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ELECTRONIC SKIN BASED ON DIRECT CURRENT TRIBOELECTRIC NANOGENERATOR

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ABSTRACT

The present work discusses the control of the slip and sliding of the objects on the surface of the electronic skin (e-skin). The slip or sliding of the object on the e-skin generates ESC that works as feedback signal generated by using the electrostatic breakdown effect to generate a direct current TENG (DC-TENG) to control the gripping force by controlling the input voltage of the control system of the grasping force between the e-skin and object. In the present work, a design of e-skin of feedback action depending on triboelectrification and electrostatic breakdown of proposed DC-TENG is proposed. During sliding of the object on the surface of the e-skin, DC-TENG generates DC current that works as feedback signal to control the gripping force.

It was found that the proposed design of the e-skin that includes latex as the outer layer can guarantee safe grasping of the objects, where results of experiments proved that latex has relatively high friction coefficient. It was observed that the highest voltage values were measured for PTFE and Kapton as friction surface (FC). When two charge collecting electrodes (CCE) at rear and front of the FE were used, the voltage in the external circuit remarkably increased. It is recommended to apply the DC-TENG in the design of e-skin. Finally, further research should be continued to optimize the factors that control the performance of DC-TENG.

KEYWORSD

Electronic skin, triboelectrification, electrostatic breakdown, Kapton, PTFE.

INTRODUCTION

One of the major problems of the TENG used in the electronic skin is the generation of electric current during sliding. It was revealed that the DC-TENG can fulfil that condition, [1 – 5]. During sliding, the density of ESC increased on the friction surface

and consequently it induced electrostatic field that causes air breakdown in the gap between the friction surface and electrode, and conducts fraction of ESC on the friction surface and thus generates direct current in the external circuit.

The essential factor in the design of e-skin is to generate feedback electric signal based on sliding on the object surface, [6]. Few attempts have been tested to develop e-skin by capacitive and resistive sensors, [7 - 10]. TENG based on triboelectrification and electrostatic induction were applied, [11 - 18]. Besides, many types of e-skin were introduced to detect finger touch, [19, 20]. A gripper design was introduced to guarantee safe grasp of objects, by controlling the sliding of the object on the gripper surface to limit the increase of the gripping force. The feedback of the proposed system depended on the triboelectrification where double layers of ESC were generated at the two contact surfaces, [21].

It is known that gripping object depends on the grip force to guarantee safe grip, [22], to avoid the risk of dropping or crushing the object, [23 - 26]. Besides, the grip force is controlled by the load force feedback, [27 - 32], where load sensor is used to measure both the grip and the tangential force acting on the surface of robotic gripper. In that condition, grip force, weight of the object and static coefficient of friction should be considered. It was revealed that the voltage measured from the proposed lightweight e-skin can be applied as feedback signal on the based on the triboelectric effect and electrostatic induction, [33], where the e-skin included carbon fibers coil on aluminium film representing the electrode in PMMA core, while the counterface was kapton film coating the substrate.

The present work proposes an electronic skin (e-skin) based on electrostatic breakdown to generate direct current in DC-TENG as feedback signal to control the gripping force.

EXPERIMENTAL

The proposed artificial finger consisted of latex as external layer due to the relative high friction values when sliding with other surfaces. The latex was adhered to PMMA sheet of 0.3 mm thickness. The friction electrode was Al sheet adhered to wooden block of 40 × 15 × 5 mm^3. On the rear edge, the charge collecting electrode (CCE) was adhered close to FE but is insulated by epoxy layer. Then another CCE was adhered to the front edge of the FE that slid on the friction surface. The CCE collects ESC generated by electrostatic breakdown. The DC-TENG is the combination of triboelectrification and electrostatic breakdown. The details of DC-TENG are shown in Figs. 1 - 3. Three materials were tested as friction surface. They are 0.05 mm PTFE film, 0.04 mm Kapton film and 0.1 mm PA film of 0.1 mm thickness. Load was applied by weights up to 2.5 N. The sliding distance was 20 mm.

Friction coefficient of the tested materials was determined by measuring the friction force displayed by their sliding on latex. The latex specimens were adhered to the base that supported with two load cells to measure the normal load and the friction force,

Fig. 4. The friction coefficient is determined by the ratio between the friction force and the normal load.

