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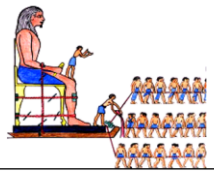

PROPER MATERIAL SELECTION OF MEDICAL GLOVES

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ABSTRACT

The possibility of making use of the electrostatic charge (ESC) generated on the surfaces of polymeric materials of the protective equipment such as gloves is investigated in the present work to develop their efficiency to protect the wearer from viruses. Because most viruses have a negative charge including COVID-19, it is necessary to recognize the sign and magnitude of the ESC generated on the surface of the gloves. Experiments were carried out to measure the ESC generated from rubbing medical gloves by different materials.

It was found that ESC generated from contact and separation as well as sliding of the tested gloves with different materials shows that PE gloves displayed the highest values while nitrile and latex recorded lower values. The relatively high negative ESC generated on PE glove would be able to repel the negatively charged virus out of the surface of the gloves. ESC generated on the gloves from their friction with face mask and face shield showed that latex gloves gained the highest positive values followed by nitrile and PE gloves. On the other side, face shield gained higher ESC than face mask. When the gloves gain positive ESC and both face mask and shield gain negative ESC, the gloves attract the negative charged viruses while face mask and shield repel those viruses away.

Based on that mentioned above, it is recommended to select such materials that gain a strong negative ESC. The relatively high negative ESC generated on PE glove would be able to repel the negatively charged viruses out of the gloves.

KEYWORDS

Electrostatic charge, contact and separation, sliding, surgical gloves, COVID-19.

INTRODUCTION

The increased exposure to electromagnetic fields introduced from electronic in operating rooms has critical influence on diseases like cancers. The intensity of electromagnetic fields was measured during surgery in 18 operating rooms, [1]. It was revealed that electromagnetic field levels exceed 2 mG that recommended by the Swedish Board for

Technical Accreditation. The electrostatic charges (ESC) generated from the dry and water wet sliding of surgical cover against disposable apron of people who are working in hospitals was investigated, [2]. It was found that dry sliding of glove against apron generated much higher ESC measured on the glove. ESC generated from sliding of hair against disposable cap and face mask as well as skin against face mask was tested, [3]. It was found that high voltage (- 4000 volts) was measured from the sliding of the disposable cap on hair.

Triboelectrification is tribocharging phenomenon in which materials rub each other, [4 - 6]. The charge transfer in tribocharging has three mechanisms: electron, ion, and material transfer, [7 – 9]. When two different materials rub each other or come to contact, electrons transfer happens, [10]. Electron transfers happen on the surfaces of insulators, [11–13]. Triboelectric series was introduced to determine the charge polarity of the rubbing materials, [14]. When two different materials contact each other, the upper material ranked in the triboelectric series will be positively charged and the lower one will be negatively charged, [15]. ESC of unstrained and strained latex sheets contacted polytetrafluoroethylene (PTFE), polyurethane (PU) and stainless steel (SS) was studied, [16]. It was revealed that strain strongly influences ESC, where strain produces ions, electrons, and radicals. Triboelectrification was measured from the sliding or rolling frictional contacts between polymers in humid conditions, [17], where humidity enhanced charge transfer, [18]. ESC accumulation is measured as triboelectrification.

The present work investigates ESC generated from the dry contact and separation as well as sliding of surgical glove against the surface of different materials to determine the sign and magnitude of ESC.

EXPERIMENTAL

The present work measured ESC generated from the contact and separation as well as sliding of latex, nitrile, and polyethylene gloves, Fig. 1, on different material surfaces. Ultra Stable Surface DC voltmeter was used. Tests were performed at 15 N load. The tested glove specimens were prepared from latex, nitrile and polyethylene adhered to the loaded surface of wooden cube of 50 × 50 × 50 mm^3. The tested surfaces, (200 × 100 mm^2), were adhered to wooden base.

PE Glove.

Nitrile Glove.

Latex Glove.

Fig. 1 Tested gloves.

The materials of the tested materials include human skin, paper, cotton, aluminium, copper, stainless steel and polymers such as polyethylene (PE), polyamide (PA), polypropylene (PP), polyester (PET) and bakelite. Besides, the outer surface of the face mask and face shield were tested. The glove material was loaded by 15 N and manually pulled horizontally on the tested materials. Each test was replicated five times. The details of the test rig are shown in Fig. 2.

