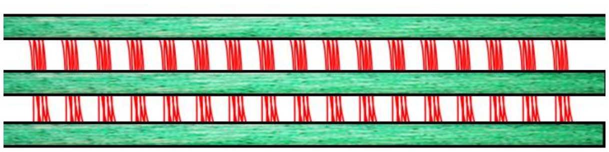
j. Fibers of PET II.



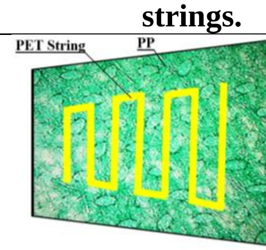
k. The tested facemask with PET simple weaves.



l. The tested facemask with PET strings.



m. The tested facemask with PET fibers.



n. PET strings in PP

Fig. 2 The tested materials.

Copper and iron wires wrapped on cartoon spacer of 0.5 mm thickness and inserted between the PP layers were investigated. The diameters of the tested copper and iron were 0.1, 0.2, 0.3, 0.4 and 0.5 mm. Besides, PP and PE nets as well polytetrafluoroethylene (PTFE) strings were tested. Carbon fibers and copper textile were used to investigate the conductivity of the materials on ESC generated from the friction of air with those materials. Fibrous polyester (PET) strings of 2.0 and 3.0 mm diameter weaved in the middle PP layer of different density were checked. The tested materials are shown in Fig. 2.

RESULTS AND DISCUSSION

The aim of the present work is to apply the ESC generated from the triboelectrification of the PP layers of the medical facemask to enhance their function. The use of PP can repel the negative charged viruses such as Covid-19. It is aimed to develop ESC generated on the facemask by separating the PP layers and introducing air gap between them using the tested materials.

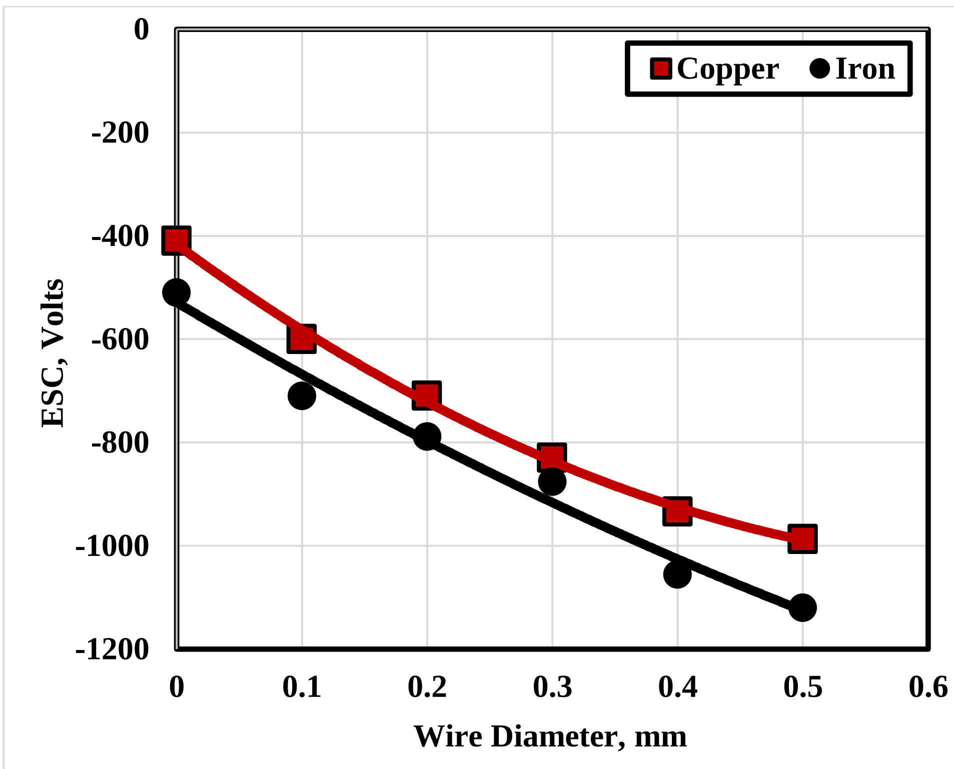


Fig. 5 ESC generated from PP separated by copper and iron wires of different diameters.

