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TRIBOELECTRIFIED MATERIALS OF FACEMASK TO RESIST COVID-19

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ABSTRACT

The present work discusses the use of triboelectrification to enhance the performance of the facemask made of polymeric fibers. Experiments were carried out to measure the electrostatic charge (ESC) generated from the friction of air with the facemask during inhalation and exhalation. The tested materials of facemask were textiles of polypropylene (PP), Polyamide (PA) and cotton.

It was found that ESC gained by the fibers of the mask increases with the time of breathing and decreases with increasing the distance from the mask. Besides, the negative ESC generated on the surface of PP fibers can ionize the air to be negatively charged, providing space of negative ESC in front of the mask of about 200 mm. In this space, repulsive force is generated, where Covid-19 viruses of negative charge are repelled away from the facemask. It is recommended that electric field outside the fibers should be strong to repel viruses. To achieve that, actively negative charge polymers should be selected for masks, while cotton, polyamide and positively charged polymeric textiles should be excluded. Finally, it is preferable to frame the PP facemask by Polytetrafluoroethylene (PTFE) to increase the negative ESC of the air to be purified from viruses before entrance and exit from the mouth and nose.

KEYWORDS

Covid-19, Facemask, triboelectrified fibers, negative charged viruses.

INTRODUCTION

The materials of the protective equipment of medical care workers should gain strong negative ESC to repel the viruses of negative ESC out of their surface. ESC generated on the surface of gloves should be of negative sign to repel the viruses of negative ESC, where that behavior is offered by PE glove, [1]. Shoes and shoe covers were recommended to be manufactured from PP and PE respectively, [2]. In addition to that, it is recommended to use epoxy floor instead of PVC tiles to allow the floor to acquire positive ESC to attract the viruses instead of the shoes where disinfection and cleaning are relatively easier.

Several researches showed that all viruses are possessing negative charge, [3 - 7]. Polymeric fibers were tested to be used as protective textiles of antiviral ability to resist the negatively charged spike proteins of airborne viruses, [8]. It was recommended to apply electric field to capture the virus particles, [9, 10]. Besides, cloths were developed to inactivate or repel COVID-19, [11, 12], by introducing silver and zinc into polyester textile, where they can generate electric field able to remove viruses deposited on the surface.

The protective equipment of the medical crews are made of polymeric materials. They are easily triboelectrified, where they gain ESC from rubbing each other. Their ESC can attract or repel the charged particles, [13]. Surgical masks were used to retard spread of COVID-19, [14 - 22]. It was reported that most viruses have negative charge, [23, 24], including COVID-19, [25].

It was revealed that polymeric textiles were tested in filtration, [26], wool and felt fabrics were used. The triboelectric series ranks materials according to their ability to gain or lose electrons, [27]. During rubbing two materials with each other, one material gains electrons and becomes negatively charged and the other loses electrons and becomes positively charged. Air ions are present in low concentrations in environments. They are vital for life, [28 – 30], are and can reduce infection and contamination, [31]. It was found that charged ceilings that generate vertical electric fields in hospital can reduce significantly airborne concentrations of microbes. Electric fields enhance immune-system, [32]. It was concluded that ESC was stronger by 1000 times compared to diffusion and gravity in particle deposition on surfaces. The size of airborne was ranging between 0.1 and 1.0 microns in size. It was explored that electrostatic forces attracting the airborne to a charged surface are stronger than the forces generated from gravity and aerodynamic forces, [33, 34].This behavior confirmed the role of ESC in filtration process of the facemask.

Natural and synthetic materials are currently used to manufacture the personal protective equipment. Cloth face coverings were made from household cloth such as cotton, polyester, nylon, propylene and silk. Those materials do not guarantee the required protection for the patient as well as the healthcare workers from the infectious viruses, [35, 36] but they trap the larger infectious droplets from the wearer, [37, 38] The effect of triboelectrified fibers is due to the electron transfer between the two rubbing materials, [39]. The behavior of triboelectrified fibers can be useful in solving the problem of the sealing of the facemasks. The leakage of air from the mask around the seal boundaries can cause exposure to air contaminants such as viruses, [40, 41]. Polypropylene has an advantage of being triboelectrified so that the filtration efficiency can be enhanced. Most of medical facemasks are composed of polypropylene nonwoven fabrics, where the primary filtration layer is made of lofty melt-blown fibers of 1.0 mm thickness. During the use the filtration efficiency is enhanced, where the fibers are triboelectrified by the friction of the air. Air will flow through gaps and leak from the skin and cloth contact areas limiting the function of filtration and respiratory protection.

