

# Optimization of Triboelectric Nanogenerator for Small Power Electronics

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**Abstract.** Triboelectric Nanogenerators (TENGs) is a new era energy source to power portable small electronic devices. This paper presents the fabrication of vertical contact separation mode TENGs. Three different TENGs device prototypes are fabricated: (1) Kapton-Aluminium; (2) Teflon-Aluminium and (3) Room Temperature Vulcanizing (RTV)-Aluminium. To optimize the performance of TENGs the effect of various parameters such as thickness of dielectric layer, contact time between two layers and contact separation movement of layers have been observed. Experimental result demonstrates that the output voltage increases initially and then decreases with the increase in thickness of dielectric layer. It is also reported that output voltage of TENGs decreases and increases with the increase in contact time and contact separation movement respectively. In this work, an output voltage obtained from TENGs is suitable to drive applications based on small power electronics.

## 1 Introduction

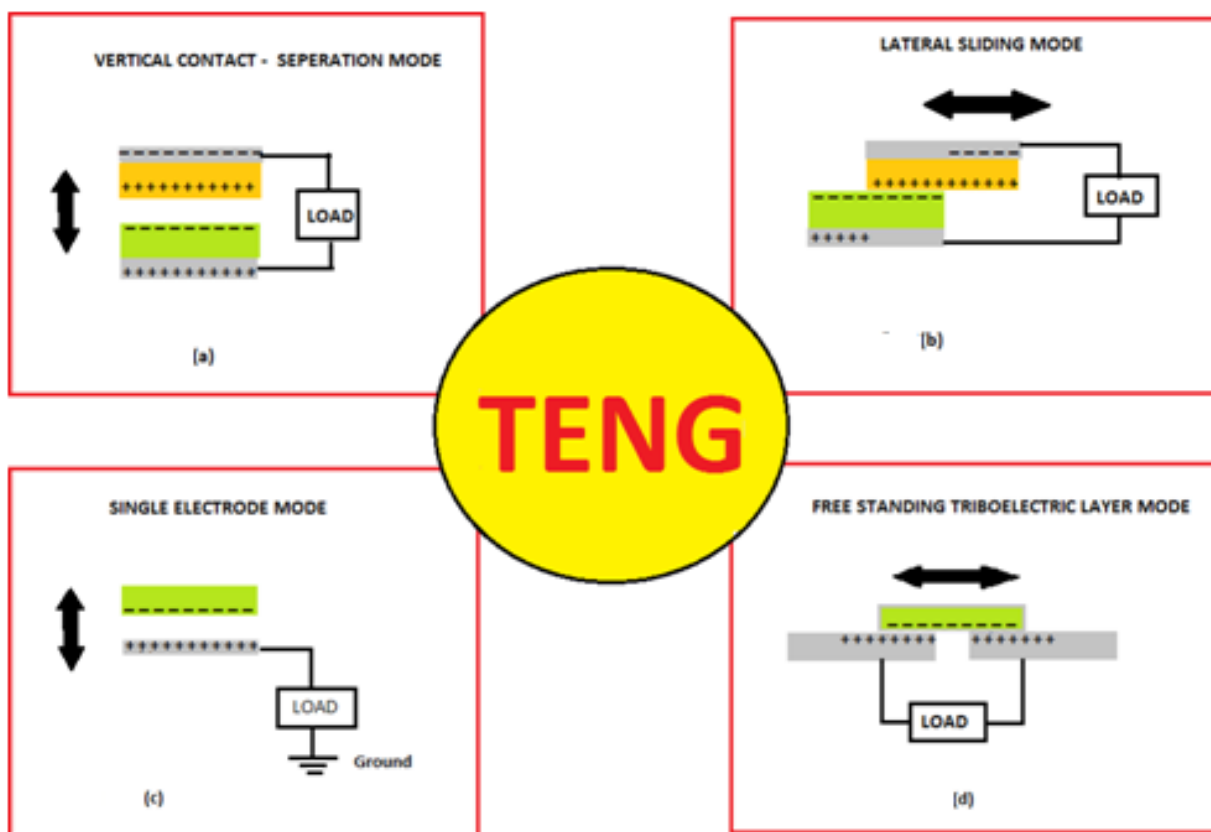
Energy plays a vital role which defines the caliber of our life and sustainable growth of modern society. To deal with the increase in on-going demand it is required to harvest energy from ambient environment energy sources such as vibration, wind, rotational, water drop, human motion etc. For the past few decades with the rapid growth in the miniaturization of electronic devices our world is surrounded by small powered electronic devices such as sensors, actuators, controllers communication devices, wearable gadgets, security devices etc. These devices are mostly powered by small powered source such as traditional batteries. Batteries have a limited lifetime and to manage its recycling is also a matter of great concern. To provide power solutions to these small scale electronic devices there is a need to harvest ambient mechanical energy from environment and convert it into electrical energy using nanogenerators. In the past decades, researchers have extensively studied nanogenerators based on different mechanical or thermal energy harvesting techniques such as piezoelectric, triboelectric, and pyroelectric. Out of all these techniques, triboelectric nanogenerators are most effective in generating electricity from mechanical energy such as human body motion, vibrations, rain droplets and winds [1-5]. TENG is based on the combination of contact induced electrification and redistribution of charges on the object [6-7]. There are four operational modes of TENGs i.e. vertical Contact-Separation (CS), Lateral-Sliding (LS), Single-Electrode (SE), and Freestanding Triboelectric-Layer (FETL) modes as shown in Figure 1.