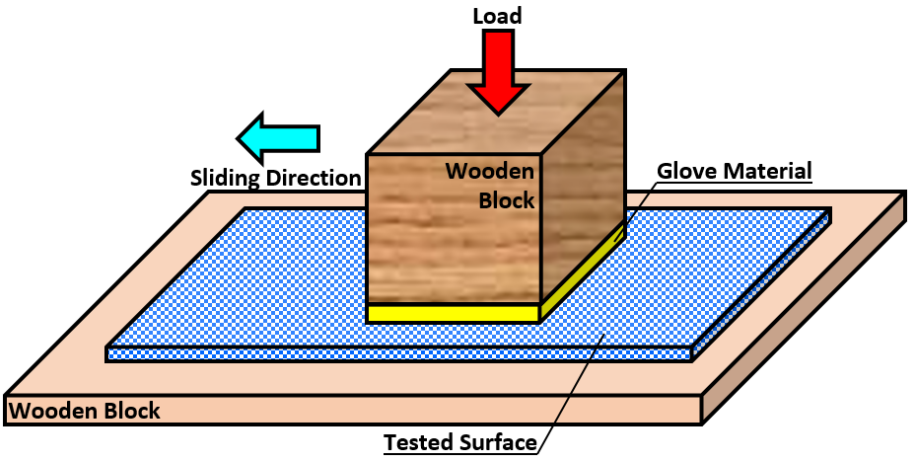


Fig. 2 Details of the test rig.

RESULTS AND DISCUSSION

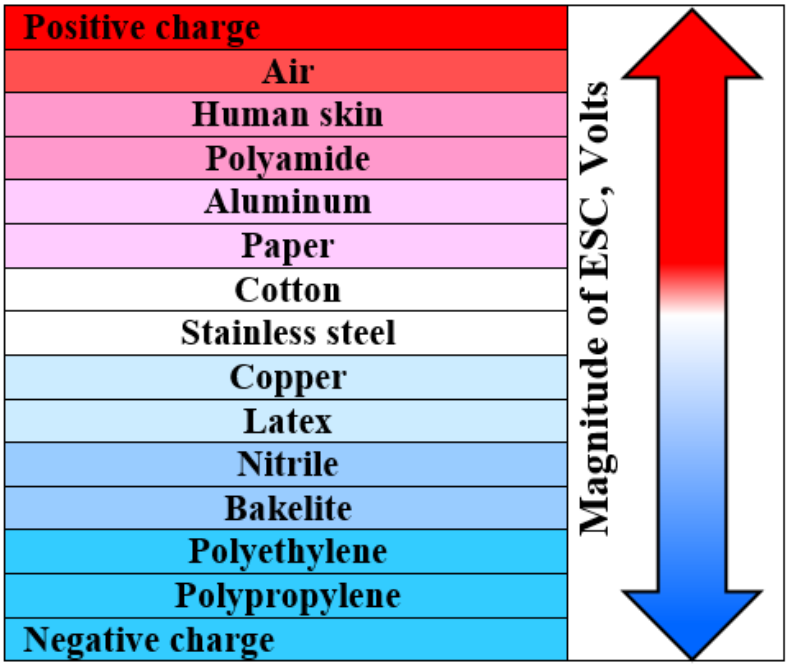
Triboelectrification is the generation of ESC from contact and separation as well as sliding of the materials, where their gain ESC during rubbing. The magnitude and sign of ESC depend on the material. Engineering materials are ranked in the triboelectric series, where the higher positioned ones gain positive ESC when being rubbed or come in contact with another material at relatively lower position in the series, [19]. When the difference in the rank of the two materials increases, the generated ESC increases. Table 1 shows the triboelectric series of the tested materials in the present work.

The measurement of ESC generated from the contact and separation as well as sliding of the tested gloves on the tested surfaces is shown in Figs. 3 - 8. ESC generated from contact and separation shows that PE gloves displayed the highest values when being rubbed all the materials tested, Fig. 3. Nitril and latex showed relatively lower values. Due to the spread of the novel coronavirus (COVID-19), medical gloves can be quite good method to protect the hands from the virus. Most viruses have a negative charge, [20], including COVID-19. The relatively high negative ESC generated on PE glove would be able to repel the negatively charged viruses out of the gloves. The use of surgical gloves is generally recommended as a method for protecting wearer from infection. Sliding of the tested gloves on the tested materials showed higher values of ESC than contact and separation, Fig. 4. PE gloves displayed the highest ESC values. It is proposed that the gloves have negative ESC so that repulsive force between the negatively charged viruses and the gloves would be generated. In this condition, the strong negative ESC repels viruses away from the gloves. When the material of the glove generates a positive ESC, it attracts viruses.

