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PROPER MATERIAL SELECTION FOR A TRIBOELECTRIC NANOGENERATOR

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ABSTRACT

The Triboelectric Nanogenerator (TENG) has been very important ever since it was invented back in 2012. Multiple designs have been made to use it in harvesting energy or in making self-powered sensors. One of those self-powered sensors are self-powered touch buttons.It can be made by adhering a layer of dielectric on an electrode, then the charge is generated when it is touched by a human finger. That charge can then flow to an electrical ground generating a usable signal. This study aims to investigate multiple designs and material choices for a TENG-based button which can be used in hospitals.

It was found that materials close to the bottom of the triboelectric series such as polytetrafluorethylene made for great dielectrics for such a button, while both human skin and latex surgical gloves are close to the top of the triboelectric series.It was revealed that buttons that had two dielectrics that are opposite to one another in the triboelectric series produced a very small amount of charge, and are thus unreliable.The intensity of charge on the person pressing the button was also thought to be major factor in determining the output voltage of the button.

KEYWORDS

Triboelectric nanogenerators, polymethyl methacrylate, polytetrafluoroethylene, polyamide, surgical gloves.

INTRODUCTION

If any two surfaces come into contact with one another, an amount of charge is generated on both surfaces.This phenomenon is known as triboelectrification, [1 - 3]. This phenomenon has been observed for thousands of years, [4]. In order to figure out the amount of charge generated from the contact of any two materials, the triboelectric series was developed, [5 - 7]. This series ranks materials to obtain a positive charge when contacting another material. The more spaced out two materials are in the triboelectric series, the higher the amount of charge generated on both surfaces.

The triboelectric effect led to the invention of the triboelectric nanogenerator (TENG), [8 - 10], which is a device that generates a voltage using terminals, where a terminal is made from a material that is to be triboelectrified connected to an electrode. If the surface of a terminal is triboelectrified, the charge is collected by the electrode and can be used to generate a usable current when connected to an electrical ground.This is known as a 1-terminal TENG, [11, 12], while 2-terminals can also be used with current flowing from one terminal to the other, [13]. The 1-terminal TENG design is usually used to make TENG buttons, [14].

Polymethylmethacrylate (PMMA) is a material with many uses such as dental implants, [15], and has been used in TENGs as it lies near the top of the triboelectric series, [16], like polyamide (PA), [17], Latex, [18], and human skin, [14]. Kapton is another material that has been used in TENGs as it is near the bottom of the triboelectric series, [19]. Polytetrafluoroethylene (PTFE) also shares this property with Kapton, [20].

Hospitals are environments that usually require special material choices, [21, 22]. This is due to the fact that hospital staff tends to wear special clothes and gloves in order to prevent infections andbad side effects from the interaction between the hospital environment and items worn by hospital staff should be reduced.One of those side effects is excess electrostatic charge due to the triboelectric effect.However, the triboelectric effect could be a blessing rather than a curse if it is used in self-powered TENG buttons.Thepresent study discusses the material selection for such a button that can be used in hospitals.

EXPERIMENTAL

Four different buttons were tested. Each button was a 1-terminal triboelectric nanogenerator made of a dielectric connected to a 0.1mm thick aluminum foil electrodeof 14 mm long and 14 mm wide. The first dielectric was made of a 2.5 mm thick PMMA, while the second one used the same PMMA dielectric but half of it was covered with a 0.1 mm thick Kapton layer. The third one was made of a 0.1 mm thick PTFE dielectric, and the fourth one had a dielectric that consisted of a mesh made with 0.75 mm wide strands of PA string.

Each button was loaded on a load cell to measure the force of the touch.The voltagedifference was measured by an Arduino Uno. The button was pressed by human finger grounded and isolated from the ground. It was then pressed twenty five times, once while wearing a medical latex glove.The finger touch was done at dry, wet and lubricated by sunflower seed oil conditions.As the touch force getting progressively higher, the average of the voltage generated and the average touch forcewererecorded for every five presses. The relationship, between touch force and the voltage generated between the button and the reference electrode upon contact, was then plotted for every test, where the results are shown in Figs. 4 - 8.