All the modes of TENG require two different materials with opposite electron affinity and atleast two electrode connection which are separated from each other. The CS mode is based on the principle of pressing and releasing two triboelectric layers to generate electricity as shown in Figure 1a. On pressing, the two layers opposite charges are created on its surface and free electrons starts flowing through the load connected to electrodes. On releasing, the gap is created between the two layers which lead to the development of potential difference between electrodes. Thus, flow of free electrons through the load is dependent on the gap distance between the two layers [8]. The output voltage of CS mode TENG is low and it is suitable for low power electronics based devices. LS mode TENG generates electricity by sliding two different dielectric materials to shown in Fig.1(b), the contact area between two layers varies during sliding process. The main advantage of the LS mode of TENG over the CS mode TENG is that the current output performance can be greatly enhanced by the using grating surfaces i.e. rotational or cylindrical shaped surfaces. One of the main drawbacks of both CS and LS mode TENG is the availability of electrodes connections on the back of both triboelectric layers which restrict its movement [9]. To overcome the problem of mobility constraints due to electrode connections, SE mode is used which contain only one electrode and ground as reference electrode as shown in Figure 1c. But the output voltage generated is very low and can be used to power self powered devices with low voltage requirements [10]. FSTL mode TENGs provide an outstanding solution to the electrode connection problems without compromising on output

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efficiency. In this mode, one triboelectric layer without electrode can move freely over another triboelectric layer with electrode in static location as shown in Figure 1d. The mechanical structure in this mode is quite robust

which make it the best mode of TENG in terms of output voltage efficiency. They are widely used for the self-powered systems with high-voltage requirements [11].



**Fig. 1.** Schematic diagram of four different modes of TENGs (a) CS method, (b) LS mode, (c) SE mode and (d) FSTLmode.

In this paper, fabrication of CS mode TENG is discussed in detail. To optimize the performance of TENG, selection of materials plays a vital role. In this work, three different combinations of Kapton-Aluminum(Au), Teflon-Au and RTV Silicon –Au TENG have been designed. Their performances are analysed by varying the thickness of the dielectric layers, contact time between two layers and contact separation movement of layers.

## 2 Experimental Details

### 2.1 Materials used

In this work, for fabrication of three different types of vertical CS TENG Kapton tape/Teflon/ RTV silicon gel based material act as negative layer and aluminum as positive layer are procured. Dimension of both the layers is kept as 10.16 cm x 7.62 cm with varied thickness of 0.04 mm to 0.2 mm.

### 2.2 Fabrication of vertical CS TENGs

TENG operates on a working principle of triboelectrification and electrostatic induction[7-8]. The amount of output voltage, current and power generated by TENG depends on surface charge density. Surface charge density maximizes when there is a huge potential difference between two dielectric layers. So, the selection of dielectric layers materials is very crucial in designing

TENG. Other parameters such as improvement in surface contact area and environmental conditions also affect the performance of TENG. To optimize the performance, three different combinations of dielectric layer based TENGs lab prototypes are proposed i.e. kapton – aluminum, Teflon – aluminum and RTV silicone – aluminum. In all the three prototypes, aluminum (Al) material is selected as positive layer due to its excellent donor characteristics. And different types of polymer materials are used as negative layer due to their flexibility, excellent electron accepting, mechanical and triboelectric properties. In this work, three different prototypes of triboelectricnanogenerators are fabricated. Their performance with respect to output voltage is compared and analysed.