The present work aims to propose the materials of facemask depending on their ability to be electrified to repel the viruses.

EXPERIMENTAL

Experiments were performed to measure the ESC generated from the friction of air with the fibers of the facemask during inhalation and exhalation. The materials of facemask were textiles of polypropylene (PP), Polyamide (PA) and cotton. The measuring device (ULTRA STABLE SURFACE DC VOLTMETER) was used to measure the ESC, Fig. 1. Readings are done with the sensor 25 mm apart from the surface of the facemask being tested. Then the distance between the tested facemask and the sensor was varied, Fig. 2, to determine the ESC distribution as function of distance from the mask.

Fig. 1 Electrostatic field measuring device.

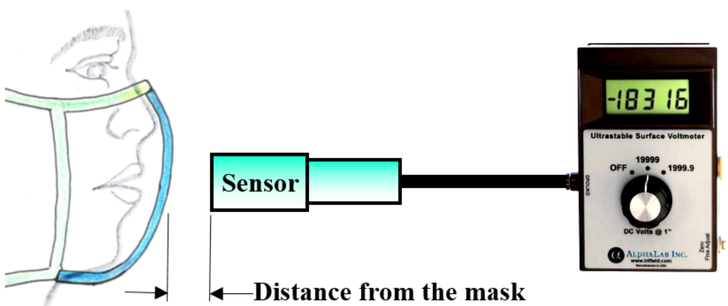

Fig. 2 Test method.

RESULTS AND DISCUSSION

ESC generated in the air passing through the fibers of the tested facemasks versus time is shown in Figs. 3 and 4. It is clearly shown that cotton textile gained positive ESC that slightly increased with the time. The other three PP facemasks showed remarkably increase in the negative ESC. The reading were measured 25 mm apart from the mask. The values of ESC for PP masks high variance depending on the properties of the PP textile such as weaves and fiber diameter, Fig. 3. The performance of two PA facemasks was compared with cotton, where ESC was measured, Fig. 4. All the three tested masks gained positive ESC. As the time increased, ESC increased. Figure 5 showed ESC generated in the air passing through the fibers of PP facemasks versus distance from the

facemask. The highest negative ESC was measured at 25 mm apart from the mask then decreased with increasing the distance.

It is known that the polymeric fibers develop ESC from air passing through them, where they get charged. The contact of fiber 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 capture ability of the fibers increases due to the increase of the electric force. When the fibers are charged, 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 to repel viruses and prevent them from passing through the fibers.