Based on that observation, it is recommended to use materials that gain a strong negative ESC.

Table 1 Triboelectric series of the tested materials.

Positive charge
Air
Human skin
Polyamide
Aluminum
Paper
Cotton
Stainless steel
Copper
Latex
Nitrile
Bakelite
Polyethylene
Polypropylene
Negative charge



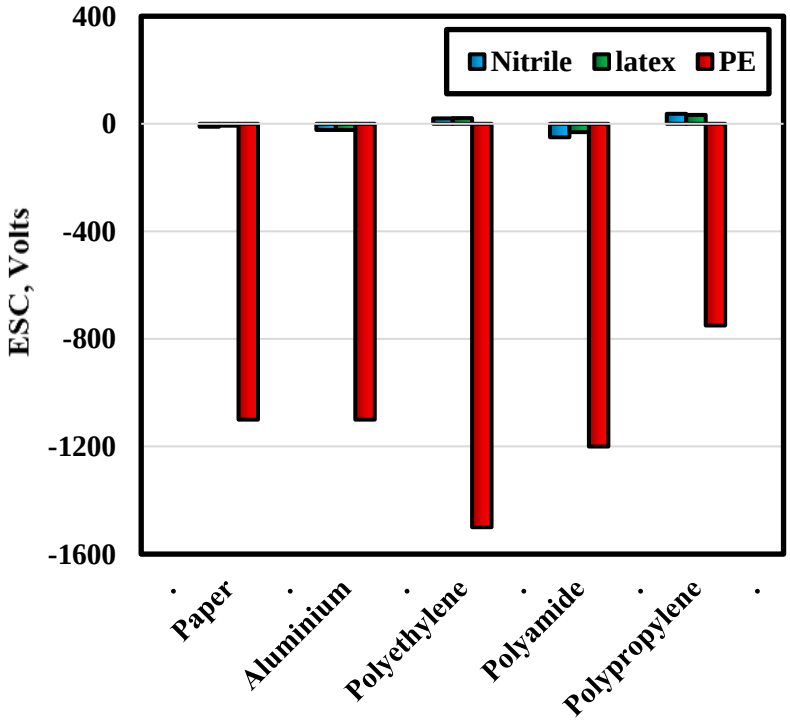


Fig. 3 ESC generated from contact and separation of the tested gloves with different materials.

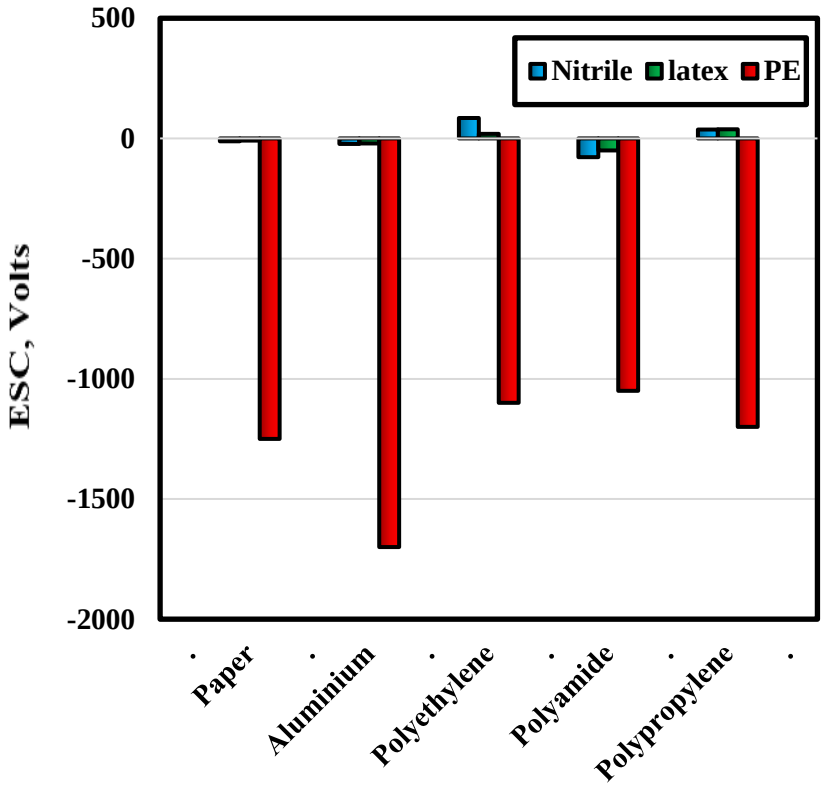


Fig. 4 ESC generated from sliding of the tested gloves on different materials.