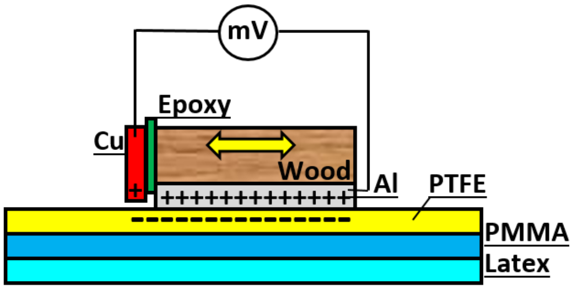

Fig. 1 Arrangement of the single charge collecting electrode and the tested materials.

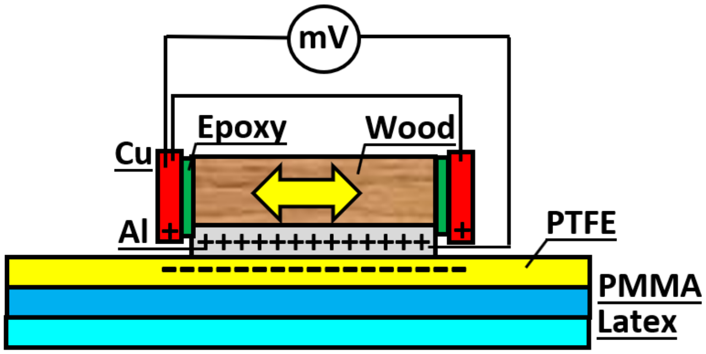

Fig. 2 Arrangement of the two charge collecting electrodes and the tested materials.

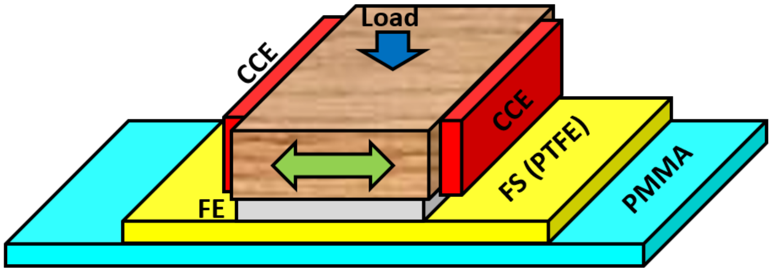

Fig. 3 Details of the DC-TENG proposed to be inserted in the e-skin.

