Triboelectric effect - generators for everyday tasks

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In this experiment, it was studied the triboelectric effect, being divided into three parts. Firstly, in order to better understand this phenomenon, it was verified the order of the triboelectric series, using two pairs of materials, Nylon 6.6-PVC and Nylon 6.6-PTFE. In the second part, using the best pair, Nylon 6.6-PTFE, the characteristic behavior of triboelectric materials was observed, being possible to determine its maximum power (6,68 mW) and its resistance (R=10$M\Omega$). Finally, it was elaborated a prototype of a road speed reducer that can harvest energy to power the street lighting.

I. Introduction

With the constant development of technology, more and more devices are becoming wireless, portable and multifunctional, increasing the search for new ways of independent and maintenance-free power sources. Since there is a great abundance of mechanical energy existing in our living environment and human body, the emerging technologies for mechanical energy harvesting are effective and promising approaches for building self-powered systems. Recently, a new creative invention appeared - the cost-effective and robust triboelectric nanogenerators. Based on the universally known contact electrification, they harvest mechanical energy through a periodic contact and separation of two polymer plates. However, in order to realize sustainable driving of electronic devices/systems, its output must be significantly improved through a rational design.[5]

The triboelectric nanogenarator has many advantages, such as reduced size, easy and low cost manufacture, and it can harvest energy from motions of the everyday life, offering a solution for the urgent need to reduce the consumption of fossil fuels.

In here, it is presented a prototype of a road speed reducer that can harvest energy by the motion of the cars.

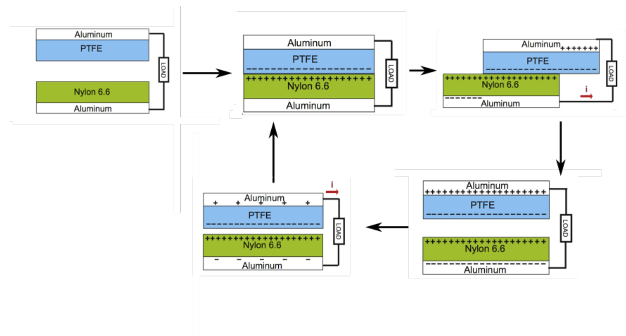

Figure 1. Mechanism of the triboelectric effect. [3]

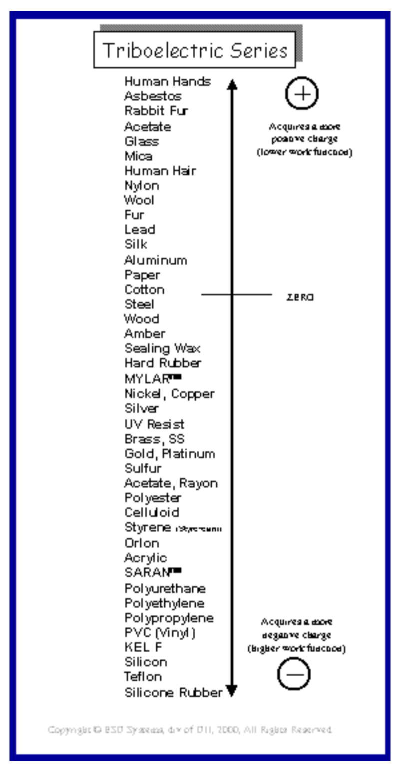

Figure 2. Triboelectric series. [2]

II. The triboelectric effect

The triboelectric effect is about a phenomenon that a material becomes electrically charged after it is contacted with a different material through friction. A physical contact between two films of two different materials creates oppositely charged surfaces. Once the two surfaces are separated by a small gap under the lifting of an external force, a potential drop is created. If the two electrodes are electrically connected by a load, free electrons in one electrode would flow to the other electrode to build an opposite potential in order to balance the electrostatic field. Once the gap is closed, the triboelectric charge created potential disappears, the electrons flow back (Figure1).[4]

III. The triboelectric series

The charging process is well understood for metals and is attributed to the transfer of electrons from the metal to the accompanying material. Charging that occurs with polymers is not as easily explained and this is unfortunate because the charging behavior must be understood to properly control the charge that may develop on these materials. On the other hand, there are several consistent charging patterns observed with these materials. In particular, insulators [2] and organic polymers can be arranged in the triboelectric series (figure 2).

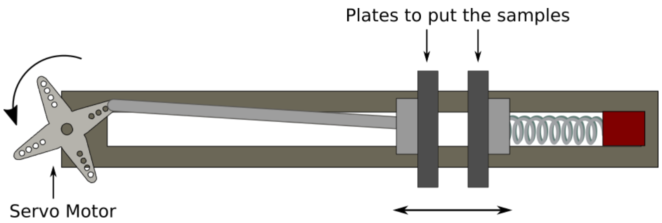

Figure 3. Experimental setup.

