EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
*VOLUME 17, No. 3, July 2020, pp. 48 – 58* ISSN 2090 - 5882
(Received May 25. 2020, Accepted in final form June 23. 2020) www.egtribjournal.com

# EFFECT OF CONDUCTING MATERIALS ON ELECTROSTATIC CHARGE GENERATED FROM SLIDING ON POLYETHYLENE TURF

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## ABSTRACT
**Polyethylene (PE) turf fibers are used in wide application such as kid gardens and sport yards. They offer durable and elastic behavior. The present work aims to investigate electrostatic charge (ESC) generated from contact and separation as well as sliding of three conducting materials such as aluminium (Al) film, copper (Cu) textile and carbon fibers (CF) on PE turf blended by polymethyl methacrylate (PMMA) yarns and polyurethane (PU) fibers.**

**The experimental results showed that Al film gained the highest ESC followed by Cu textile and CF. This observation confirms that the conductor of lower measured resistivity gains higher ESC. It was found that as the content of PMMA or PU increased, ESC decreased then became negative when PMMA yarns content was triple the content of PE fibers.**

**In addition to that, it was observed that the intensity of ESC measured for the tested conductors is very low compared to that measured for the tested fibers. It seems that ESC generated on the conductor quickly moved from the surface into the depth. Because electrons accumulate on the peaks of the surface asperities in form of isolated islands, the role of conductive counterface is to collect them and uniformly distribute on the contact area. Besides, some of the electrons moved to the conductor and consequently the intensity of ESC decreased on the polymer surface. Finally, the blending process showed significant enhancement where ESC drastically decreased with increasing PMMA yarns and PU fibers.**

## KEYWORDS
**Polyethylene turf, polymethyl methacrylate, polyurethane, conductors, aluminium film, copper textile, carbon fibers, triboelectrification.**

## INTRODUCTION

**There is an increasing demand to introduce proper solutions for reducing ESC generated from sliding of rubber sole on PE turf. The application of artificial turf for indoors and sport yards to replace natural fibers has increased, [1, 2], to substitute limitation of rainfall and water. Safety of players against abrasion of PE fibers were tested, [3, 4], by developing skin-friendly turf. Polymeric yarns were tested as turf sliding against silicone skin, [5]. It was revealed that skin injuries depend on the degree of abrasion of the turf, [6 - 8]. Polymeric yarn turfs blended by rubber or sand infill were investigated, [9, 10]. It was shown that polymeric fibers displayed higher degree of injuries than natural fibers, [11 - 13]. The effect of environment was tested, [14]. It was proved that artificial turf offered more elastic behavior and consequently reduced the risk of knee injury. The friction behavior and the effect of applied load acting on footwear sliding against PE turf were investigated, [15, 16], where friction coefficient drastically decreased for flat sole.**

**The extensive use of PE turf in sport yards should be balanced by reducing ESC generated from friction. It was proposed to blend PE fibers by polyurethane (PU) to decrease ESC, [17]. PE substrate was replaced by polypropylene (PP), [18]. It was found that, metallic substrates such as steel and copper sheet influenced ESC. Grounding the metallic substrate decreased ESC. PE turf fibers were blended by PMMA and PA yarns and textiles, [19], where experiments showed that PA and PMMA textiles and yarns drastic reduction in ESC was observed.**

**The dimensions of PE fibers such as length and thickness influenced their friction behavior during sliding against rubber. Football shoes experienced the lowest friction values. ESC generated on the surfaces of human skin and artificial turf in dry sliding showed high values, [20 - 22], while PE fibers of smooth surface generated higher ESC than the rough ones. Recently, it was found that Cu textile blending PE fibers showed drastic decrease in ESC, [23]. Besides, when Cu substrate replaced PE substrate ESC recorded the lowest values.**

**The present work investigates ESC generated from contact and separation as well as sliding of Al film, Cu textile and CF on PE turf blended by PU and PMMA fibers.**