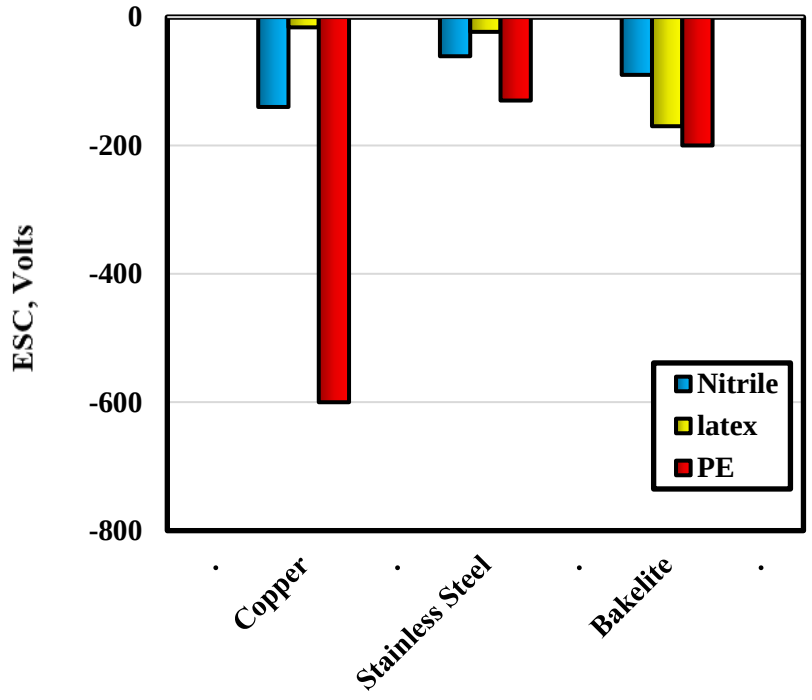


Fig. 5 ESC generated from contact and separation of the tested gloves with different materials.

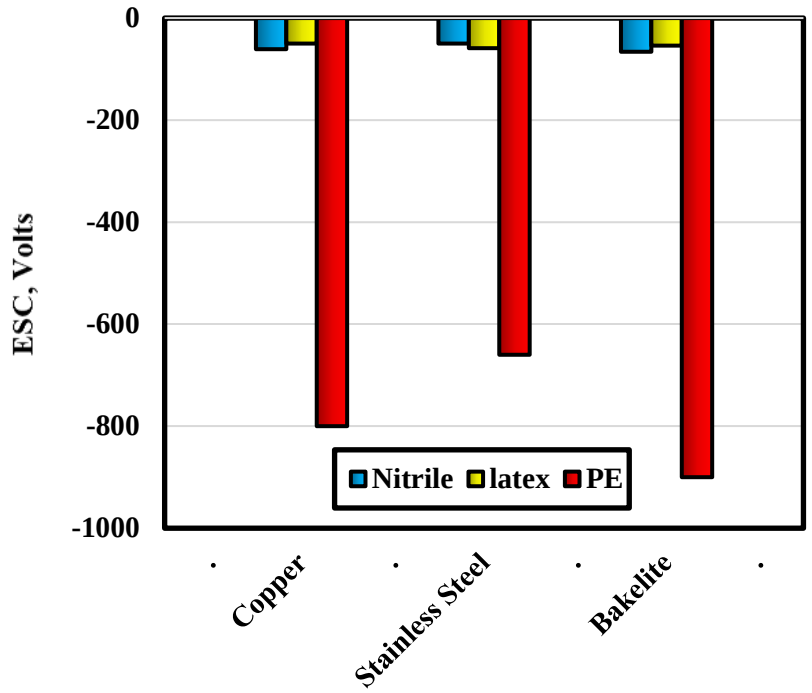


Fig. 6 ESC generated from sliding of the tested gloves on different materials.