First, kapton-Al, Teflon-Al and RTV Silicone –Al TENGs devices are developed by attaching the kapton, Teflon and RTV silicone with the dimension of 10.16 cm x 7.62 cm on Al film of dimension (10.16 cm x .8cm). Kapton, teflon and RTV Silicone act as dielectric layer and Al as lower and upper electrode layer. When upper Al electrode layer contacted dielectric layer electrical charge carriers are developed at the interface. Positive charge is developed at the surface of upper Al electrode and negative charge at the surface of dielectric layer. On separating the upper Al electrode layer from

dielectric layer a potential difference is established between two electrodes. Due to the presence of potential difference, flow of free electrons through the load cells connected to electrodes is restricted. When upper electrode layer is fully separated from dielectric layer it become electrically neutral and lower electrode layer become electrically positive due to lack of free electrons. Free electrons start flowing from lower Al electrode to

upper Al electrode. On contacting again, electrons starts flowing in reverse order i.e. from upper

to lower electrode. Thus by repeating contact and separation an alternating current is generated using TENGs as shown in Fig. 2.

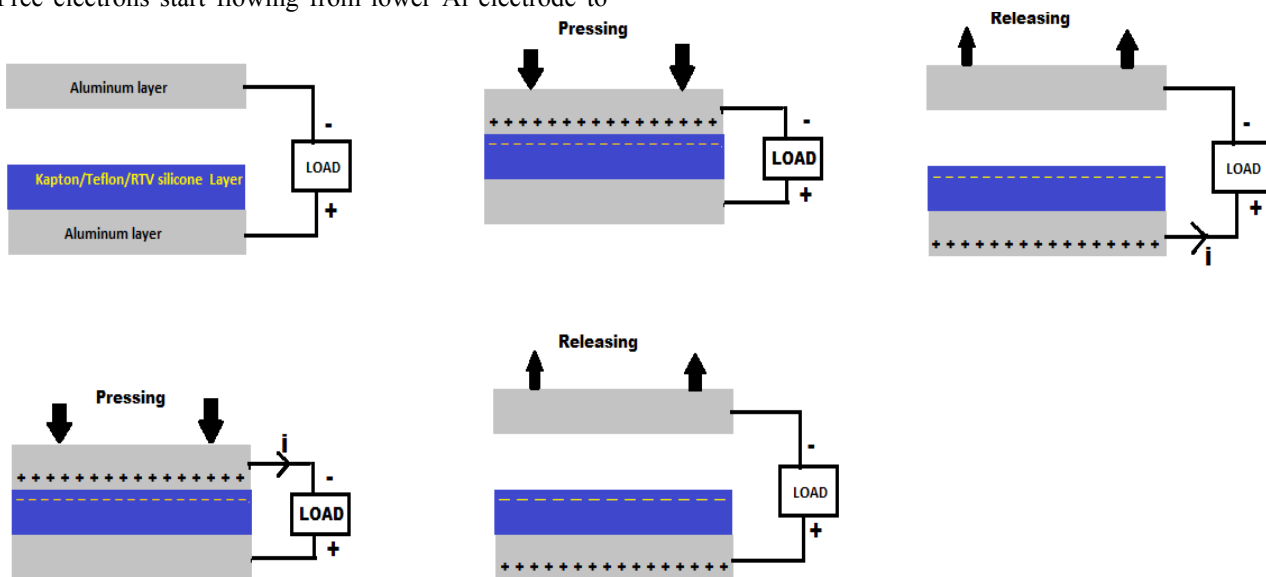
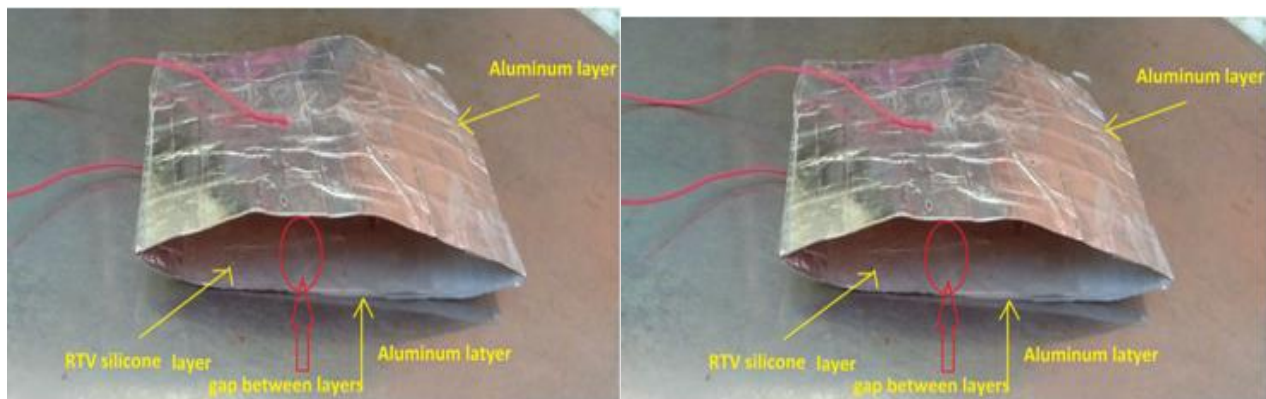