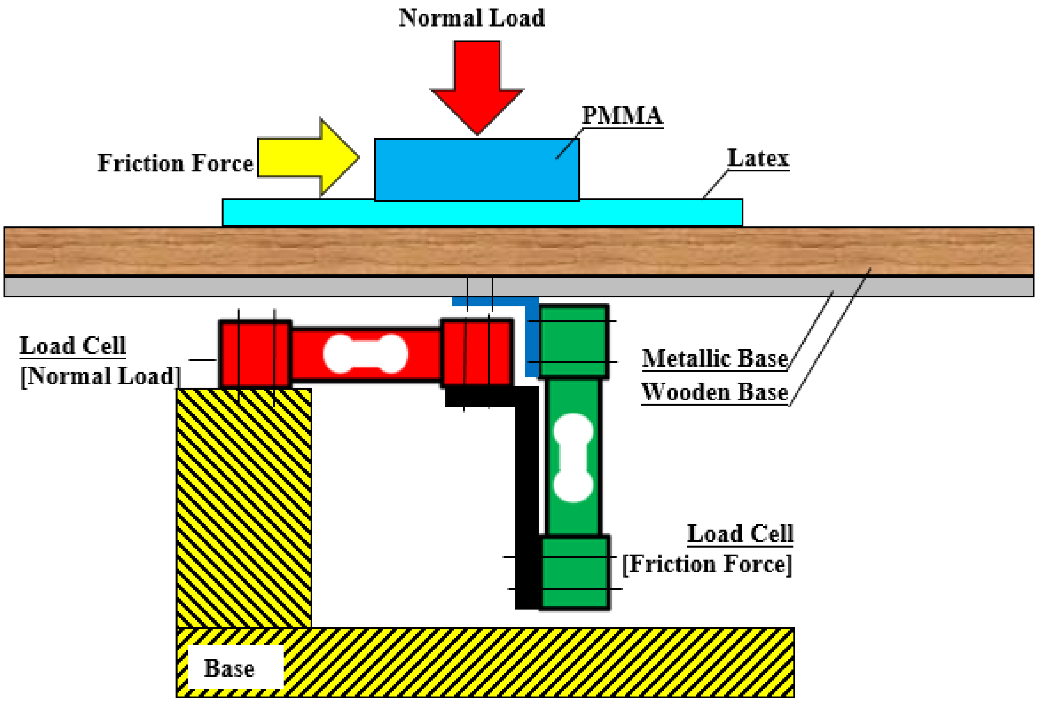

Fig. 4 Arrangement of the test rig to measure the friction force.

RESULTS AND DISCUSSION

The design of the proposed e-skin depends on generating DC current from the relative sliding between the tested materials. As shown in Figs. 1 - 3, the outer surface of the e-skin was latex. It is essential that friction coefficient (µ) between latex and the majority of the handled materials should be relatively high. In that condition, the grasp of the latex to the objects would be secure. Besides, µ between latex and PMMA sheet should also be high to guarantee the free slip of PTFE or Kapton on the FC. Results of experiments carried out to determine µ of the tested materials shown in Fig. 4 proved that latex was proper choice because it displayed the highest friction values when slid on PMMA and epoxy. The easy sliding of the FE and PTFE as well kapton was guaranteed by the lower values of µ.

Voltage between charge collecting electrode and the tested materials during sliding is shown in Fig. 6. It is seen that voltage increased with increasing the applied load due to the increase of the contact area. The highest voltage values were observed for PTFE followed by Kapton. While PA showed very low values. When the surface of PTFE and Kapton were roughened by inserting emery paper of 80 grit size under them, voltage increased for Kapton and decreased for PTFE, Fig. 7. It seems that PTFE stuck in the FE surface. The highest voltage value observed for Kapton increased from 16.1 mV for smooth surface to 18 mV for rough one.

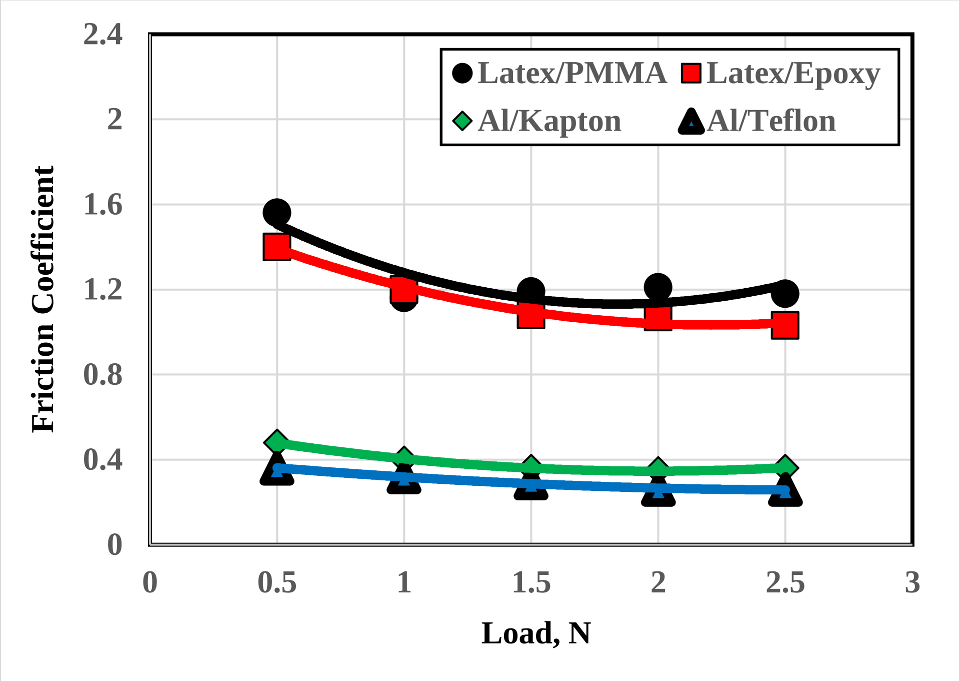

Fig. 5 Friction coefficient displayed by the sliding of the tested materials.