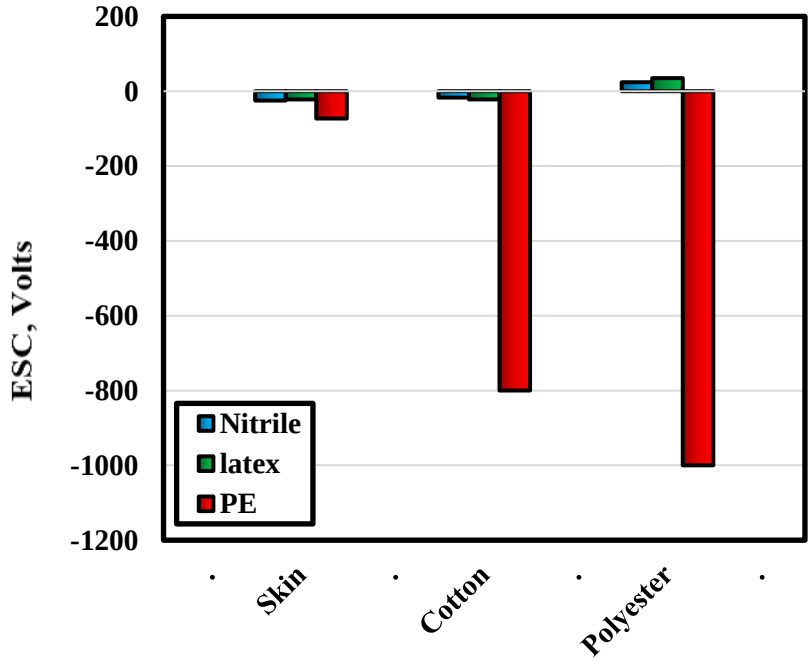


Fig. 7 ESC generated from contact and separation of the tested gloves with different surfaces.

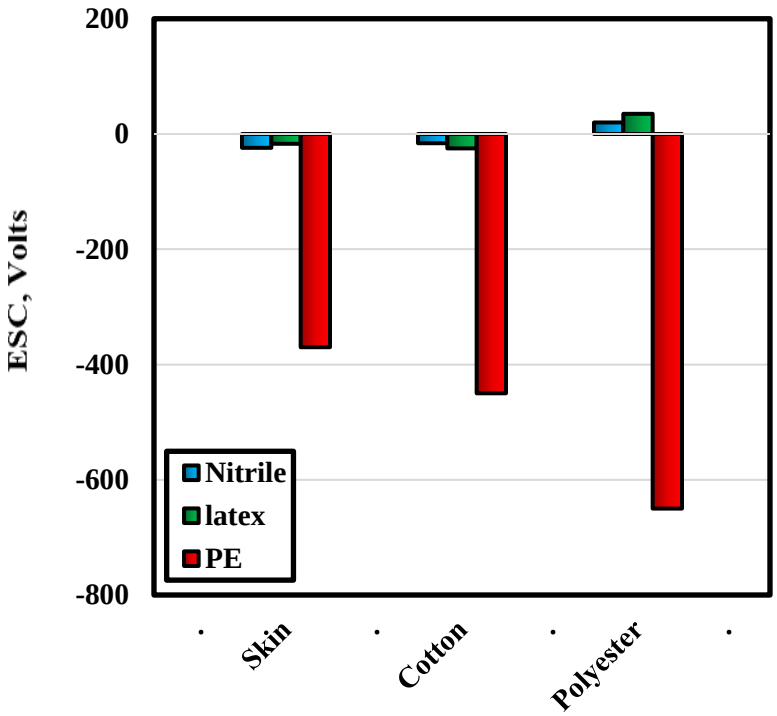


Fig. 8 ESC generated from sliding of the tested gloves on different surfaces.

Testing copper, stainless steel and bakelite showed the same trend as observed for the other materials for contact and separation as well as sliding, Figs. 5 and 6 respectively, where PE gloves gained the highest negative ESC. The reason of gaining PE the highest negative ESC is attributed to its rank in the triboelectric series that control the sign and magnitude.