## EXPERIMENTAL

**ESC generated from the contact of PE turf blended by PU (5.0 mm wide and 0.25 mm thickness) and PMMA yarn (3.5 mm diameter) and conducting counterface was measured in the present work, Figs. 1, 2. It is planned to use conducting materials such as aluminium film (0.25 mm thickness), copper (Cu) textile as well as carbon fibers (CF) as counterface, Fig. 3. The resistivity measured for the conducting materials was 5.6, 11.4 and 42.2 Ohms for Al film, Cu textile and CF respectively. The aim of that arrangement is to reduce ESC generated on both of the turf and counterface. Two sets of the proposed fibers were prepared. The first set contained PE and PMMA yarns. The second one contained PE fibers and PU fibers. The tests were performed to measure ESC at contact and separation as well as sliding of the tested conducting materials on PE turf fibers. The tested fibers were adhered on paper substrate. One surface, of wooden block in form of**

**cube (50 × 50 × 50 mm$^3$), was covered by the conducting material. The width and thickness of PE fibers were 2.0, 0.22 mm respectively. The test specimen indicated by (1 PU) refers that the number of both PE fiber and PA yarns are equal, while (2 PU) and (3 PU) shows that the number of PU fibers are double and triple the PE fibers respectively. The same definition is considered for PMMA. The conducting surface was loaded against the tested turf surface at 15 N weights and slid horizontally at dry condition for 100 mm distance. ESC generated on the two rubbing surfaces of the tested turf and the conducting materials was measured by Surface DC Voltmeter SVM2.**


**Fig. 1 PE fibers blended by PU fibers.**

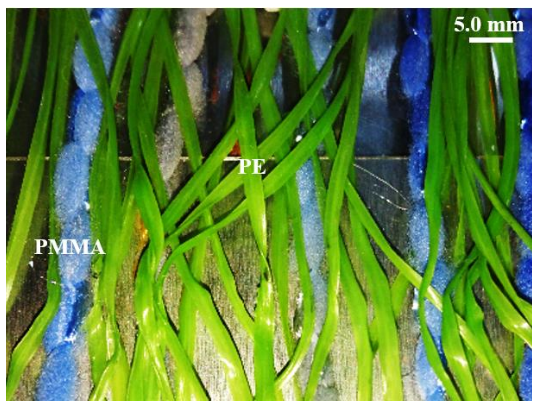


**Fig. 2 PE fibers blended by PMMA yarns.**

| | | |
|---|---|---|
|  |  |  |
| **Al Film.** | **Cu Textile.** | **Carbon Fibers.** |

**Fig. 3 The conducting materials used as counterface.**

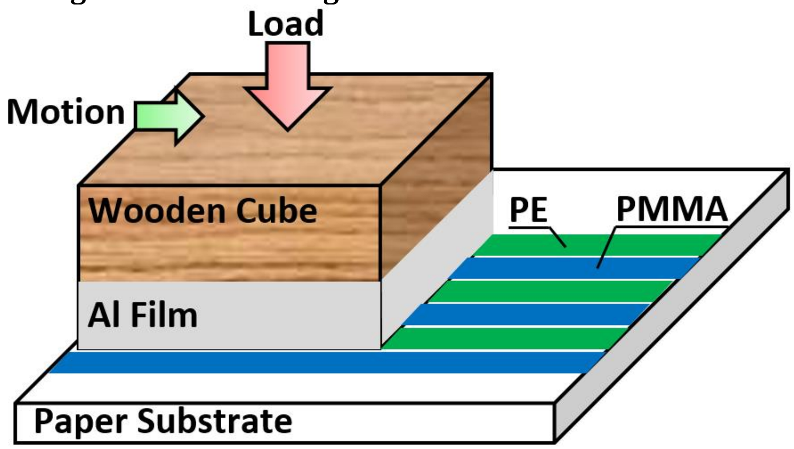


**Fig. 4 Arrangement of the test procedure.**

## RESULTS AND DISCUSSION

**Triboelectrification is the generation of ESC from contact and separation as well as sliding of the materials. Based on the electrostatic properties of the engineering materials, each material during contact and sliding develops static charge. The intensity and polarity of the charge depends on the type of the material. Several factors influence the ESC generated on the surface of the materials, such as, surface roughness and contact conditions like pressure, sliding velocity and contact area. Engineering materials are arranged in the triboelectric series, where the higher positioned materials gain positive ESC when contacts or being rubbed with a material at relatively lower position in the series, [24]. Based on that, triboelectric series can be used to qualify the polarity of the materials. Table 1 shows the triboelectric series of the tested materials.**