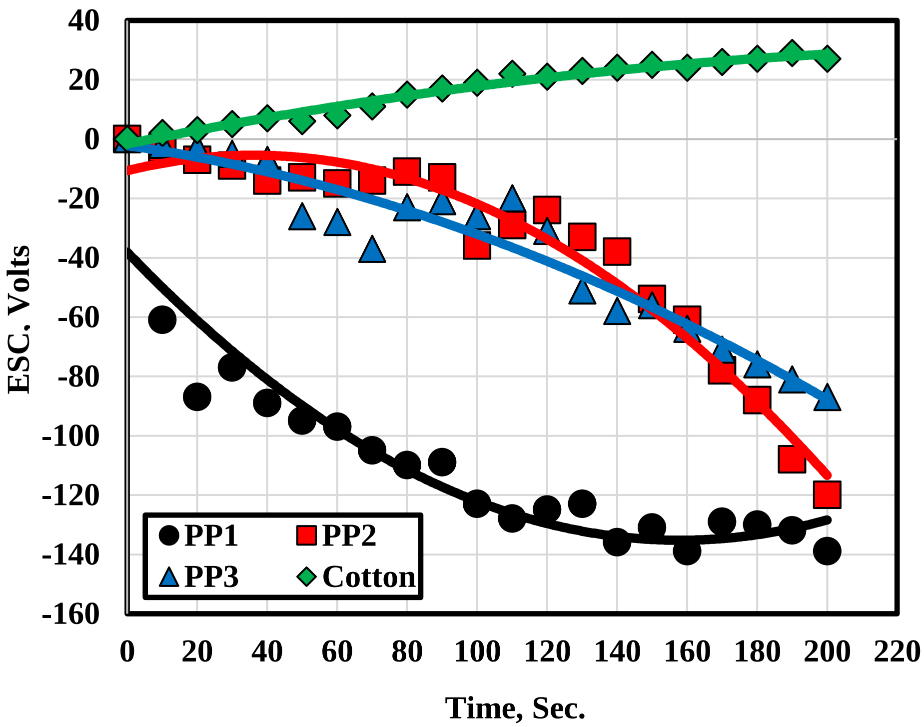

Fig. 3 ESC generated in the air passing through the fibers of the facemask versus time.

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. Based on the observation in Figs. 3 and 4 it is proposed that only the textile masks that can filter the COVID-19 virion should be negatively charged. PP can be capable of stopping the COVID-19 virion due to the electrocharged layer that repels viruses. Polypropylene has an advantage of being actively triboelectrified due to its rank in the triboelectric series, so that the filtration efficiency can be enhanced. Most of medical facemasks are composed of polypropylene nonwoven fabrics. During the use, the filtration efficiency is enhanced, where the fibers are negatively triboelectrified by the friction of the air. The negative ESC generated on the surface of PP fibers can ionize the air to be negatively charged, Figs. 5 and 6, providing space of negative ESC in front of the

mask, Fig. 6, of about 200 mm. In this space, repulsive force is generated, where Covid-19 viruses of negative charge are repelled away from the facemask.

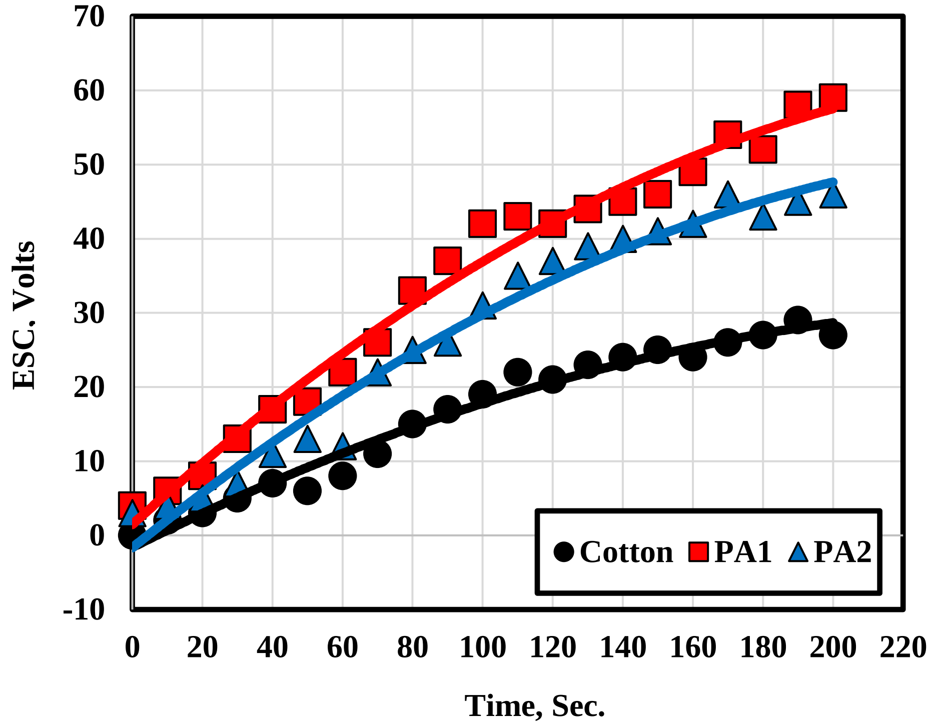

Fig. 4 ESC generated in the air passing through the fibers of the facemask versus time.