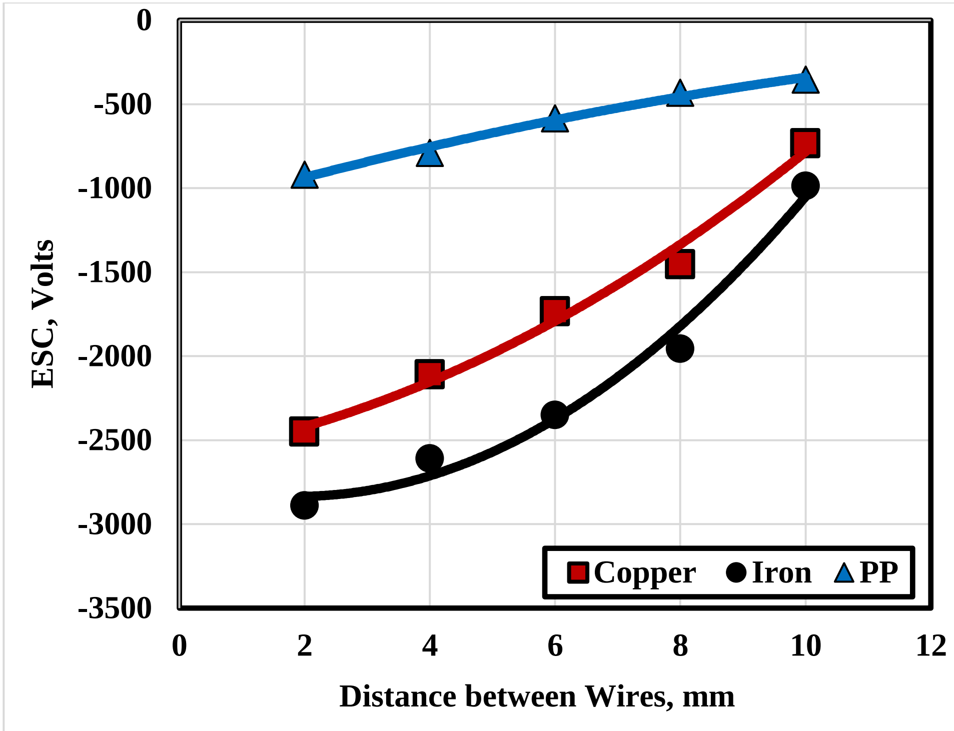


Fig. 4 ESC generated from PP separated by copper and iron wires as well as PP strings of 0.5 mm diameter.

ESC generated from the friction of air with three layers of PP textile and that separated by copper and iron wires is shown in Fig. 3. ESC as function of the diameter of the tested wires during exhaling and inhaling showed significant increase with increasing the wires diameter. PP layers without wires generated the lowest values of ESC. Iron wires caused higher values of ESC. It seems that the electric field generated as result of ESC as well iron wires are responsible for the increase. Figure 4 shows ESC generated from PP separated by copper and iron wires as well as PP strings of 0.5 mm diameter, where PP strings displayed lower ESC than copper and iron wires confirming the effect of the electric field induced by copper and iron wires. When the distance between wires increased i.e. the density decreased, ESC decreased. The presence of the wires and strings increased the gap between PP layers and therefore increased ESC. That was the reason of the increase of ESC in the presence of PP strings.

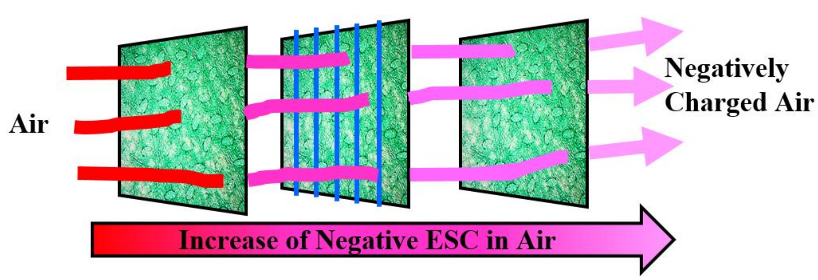


Fig. 5 Illustration of the increase of ESC generated on the surfaces of the PP layers.