Fig. 2. Working model of TENG.

### 3 Results and Discussion

In this work, three different types of TENGs devices are developed. Fig. 3.shows the photographs of three different types of TENGs. For experimentation, an external force of 15 Newton is applied onto upper

electrode aluminum layer and variation of dielectric layer thickness on output characteristics across load resistor of three devices is investigated as shown in Fig. 4.



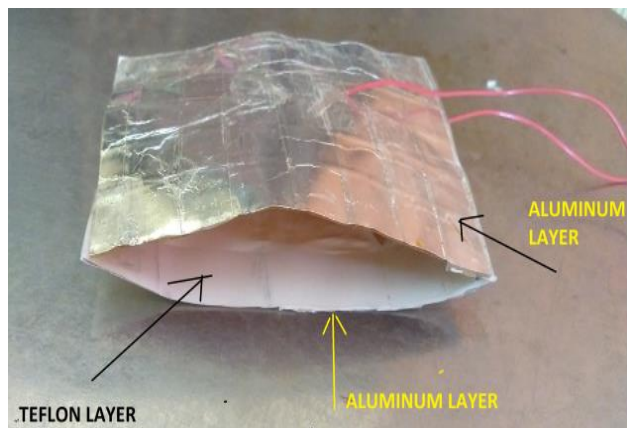


Fig. 3. Photographs of (a) Kapton-Aluminium TENG, (b) Teflon-Aluminium TENG and (c) RTV silicone-Aluminium TENG.