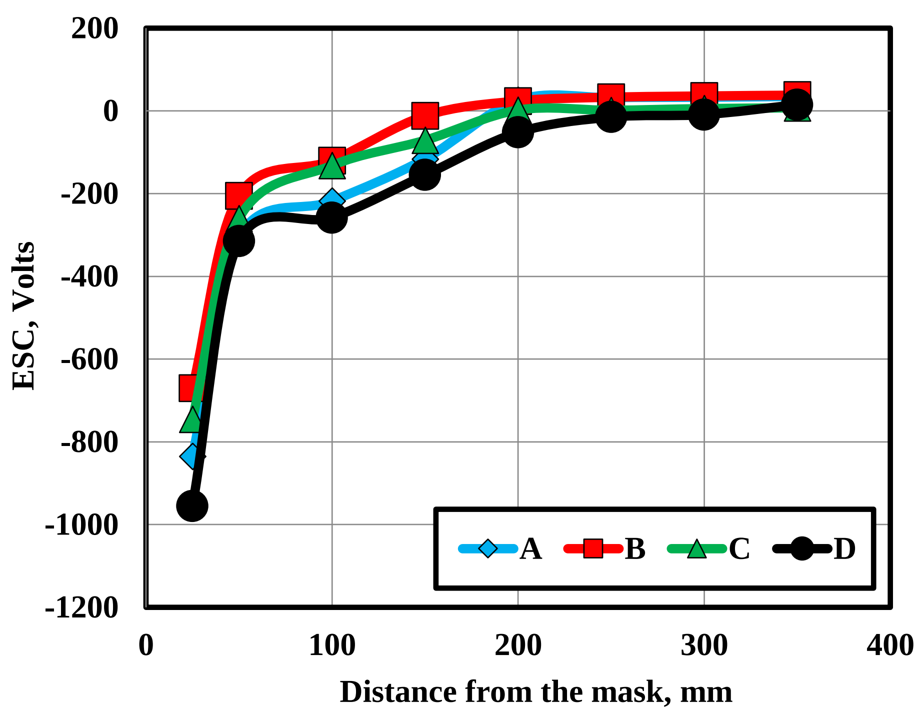

Fig. 5 ESC generated in the air passing through the fibers of the facemask versus distance from the facemask.

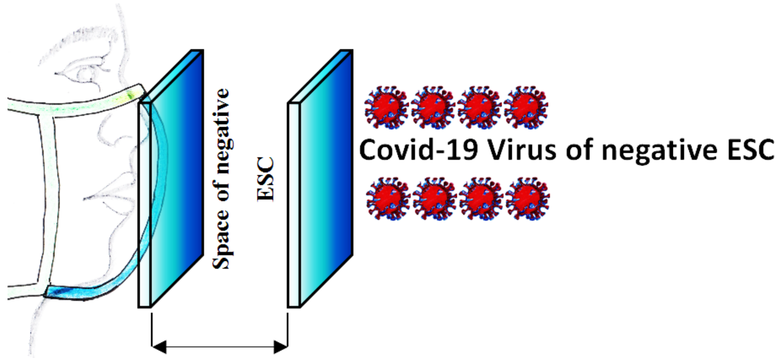

Fig. 6 Illustration of the ability of the negative ESC to purify the air from viruses before entering into the mouth and nose.

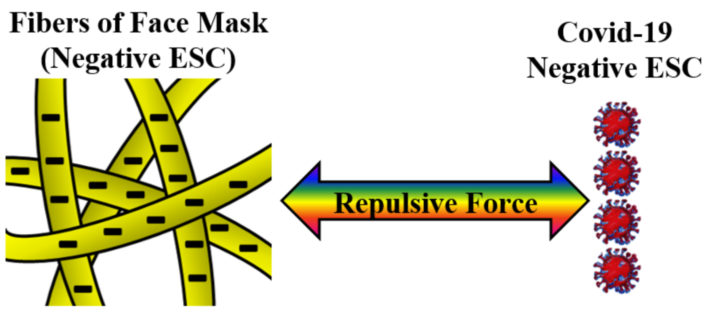

Fig. 7 Illustration of the effect of the triboelectrified fibers to generate repulsive force to repel the negatively charged negative viruses.

The filtration function of the tested textile should balance between having pore size able to trap very small particles and enable the people of breathing. The filter material of the mask should prevent particles of 1.0 µm passing through the fibers of the filter, while particles smaller than 1.0 µm should be stuck to the surface of the fibers by diffusion. The triboelectrified fibers can repel viruses of the same ESC. The polymeric fibers due to their charge are able to remove particles below 1.0 µm with low pressure drop. Although the small particles are much smaller than the mesh size of filter materials, electrostatic forces can repel those particles outside the filter depth.