**Table 1 Triboelectric series of the tested materials.**

| Air | Positive Charge |
|---|---|
| PMMA | |
| PA | |
| PU | |
| CF | |
| Al | |
| Paper | |
| St | |
| rubber | |
| Cu | |
| PE | Negative Charge |

**The results of ESC measurement of the first set that contained PE and PMMA yarns are shown in Figs. 5 - 8. ESC generated on conducting materials from contact and separation of the tested turf blended by PMMA fibers, Fig. 5, showed that Al film gained the highest ESC followed by Cu textile and CF. This order indicates that the conductor of lower resistivity can gain relatively higher ESC. As the content of PMMA increased, ESC decreased then became negative when PMMA yarns content was triple the content of PE**

**fibers. The intensity of ESC measured for the tested conductors is very low compared to that measured for the tested fibers, Fig. 6. It seems that ESC generated on the conductor quickly moves from the surface into the depth so that the measured magnitude was very low. Knowing that electrons accumulates on the peaks of the surface asperities in form of isolated islands, the role of conductive counterface is to collect them and uniformly distribute on the whole contact surface. Besides, some of the electrons move to the conductor and consequently the intensity of ESC decreased on the polymer surface. Based on that, it is expected that the ESC intensity that remain on the insulator would be lower. The highest value of ESC (-3700 Volts) was represented by PE fibers then decreased with increasing the blending ratio of PMMA yarns until it turned to positive (+510) at triple content of PMMA.**

**In condition of sliding, Fig. 7, the same trend was observed with slight increase in the values of ESC. Al film slid on PE fibers recorded 103 Volts, while Cu textile and CF displayed 87 and 84 Volts respectively. ESC generated on the tested turf blended by PMMA yarns sliding against the tested conducting materials is illustrated in Fig. 8. PE fibers showed relatively high ESC values up to -5900 Volts when Al film slid on the fibers then decreased to -5600 and -3200 Volts for Cu textile and CF respectively. The blending process showed significant enhancement where ESC drastically decreased with increasing PMMA yarns.**