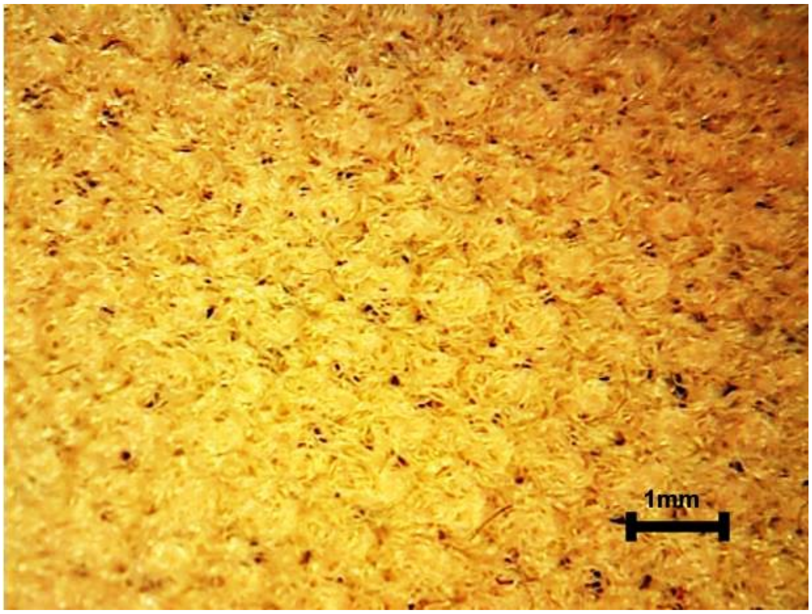

Fig. 1 Photomicrograph of PA mesh.

Fig. 2 The Kapton-PMMA button.

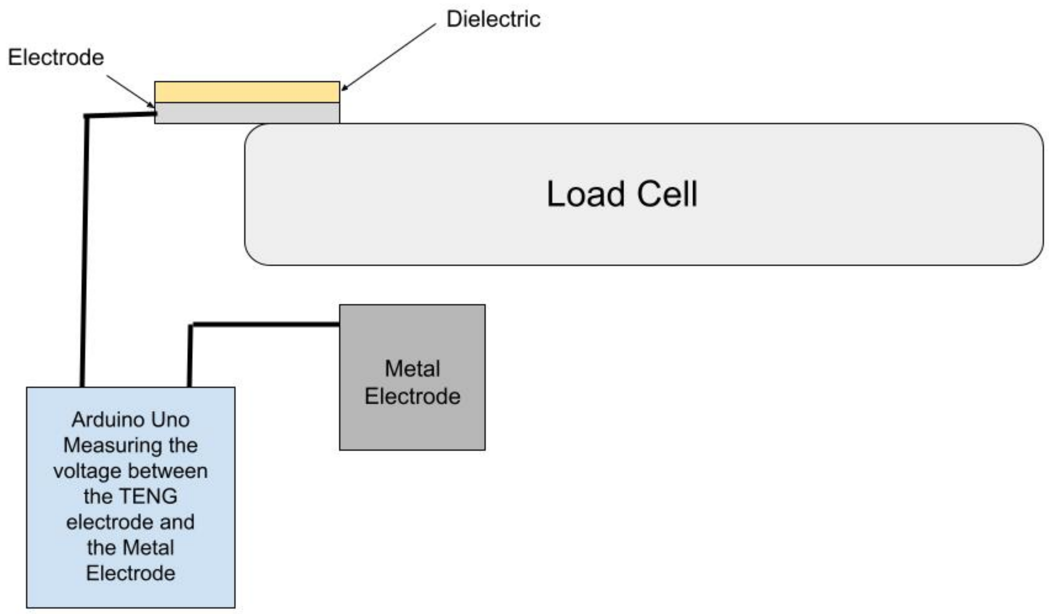

Fig. 3 Experimental setup.