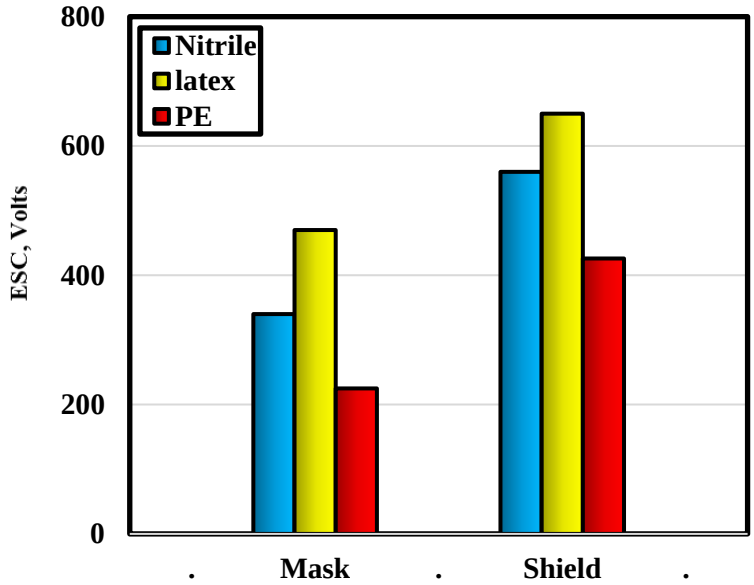


Fig. 9 ESC generated on the gloves from their contact and separation with face mask and face shield.

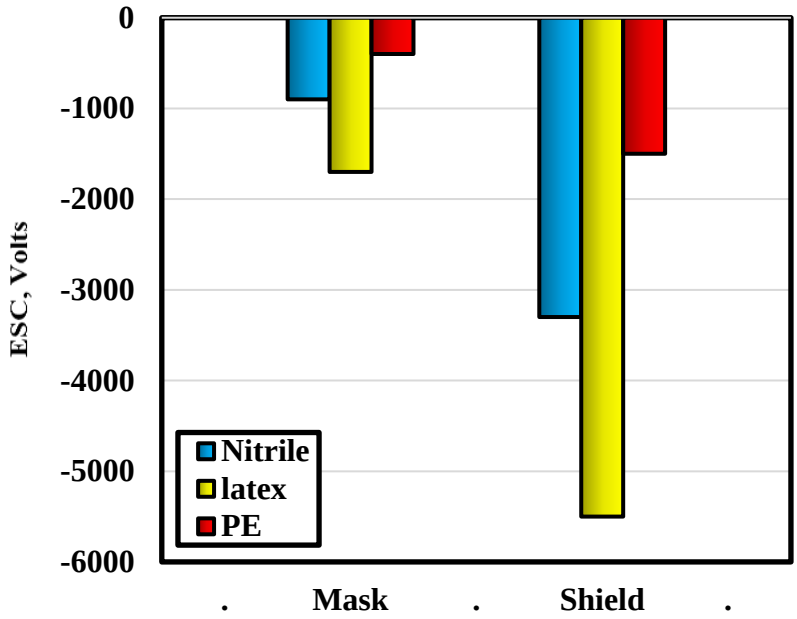


Fig. 10 ESC generated on the face mask and face shield from their contact and separation with the tested gloves.

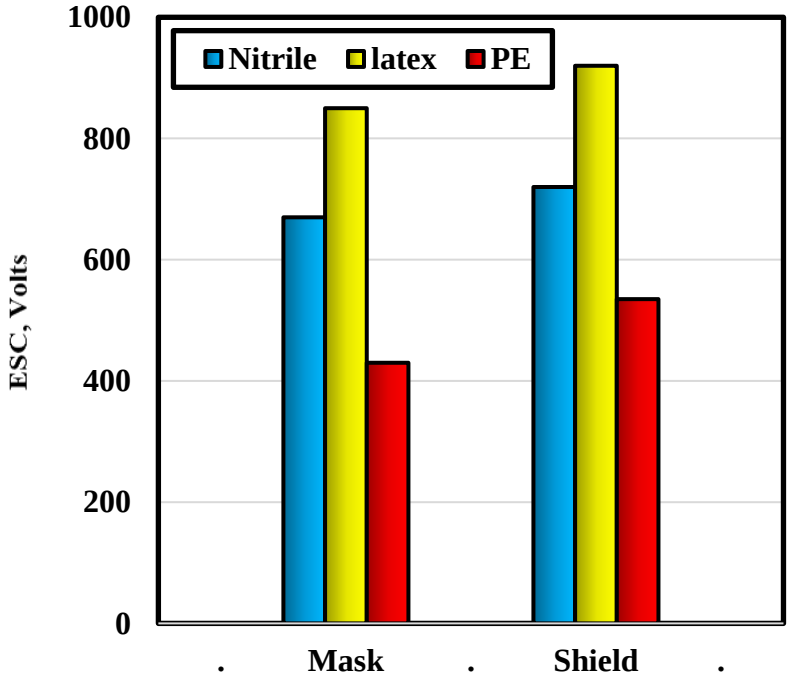


Fig. 11 ESC generated on the gloves from their sliding on face mask and face shield.