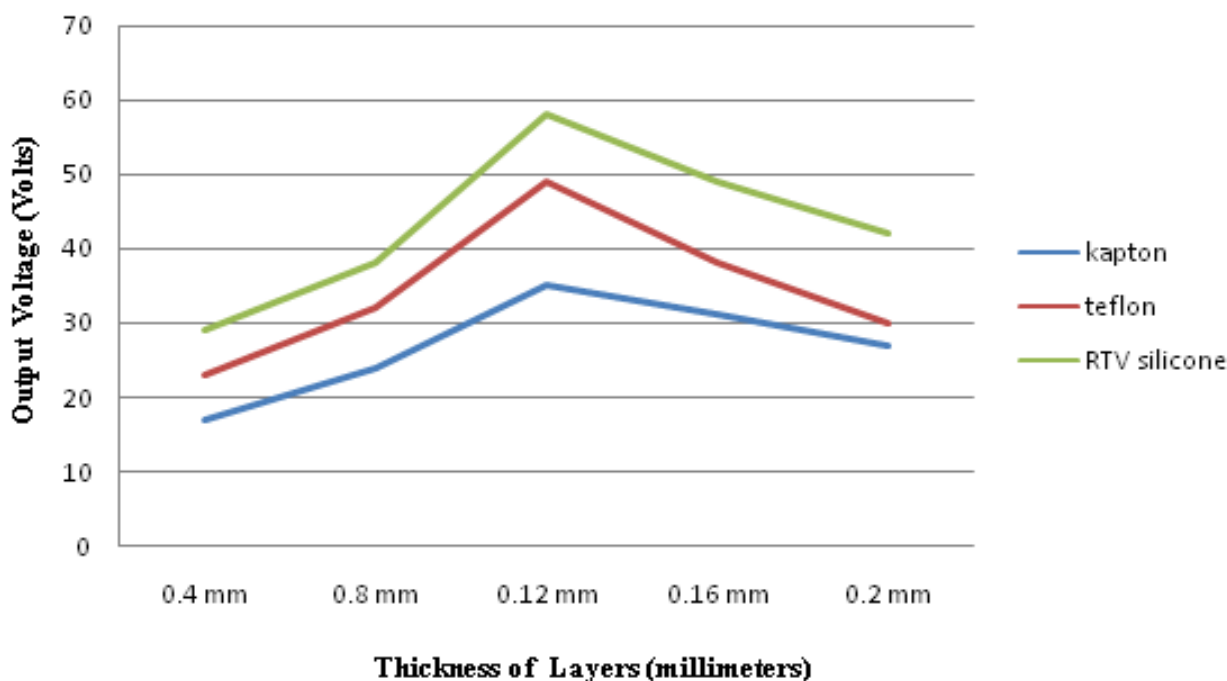


Fig. 4. Effect of dielectric layer thickness on output voltage of three TENG based devices.

From Fig. 4, it is found that for the same force applied, the output voltage across load resistor is highest in case of RTV Silicone-Al TENG device i.e 30 V with the load resistance of 15 mega-ohm for 0.4mm dielectric layer thickness in comparison to 25 V and 18 V for Teflon-Al and Kapton-Al respectively for the same load 15 mega-ohm. All devices show a linear rise in the output voltage on increasing the thickness of dielectric layer from 0.4 mm to 0.12 mm. On further increasing the thickness of dielectric layer from 0.12mm to 0.2 mm a downward trend is visible which is less predominant in case of Kapton-Al TENG based device. This suggests that 0.12 mm thickness is considered to be optimum for TENGs. This result is in conformation with Distance Dependent Electric Field Model (DDEF) which suggests that on

increasing the thickness of dielectric layer output voltage of TENG decreases significantly [12].

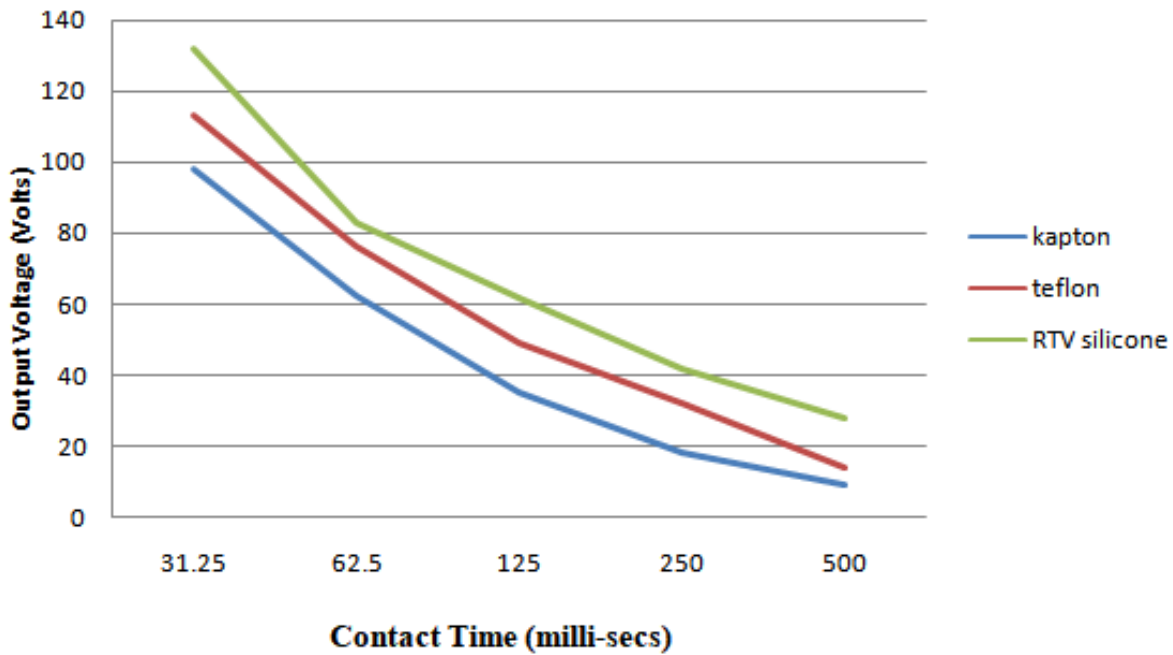
Further experimentation is carried out to find the effect of contact time and contact frequency on the output voltage of TENGs. It is performed by choosing three TENG devices with dielectric layer of thickness 0.12 mm and an external force of 15 N. First of all, the contact time of layer is varied from 0 to 500 milliseconds and output voltages of all the three TENGs are reported as shown in Fig. 5.