RESULTS AND DISCUSSION

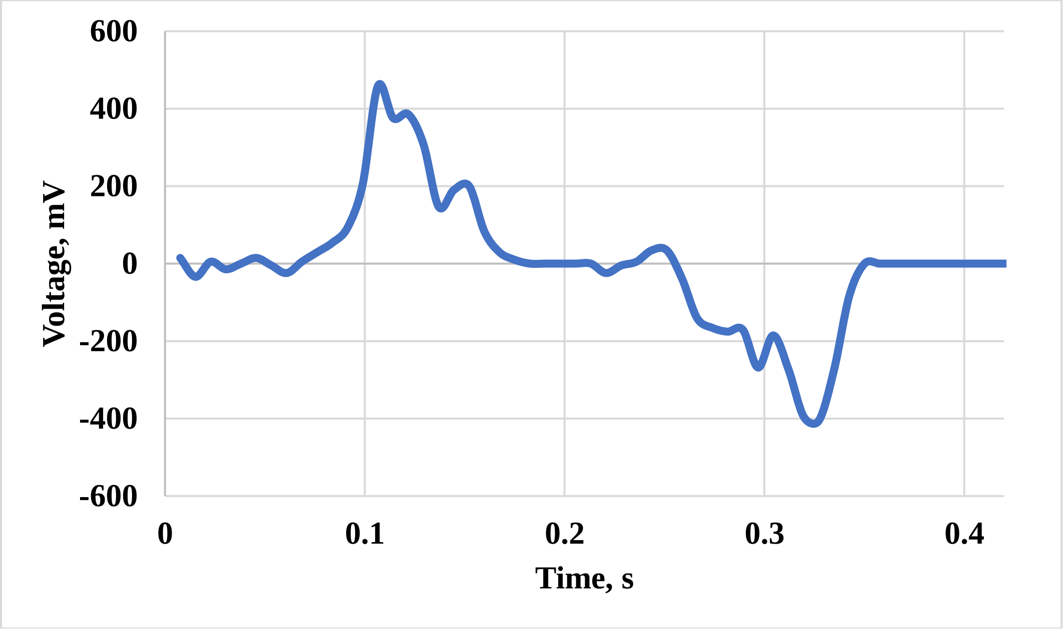

Fig. 4 Example of the voltage response of a button when touched, the positive voltage pulse is at contact, and the negative pulse is at separation.

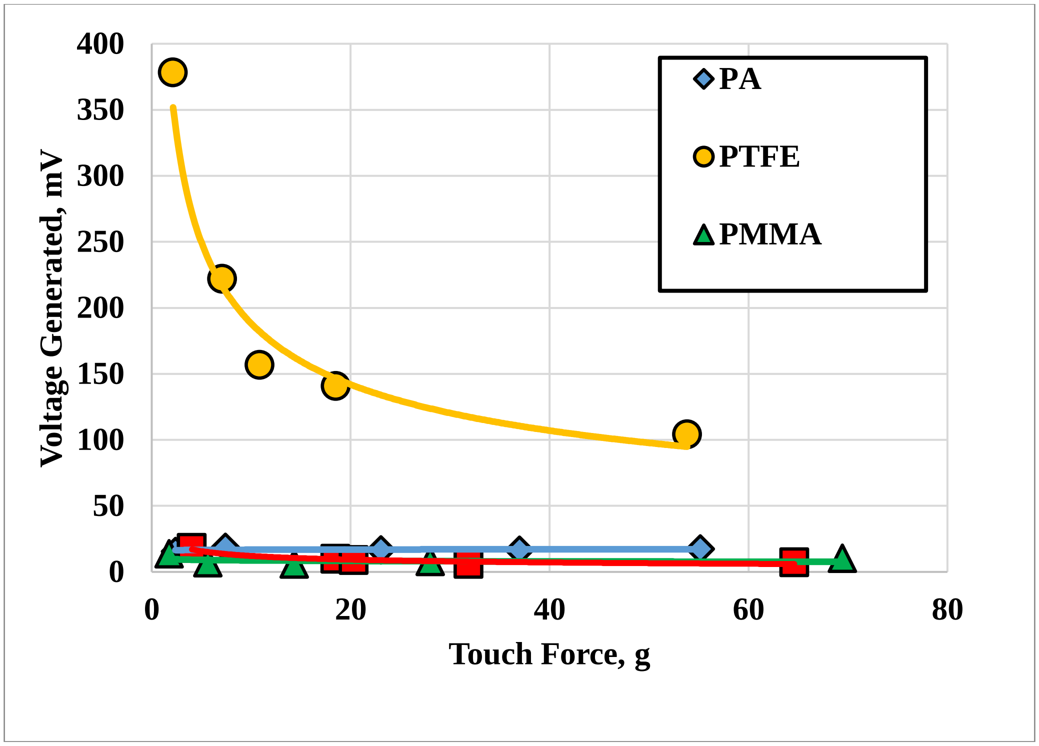

Fig. 5 Voltage generated by each tested button when pressed with a surgical glove at different forces.