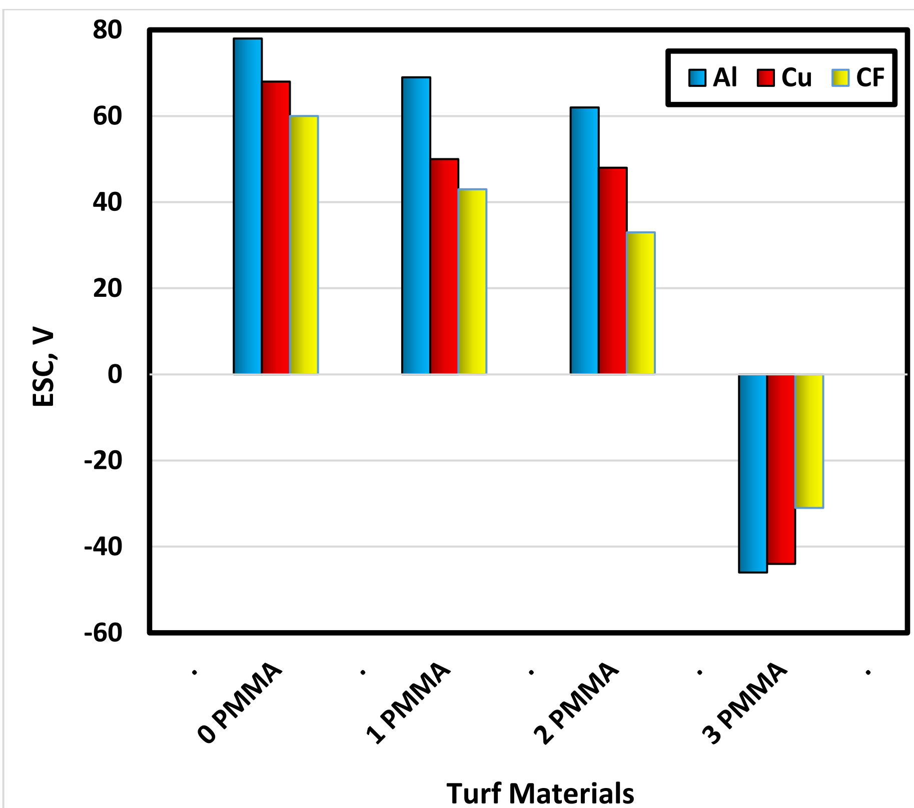


**Fig. 5 ESC generated on conducting materials from contact and separation of the tested turf blended by PMMA fibers.**

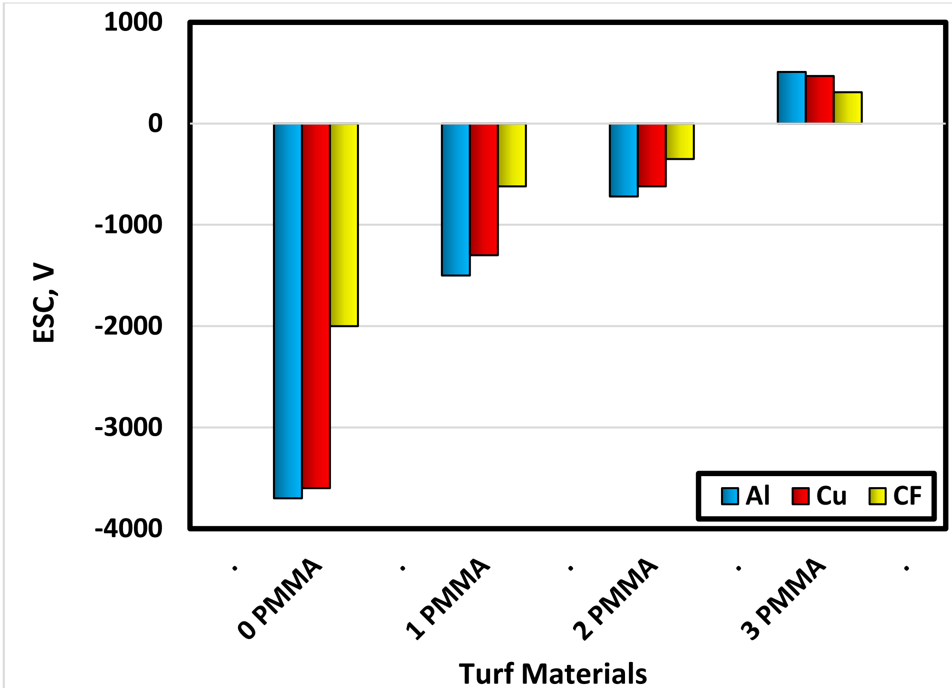


**Fig. 6 ESC generated on the tested turf blended by PMMA yarns from contact and separation.**

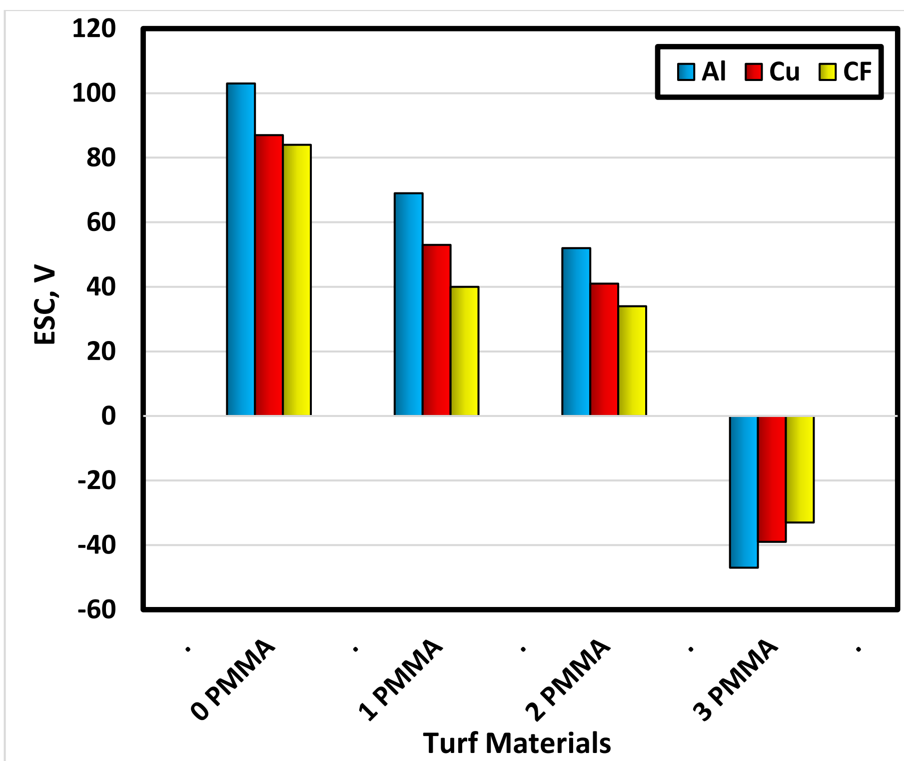