It was found that when the layers were separated, ESC increased, where the strength of the electric field was proportional to the value of the generated ESC, [32 – 34]. It seems that the surface area activated by ESC increased in condition of the separation of PP layers. Consequently, the electric field intensity in front of the facemask increased. Besides, the double layer of ESC generated on the sliding surfaces generated induced electric field inside the gap, Figs. 5 and 6. When air passes through polymeric fibers, it generated ESC on their surfaces, where they get charged. It is well known that the strength of the electric field is proportional to how much ESC is generated. That is because the double layer of ESC generated on the PP surface would generate electric field inside the gap. Added to that, presence of copper and iron wires would generate extra ESC on the sliding surfaces due to the electric field generated on PP surfaces.

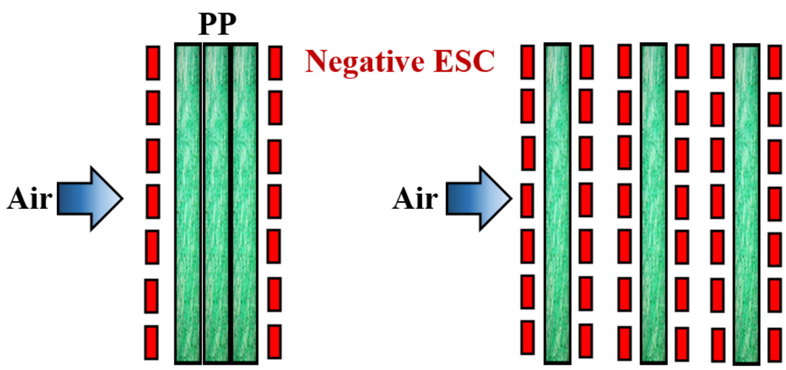


Fig. 6 ESC distribution on the surfaces of the tested PP layers.

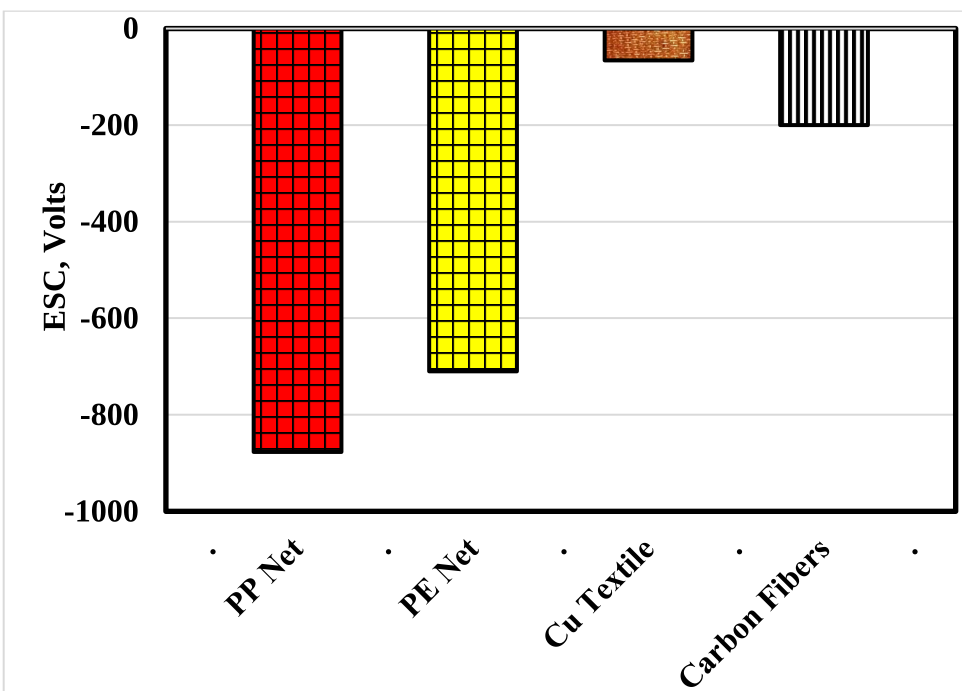


Fig. 7 ESC generated from PP separated by PP and PE net as well as copper textile and carbon fibers.