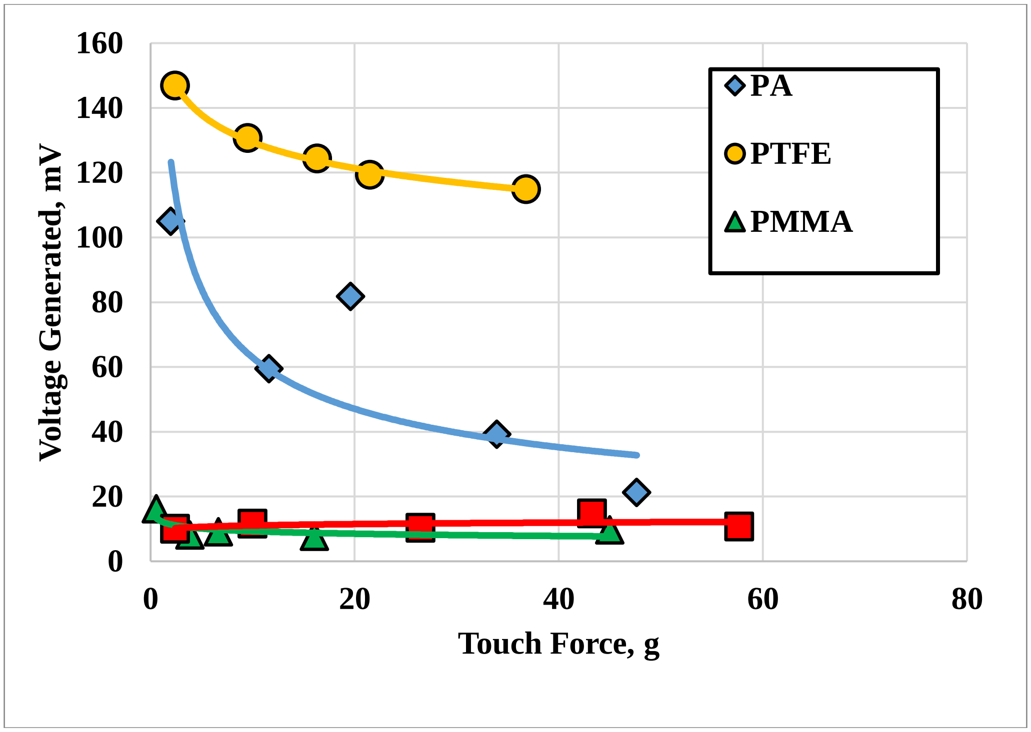

Fig. 6 Voltage generated by each tested button when pressed by a dry human finger at different forces.

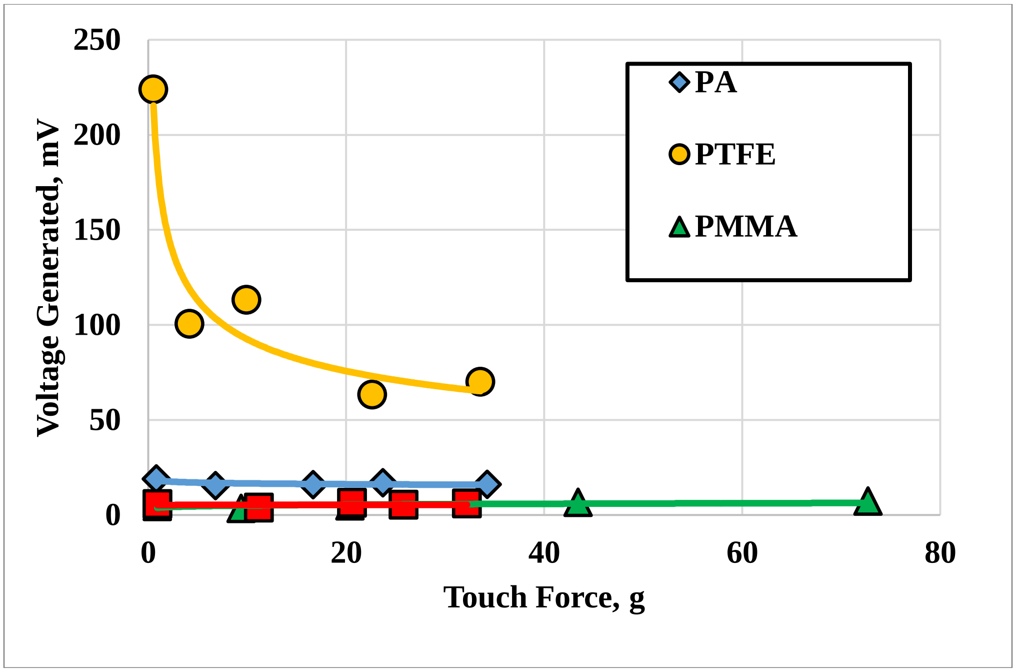

Fig. 7 Voltage generated by each tested button when pressed by a wet human finger at different forces.