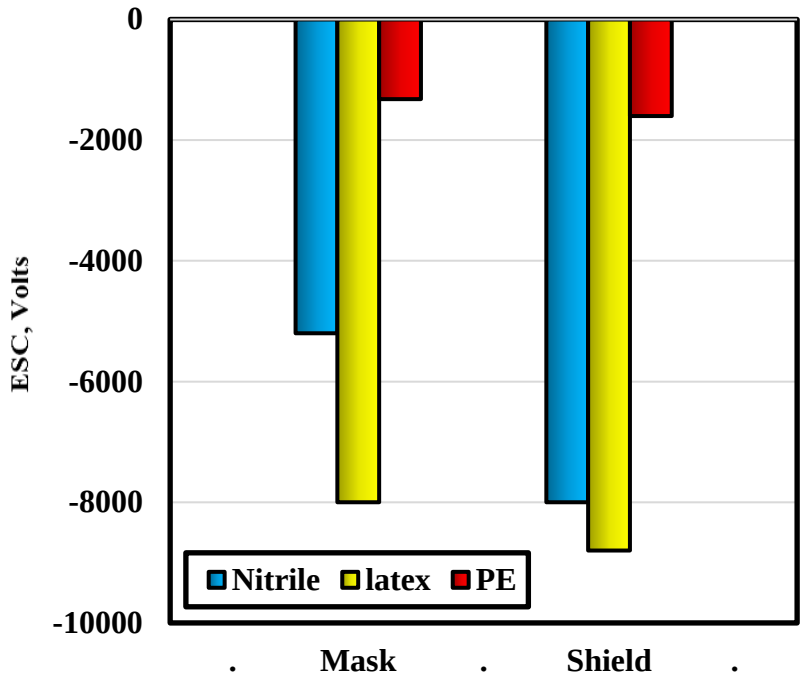


Fig. 12 ESC generated on the face mask and face shield from their sliding on the tested gloves.

ESC generated from the contact and separation as well as sliding of the tested gloves on skin, cotton and polyester textiles is shown in Figs. 7 and 8 respectively. It was found that PE glove gained the highest ESC up to - 370, - 450 and - 650 volts when slid on skin, cotton and polyester respectively.

Medical gloves, medical face masks and face shields are considered as the main protective equipment of people who are working in health care. It is necessary to guarantee high levels of precaution that includes selecting proper materials for infection prevention and control of respiratory infections. ESC generated on the gloves, face mask and face shield from their contact and separation and sliding is illustrated in Figs. 9 - 12. ESC generated on the gloves from their contact and separation with face mask and face shield, Fig. 9, showed that latex gained the highest positive ESC followed by nitrile and PE gloves. Gloves contacted face shield gained higher ESC than face mask, where the maximum value reached 650 Volts. On the surfaces of face mask and face shield, ESC recorded very high values up to -5500 Volts, Fig. 10. Although the materials of both face mask and face shield is polypropylene (PP), face shield generated higher values than face mask. It is favorable that the outer surface of face shield has negative ESC to repel the negatively charged viruses. When the material of the face shield has a positive ESC, it attracts viruses towards the shield and the face of the wearer. On sliding, Figs. 11 and 12, the same trend was observed with higher ESC values due to the increased mobility of the electrons. It was indicated that the gloves gained positive ESC and both face mask and shield gained negative ESC. In this condition, gloves attract the negative charged viruses while face mask and shield repel those viruses away.

CONCLUSIONS

1. ESC generated from contact and separation of the tested gloves with different materials shows that PE gloves displayed the highest values for all the materials tested, while nitrile and latex gained lower values.

2. The relatively high negative ESC generated on PE glove is recommended to repel the negatively charged virus out of the gloves.

3. Sliding of the tested gloves on the tested materials showed higher values of ESC than contact and separation.

4. ESC generated on the gloves from their contact and separation with face mask and face shield showed that latex gained the highest positive ESC followed by nitrile and PE gloves.

5. Face shield generated higher ESC values than face mask.

6. When the gloves gained positive ESC and both face mask and shield gained negative ESC, gloves attract the negative charged viruses while face mask and shield repel those viruses away.

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