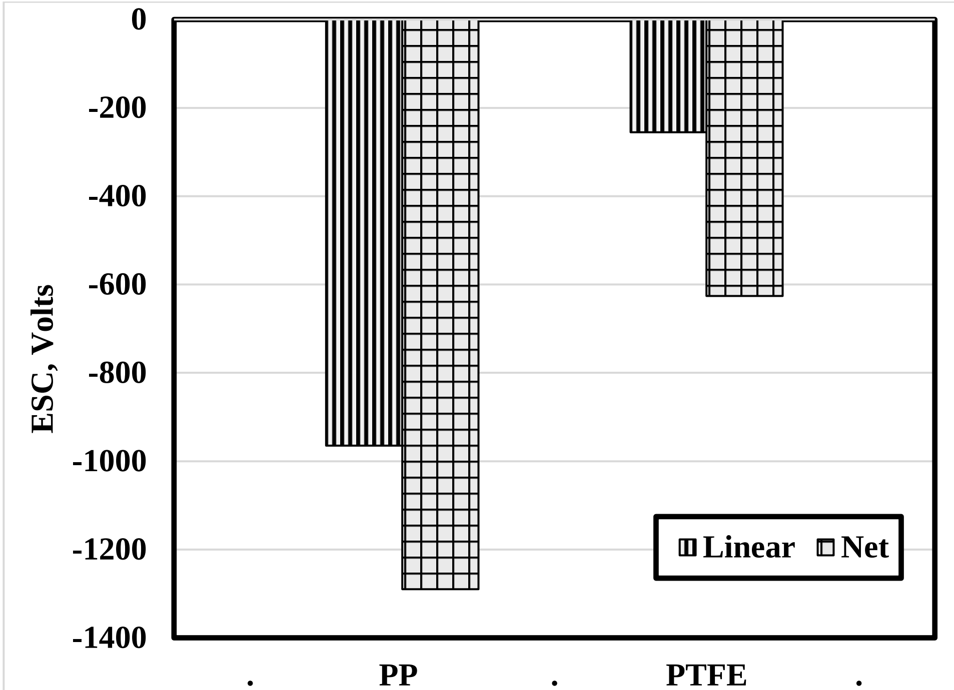


Fig. 8 ESC generated from PP separated by PP and PTFE strings.