It is clearly observed from Fig. 5 that in all the three cases output voltage decreases with the increase in contact time of layers. This is because of high external load (i.e. in

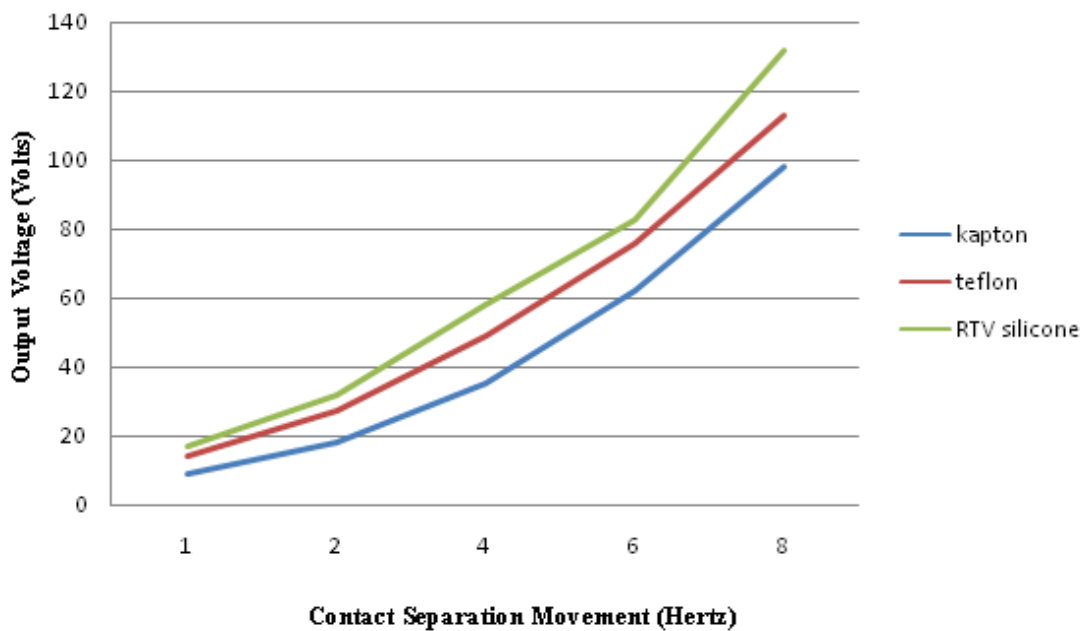
mega ohms) and fast deformation period of dielectric layer. This result is in conformation with the published literature [13].

Secondly, the effect of contact-separation movement of layer on TENG performance is analysed. For analysis, three devices of fixed dielectric thickness (i.e 0.12 mm) is considered and motor is used to vary the contact separation frequency of layer from 1 to 8 Hz as shown in

Fig. 6. It is observed from the result that the output voltage of all the three devices increases with the increase in contact separation cycle per seconds and it is predominant in case of Kapton-Al device. This is due to the fact that larger the value of contact-separation cycles per second shorter is the contact-separation time per second, smaller the contact separation time per sec higher is the output voltage. this result is in conformation with the published literature[13-14].



**Fig. 5.** Effect of contact time on output voltage of three TENG based devices (dielectric layer thickness of 0.12mm corresponding to 15 mega-Ohm load)



**Fig. 6.** Effect of contact separation movement on the output voltage of three TENG based devices (dielectric layer thickness of 0.12mm with 15 mega ohm)

## 4 Conclusion

In this paper, three different types of vertical CS TENGs device prototypes are fabricated: (1) Kapton-Au; (2) Teflon-Au and (3) RTV-Au. To analyze the performance of fabricated TENGs various parameters i.e. thickness of dielectric layer, contact time between two layers and contact separation movement of layers are varied. From experimental results following conclusions are: (i) for better output voltage RTV-Au is the preferred prototype over the other two; (ii) output voltage increases linearly with the increase in thickness of dielectric layer from 0.4 mm to 0.12 mm & shows a downward trend thereafter, (iii) for designing TENGs 0.12mm is considered to be an optimum thickness, (iv) output voltage decreases with the increase in contact time of layers and (v) output voltage increases with the increase in contact separation cycle per seconds and it is predominant in case of Kapton-Al device. In future, effect of contact surface layer width and ion injection density on output voltage of TENG must be studied to give researchers deeper insight for optimizing the performance of TENGs .

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