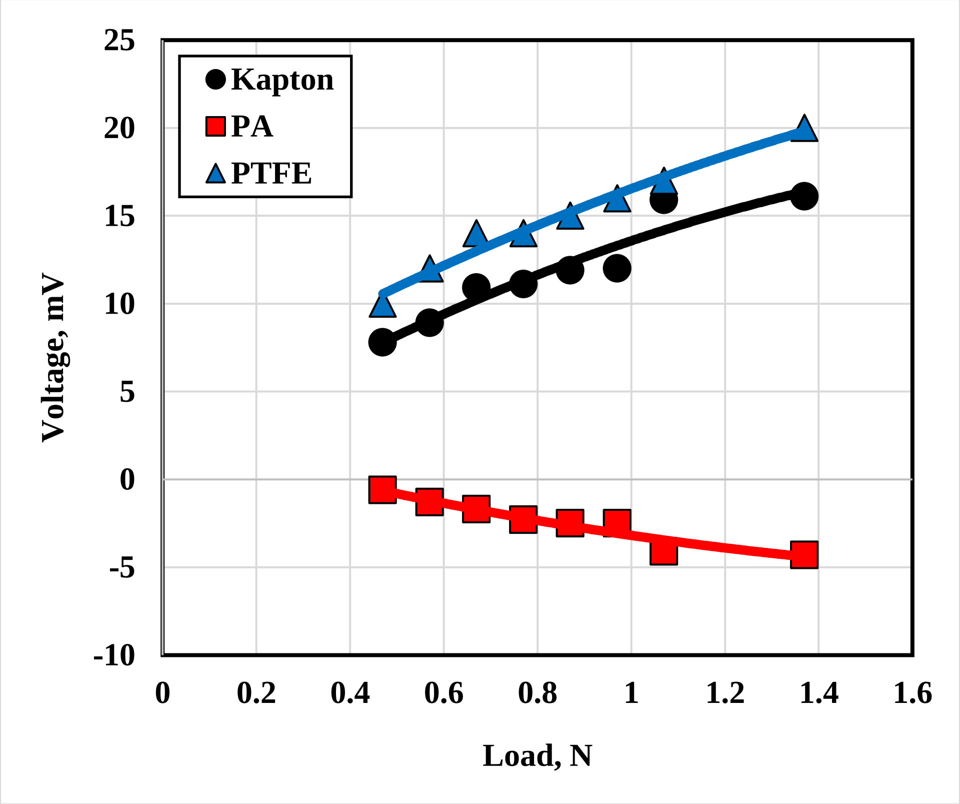

Fig. 6 Voltage difference between charge collecting electrode and the tested materials.