**Fig. 7 ESC generated on conducting materials from sliding against the tested turf blended by PMMA fibers.**

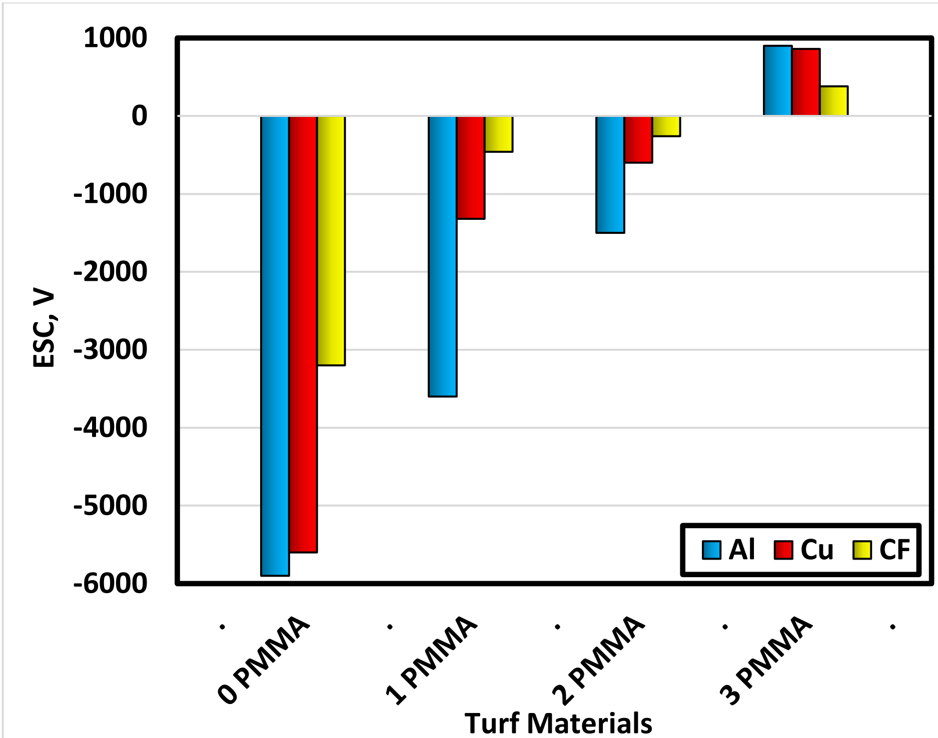


**Fig. 8 ESC generated on the tested turf blended by PMMA yarns sliding.**

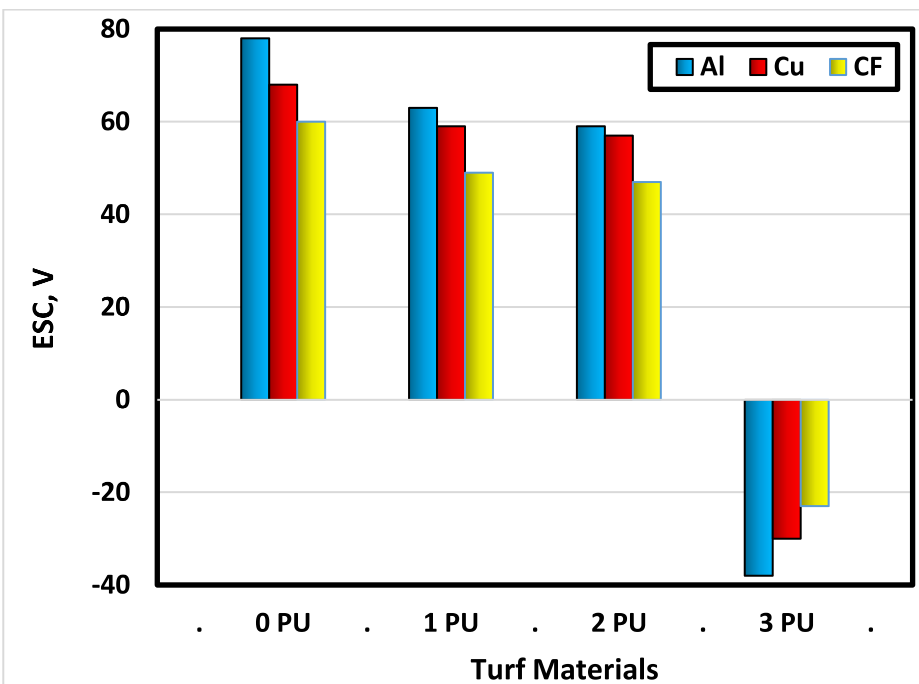


**Fig. 9 ESC generated on the conducting materials after contact and separation of the tested turf blended by PU fibers.**