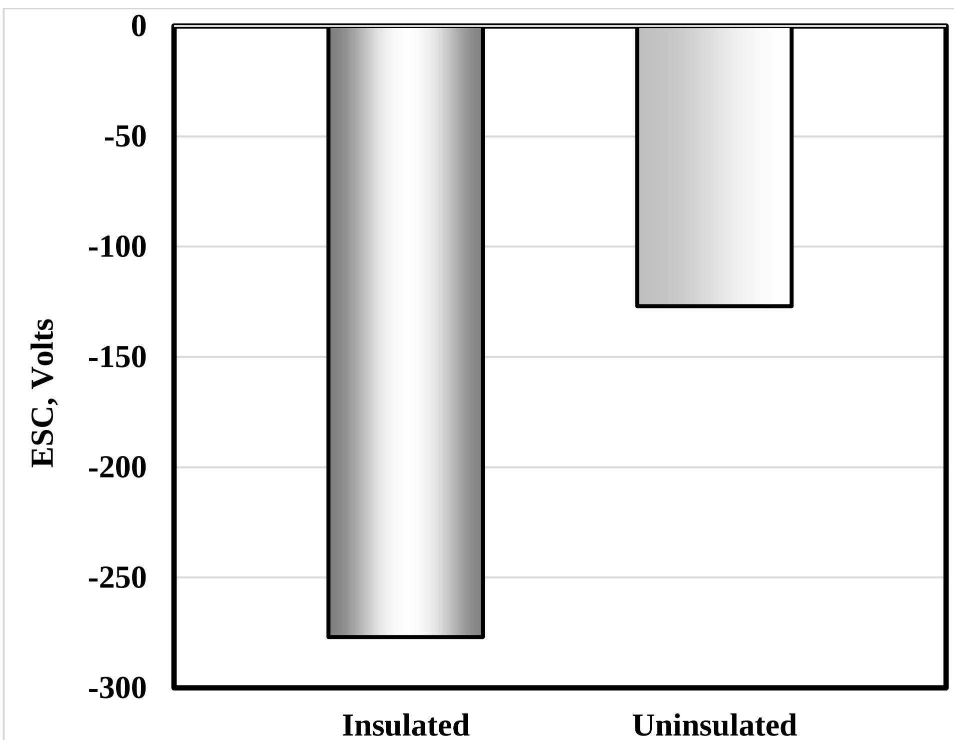


Fig. 9 ESC generated from PP separated by copper wires.

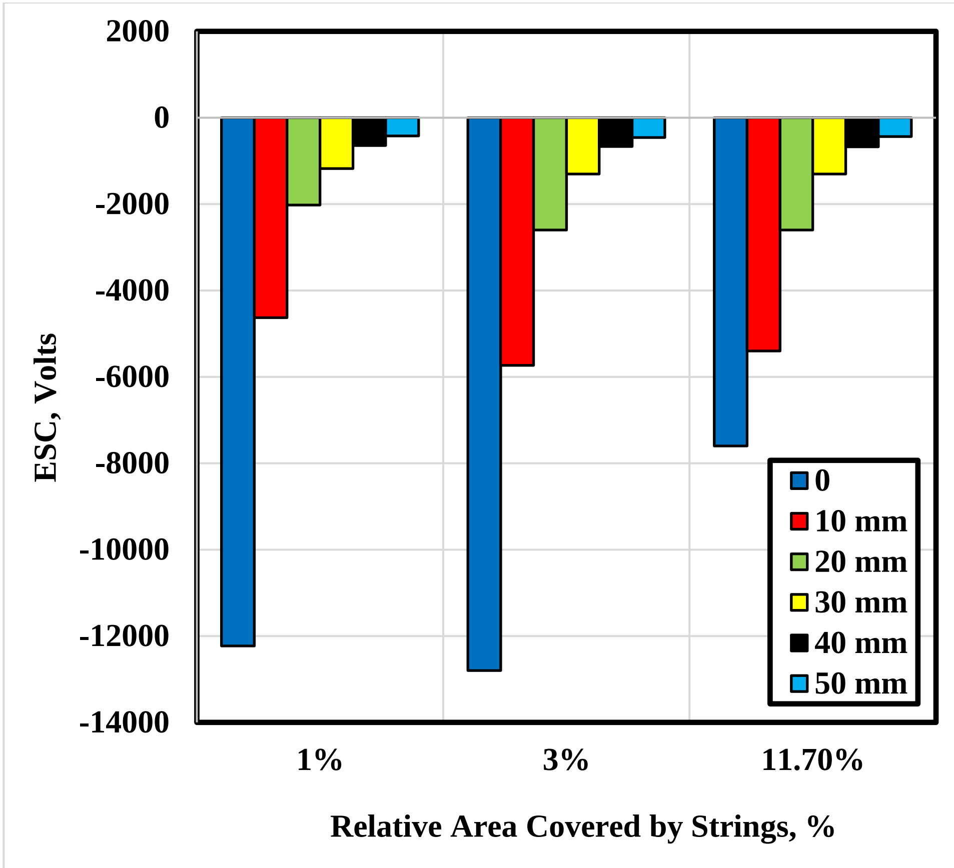


Fig. 10 Effect of the relative area covered by PET strings on ESC.