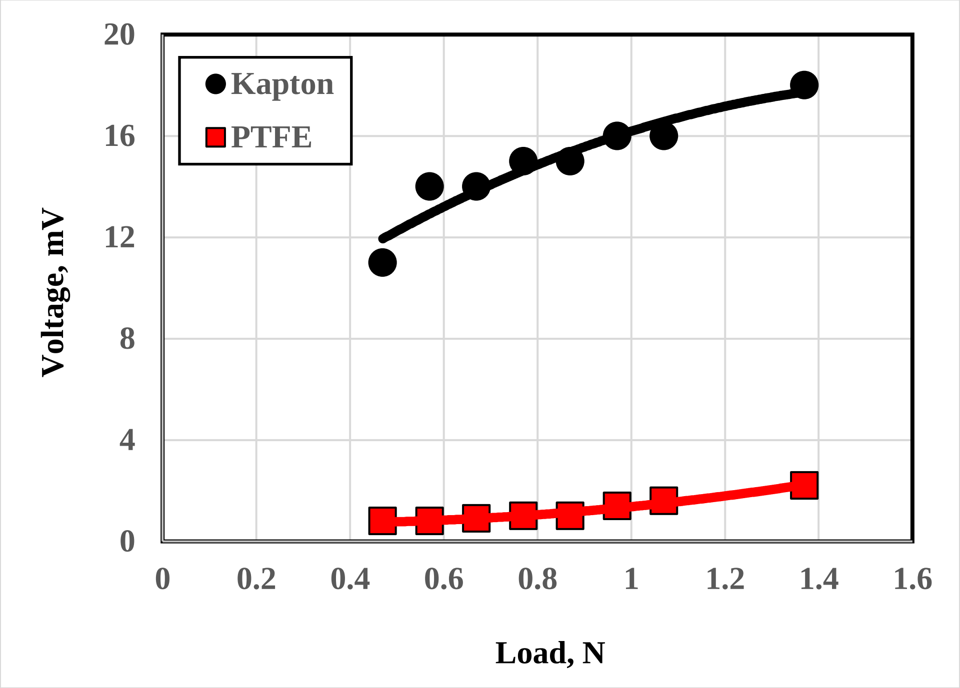

Fig. 7 Voltage difference between charge collecting electrode and the tested materials of rough surfaces.

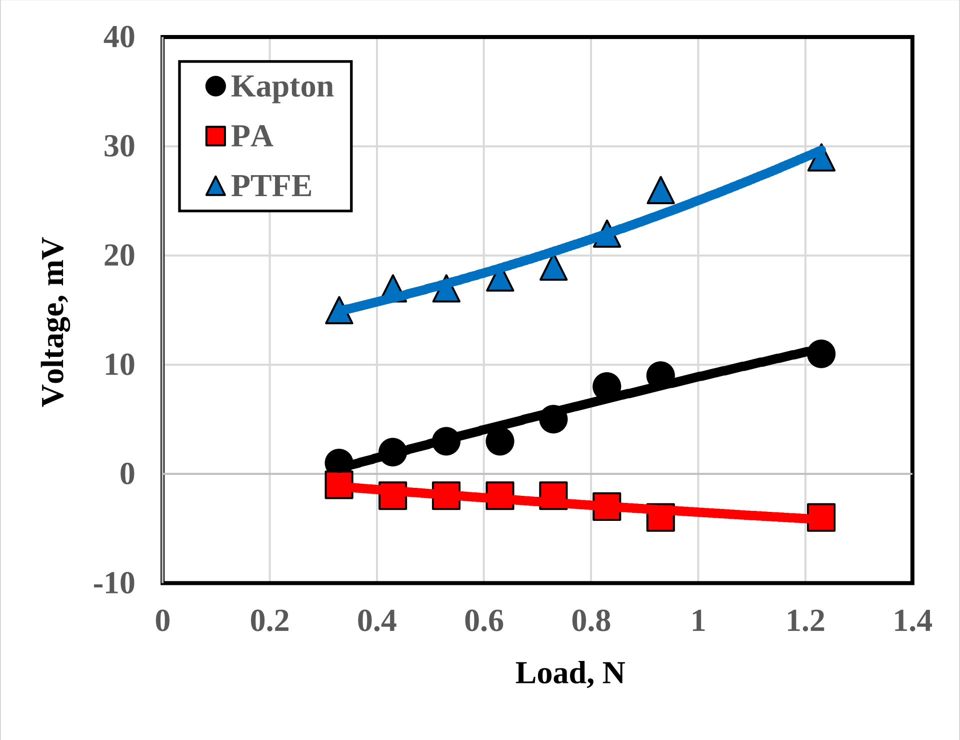

Fig. 8 Voltage difference between the two charge collecting electrodes and the tested materials.