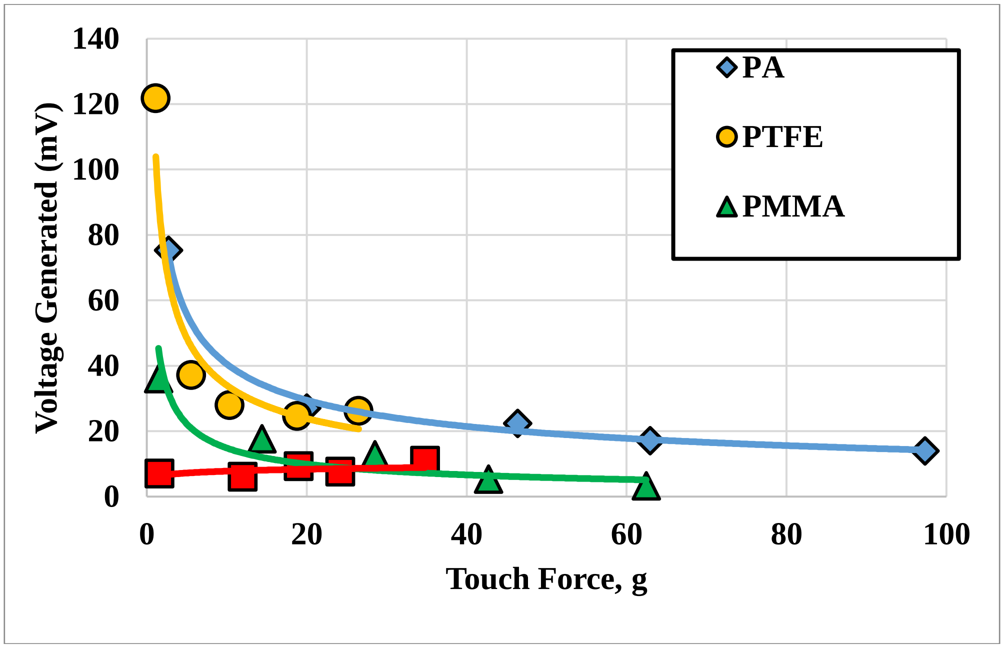

Fig. 8 Voltage generated by each tested button when pressed by an oily human finger at different forces.

It was observed that the PTFE button gave the highest voltage values when touched by a surgical glove, dry or wet finger, with a peak of 378.2 mV, average of the 5 presses at 2.148 g average when touched with a surgical glove. It was followed by PA buttonthat had a very similar performance to the PTFE button when touched by an

oily finger. The Half-Kapton Half-PMMA (Kapton/PMMA) button generated the lowest voltage. This is a confirmation that surgical latex gloves do tend to generate a positive charge when they contact other materials. As PTFE lies near the bottom of the triboelectric series, while PMMA and PAare near the top of the series, the results suggest that sunflower seed oil is lower than human skin in the triboelectric series as it improved the performance of the PA and PMMA button while decreasing the voltage of the signal generated by the PTFE button.

Another observation thatcan be made from the above results is that the output voltage seems to deviate from the traditional relationship between voltage and contact force.It is expected that the voltage should increase with contact force up to a certain point, then it plateaus, [23]. However, in most cases in this experiment, it seems that the voltage started high with a low touch force, then declined as the force increased.An explanation of this behavior canstated as the person pressing the button gained an amount of charge after grounding. This charge increased the induced charge on the button when pressed during the first few presses at low force then it went away gradually, this behavior should thus be expected in real-life situations.

CONCLUSIONS

1. Materials that are lower in the triboelectric series such as PTFE should be used in triboelectric buttons that are designed to be touched either by bare skin or by a surgical glove.
2. If a button has two different dielectrics opposite one another in the triboelectric series, the signal obtained from the button will be very low and thus unreliable.
3. Materials that are high in the triboelectric series should be avoided in the design of TENG-based buttons.
4. The charge on the human body of the person touching the button can play an important role in the output voltage of the button.

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