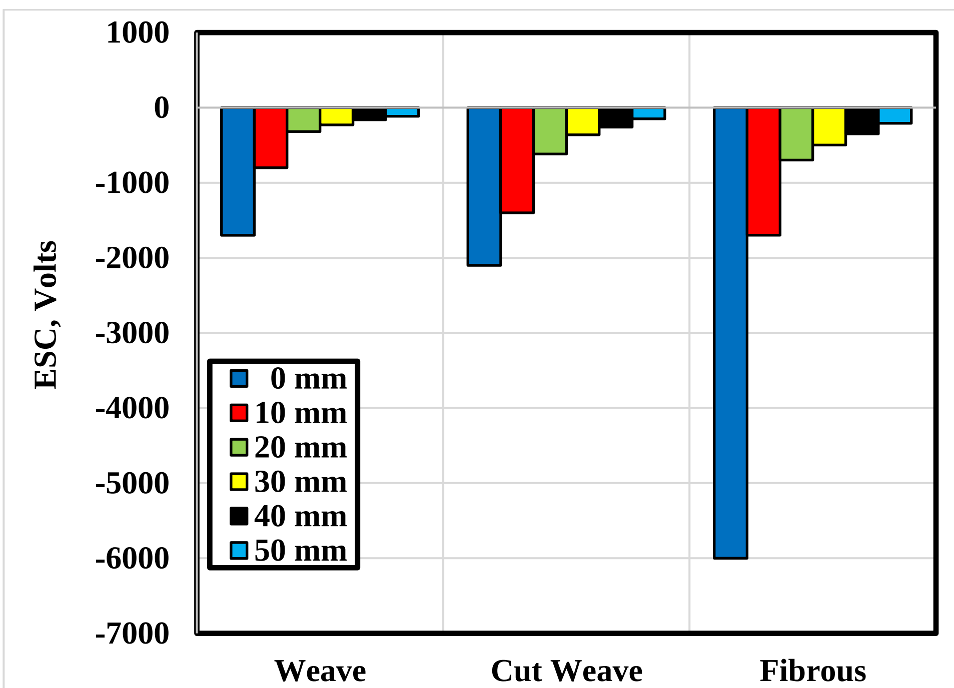


Fig. 11 Effect of the fibers of PET strings on ESC.

The effect of the distribution of the PP and PTFE strings on the generated ESC is shown in Fig. 8, where the strings distributed as net generated relatively higher ESC, because the area subjected to the friction of the air increased. It is shown that both PP and PTFE nets generated higher ESC than the linear strings. Besides, the insulated copper wires displayed higher ESC than the uninsulated wires because the uninsulated wires leak ESC, Fig. 9.

Figures 10 and 11 displayed ESC generated in front of the PP layers separated by PET strings. The effect of the relative area covered by PET strings on ESC is shown in Fig. 10. Increasing the relative area of PET up to 3 % showed an ESC increase then ESC decreased with increasing the PET area due to the resistance offered by the strings against air flow. Generally, ESC decreased with increasing the distance in front of the PP layers. The Effect of the fibers of PET strings on ESC is illustrated in Fig. 11, where fibrous PET, Fig. 2, m, showed the highest values of ESC. This behavior can be attributed to the fact that electrons are formed on the surface of the fibers. As the fibers are scattered their surface area increased and consequently ESC increased.

Based on the experimental results, it was observed that when the magnitude of ESC increased, it is expected that the intensity of the electric field increased in front of PP layers of the facemask. Because the fibers were negatively charged they can repel negative charged viruses. It is desirable that electric field outside in front of the mask should be enough high to repel viruses and prevent them from passing through the PP fibers. The electric field generated in front of the mask can polarize the neutral particles by inducing dipoles, where they will be attracted and adhered to fibers.

CONCLUSIONS

1. The separation of PP layers by different materials increased ESC generated by the friction of air stream with PP fibers. The surface area charged by ESC increased due to the double layer of ESC formed on every PP layer.
2. ESC generated from PP layers separated by copper and iron wires showed significant increase with increasing the wires diameter due to the electric field generated on PP surfaces. Iron wires caused higher values of ESC.
3. Using the materials inserted between PP layers in form of net significantly increased ESC due to the increase of area subjected to the air friction. Besides, insulated copper wires displayed higher ESC than uninsulated ones.
4. Inserting conductive materials such as copper textile as well as carbon fibers generated relatively lower ESC than that generated in the presence of polymeric spacers due to the leakage of ESC from the charged PP layers.
4. Fibrous PET separating PP layers showed the highest values of ESC due to increase of the surface area.

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