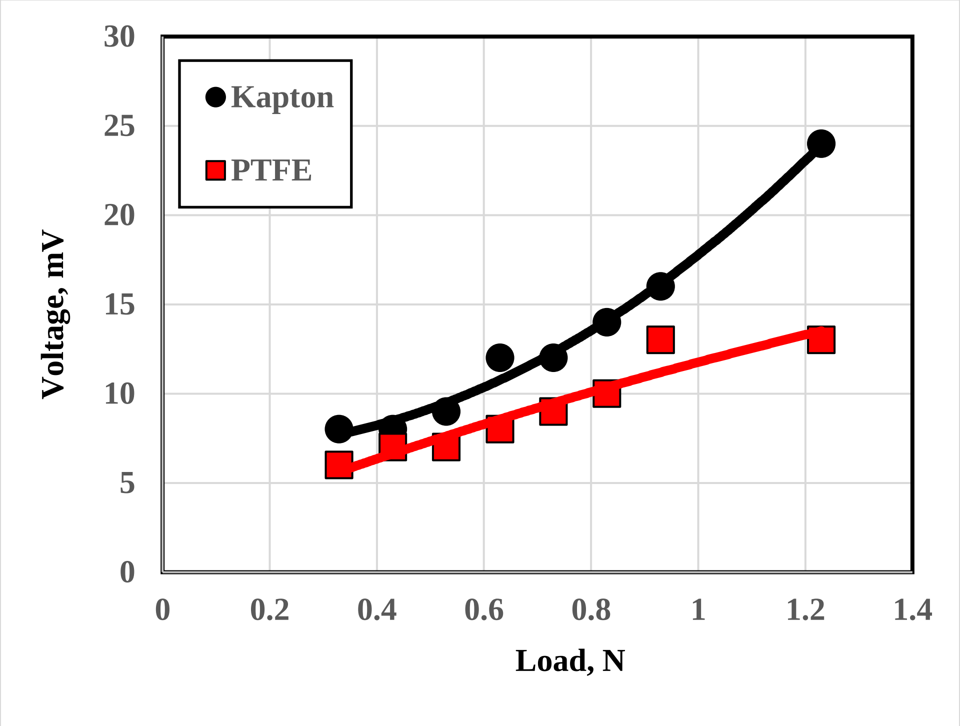

Fig. 9 Voltage difference between the two charge collecting electrodes and the tested materials of rough surfaces.

When the arrangement of the two CCE was used, voltage difference showed remarkable increase, Fig. 8, where PTFE recorded 29 mV instead of 20 mV measured by one CCE. For rough surfaces, Kapton displayed 24 mV at 1.37 N load, Fig. 9.

The voltage difference is harvested by the DC-TENG that works by the combination of triboelectrification and electrostatic breakdown. During sliding, electrostatic breakdown occurs between the CCE and FS due to the electrostatic field, and consequently generates direct current. During sliding, the air gap between the CCE and PTFE is ionized generating direct current flowing in the external circuit. As the FE slides forward, the air breakdown occurs in the gap and fraction of the ESC to flow from PTFE to CCE. In the present work, the PTFE film is FS due to the electrostatic properties of PTFE that gain negative charges. When the FE moves forward the electrostatic field will be induced between PTFE surface of negative charge and CCE of positive charge. The increase of the electrostatic field to be higher than the dielectric strength of the air gap, the breakdown occurs and the DC current flows in the external circuit. Motion of FE forward makes air breakdown occurs continuously in the gap causing fraction of ESC generated by contact electrification to flow from PTFE to CCE. Then the collected charges flow to the FE through the external circuit, resulting in a continuous DC output. When the FE is at rest, the charge on the surface of PTFE rapidly decreased so that the air breakdown stops and consequently decreasing the DC current in the external circuit.

It is clearly noticed that the application of DC-TENG is promising in e-skin design. It is necessary to optimize new methods to enhance its performance and stability. It is essential that more accurate and quantitative model should be further studied to investigate its working process. The compactness of the DC-TENG made it applicable for various area as an energy source or self-powered sensor in e-skin design. DC-TENG can directly drive continuously the electronics with relatively high effective charge density. Further work should be carried out to develop the surface charge density and proper selection of materials of FE and FS as well as gap distance and feature of CCE.

CONCLUSIONS

1. The proposed design of the e-skin includes latex as the outer layer to guarantee secure grasping of the handled objects. Experiments revealed that latex was proper choice due to its relative high friction values when slid on PMMA and epoxy.
2. The highest voltage values were measured for PTFE followed by Kapton as FC.
3. Kapton displayed higher voltage when the FS was roughened by emery paper.
4. Using two CCE at rear and front of the FE remarkably increased the voltage where the same trend was observed for rough surface.
5. Application of DC-TENG is promising in the design of e-skin due to its compactness.
6. Further work should be carried out to optimize the parameters that control the performance of DC-TENG in e-skin design.

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