When the air passes through the fibers, ESC generated on the surface of fibers has negative charge because air is in the top of the triboelectic series. The air in this condition will be ionized and transfer negative charge if the fibers have the tendency to generate negative ESC. Materials generate ESC during friction with each other, where the intensity and polarity depend on the rank of materials in the triboelectic series. The higher positioned materials gain positive ESC, while the relatively lower position in the series gain negative ESC. Figure 8 shows the triboelectric series of the tested materials and their relative position relative to the some common materials. The materials that are in blue colors are active in gaining negative ESC, so they are recommended to be used for facemask due to their activity to repel the negatively charged viruses away such as COVID-19.

Fig. 8 Triboelectric series of the proposed materials.

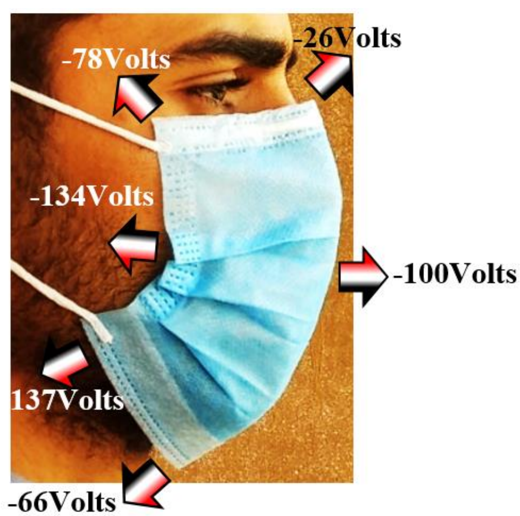

Fig. 9 ESC generated in the air flows through gaps and leaks from the skin and facemask contact areas.

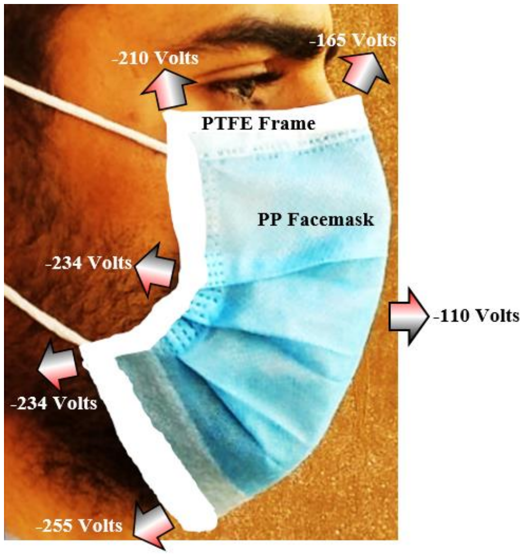

Fig. 10 ESC generated in the air flows out of the facemask framed by PTFE.

ESC of air flowing through gaps and leak from the skin and facemask contact areas was measured to evaluate the function of the tested facemask, Fig. 9. The charge of ESC was negative due the ionization of the air of exhalation by the negative charge generated on the tested PP fibers. The magnitude of the charge reveal the amount of air that leaked from the facemask.

In the present work, the PP tested facemask was framed by PTFE ribbon to increase the negative ESC of air to purify from viruses before entering and exit from the mouth and nose, Fig. 10, where PTFE would gain strong negative ESC during its contact to the human skin and hair. By this way, the facemask ability to repel viruses would enhance. Because PP and PTFE are insolating materials, their negative ESC will remain, while the positive charge generated on the skin and hair would be released due to the good electrical conduction of the human body.

CONCLUSIONS

1. Facemask should be made of only polymeric materials that are negatively electrified to repel Covid-19 viruses. Cotton and polyamide textiles should be excluded.
2. ESC gained by the fibers of the mask increases with the time of breathing and decreases with increasing the distance from the mask.
3. Polymeric fibers get charged from air passing through them, where they gain ESC. As the magnitude of ESC increases, the intensity of the electric field increases and consequently the capture ability of the fibers increases due to the increase of the electric force. It is recommended that electric field outside the fibers should be strong to repel viruses.
4. The negative ESC generated on the surface of PP fibers can ionize the air to be negatively charged, providing space of negative ESC in front of the mask of about 200 mm. In this space, repulsive force is generated, where Covid-19 viruses of negative charge are repelled away from the facemask.

5. It is recommended to frame the PP facemask PTFE ribbon to increase the negative ESC of air to purify from viruses before entrance and exit from the mouth and nose.

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