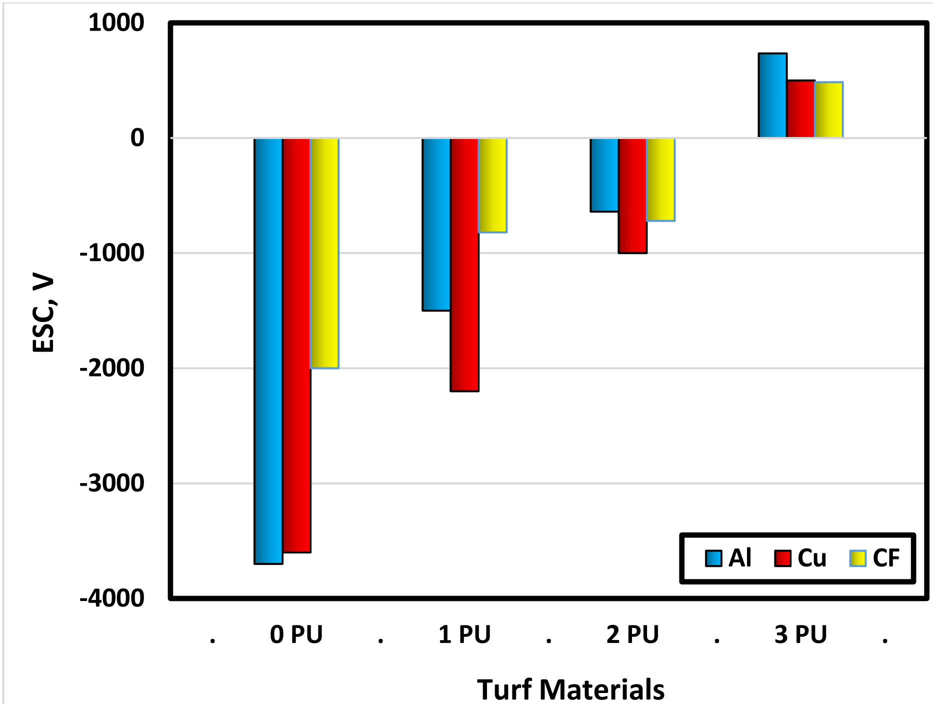


**Fig. 10 ESC generated on the tested turf blended by PU from contact and separation.**

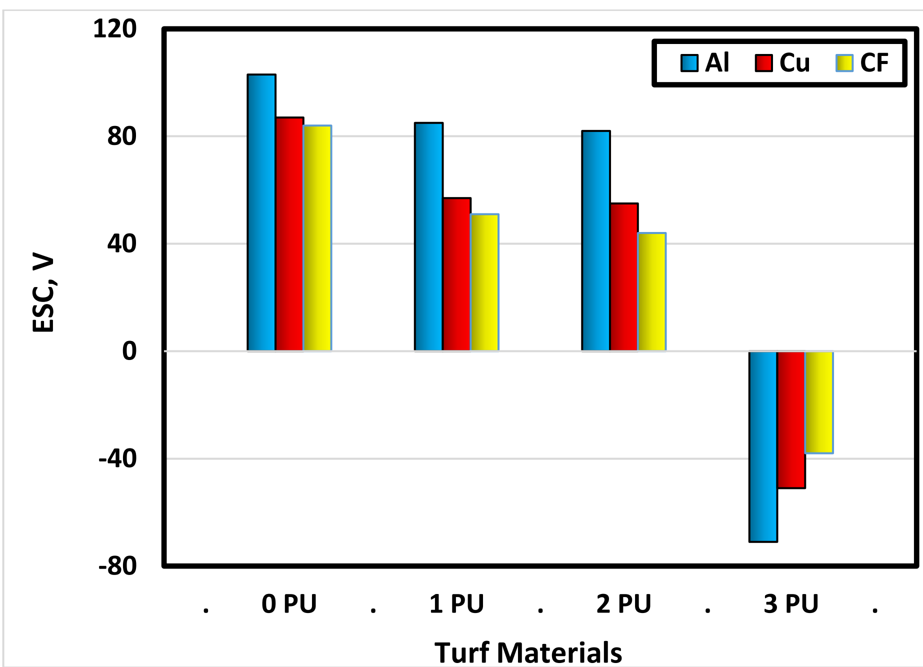


**Fig. 11 ESC generated on conducting materials from sliding against the tested turf blended by PU.**

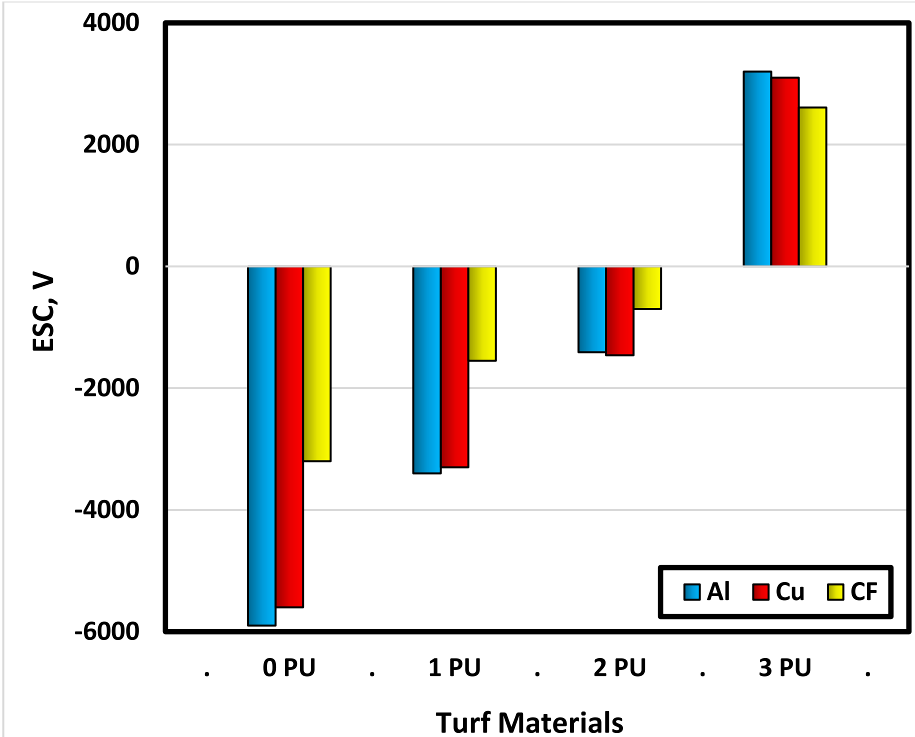


**Fig. 12 ESC generated on the tested turf blended by PU after sliding.**

**The same trend observed for the tested blend of PE and PMMA was found for PU blended PE fibers at contact and separation, Figs. 9 – 10. Al film gained the highest ESC followed by Cu textile and CF. When PU fibers content blending PE increased, ESC decreased. Values of ESC gained by PE fibers were higher than that observed for the conductors. ESC generated on conducting materials from sliding against the tested turf blended by PU, Fig. 11, could record minimum values at PU/PE ratio of 2.5. ESC generated on the tested turf blended by PU after sliding is displayed in Fig. 12. Al film uniformly distributed ESC on the PE fibers, where the intensity of ESC reached -5900 Volts. Blending by PU decreased ESC generated on the surfaces of the fibers and conductors.**

## CONCLUSIONS

**1. The conductor of lower resistivity can gain relatively higher ESC.**
**2. As the content of PMMA or PU increased, ESC decreased then became negative when PMMA yarns content was triple the content of PE fibers.**
**3. The intensity of ESC measured for the tested conductors is very low compared to the that measured for the tested fibers.**
**4. The blending process showed significant enhancement where ESC drastically decreased with increasing PMMA yarns and PU fibers.**

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