In this series, the materials are ordered by the relative polarity of the contact charge acquired, from those that charge most positive, like nylon, to those that charge most negative, like the halogenated polymers. In the triboelectric series the higher positioned materials will acquire a positive charge when contacted with a material at a lower position along the series, which means that the more the two materials used in the triboelectric device are distant from each other in the triboelectric series, more efficient is the device. [1]

IV. Experimental, Results and Discussion

A. Experimental Setup

To analyze the triboelectic effect, it was assembled the setup represented in figure 3.

For the study of the typical triboelectric behavior, it was connected a relay between the second sample and the oscilloscope, to vary the load resistor.

The servo motor and the relay were controlled using Arduino, connected to the computer.

B. Triboelectric series

In order to verify the order of the materials in the triboelectric series, it was tested the triboelectric effect between different materials of the series, by analyzing the mean value of the open-circuit voltage of the peaks created by the junction and instant separation of the films. There were tested two combinations, using Nylon 6.6 as the common material, paring it with PVC and PTFE.

As expected, the results are in concordance with the triboelectric series, and the best pair to obtain the most effective device is Nylon 6.6 - PTFE, with a mean open-circuit voltage of 0,65 V, while Nylon-PVC reached 0,55 V.

Figure 4 represents the typical behavior for any pair of triboelectric materials. The positive peak corresponds to the junction of the planes, and negative peak to their separation. Sometimes it is possible to see zero voltage between the two peaks because the separation is not immediate, and they stay in touch with each other for a short period of time.

C. Triboelectric behavior

In order to analyze the triboelectric behavior, it was used the most effective pair of materials, Nylon 6.6 and PTFE, and it was measured the tension in open-circuit and determined the current in short-circuit[1] (using the measured tension in short-circuit, applying Ohm's law with a resistance of 10Ω), as functions of the connected load resistor. These measurements allowed the determination of the maximum power, corresponding to the resistance of the device.

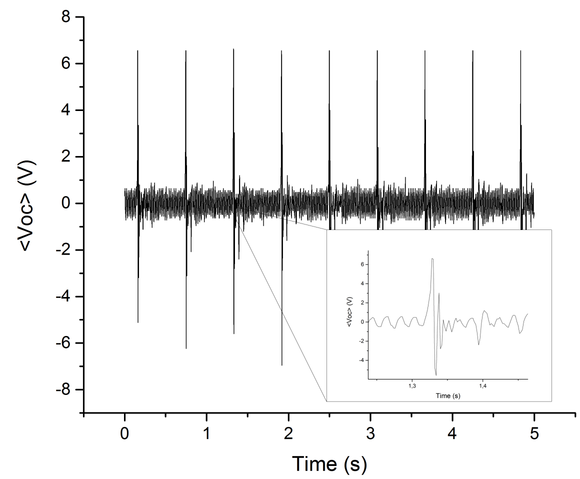

Figure 4. Typical peak of a triboelectric behavior.

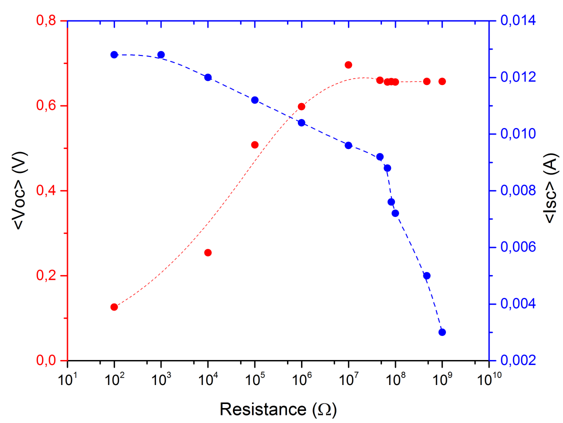

Figure 5. Voltage and current measurements, as functions of resistance.

Figure 5 shows the obtain results. It is possible to identify three different regions: Region I, where the resistance is low (0.1–100 kΩ), the output characteristics are close to the short-circuit condition (V=0) and there is a maximum transfer of charge between the materials; Region II, where the output current drops dramatically, but the voltage increases at a reverse trend; region III, where the resistance is larger than 1GΩ, the output characteristics are close to the open-circuit condition, in which the maximum voltage saturates and the current goes to zero.

Analyzing the results from figure 6, the maximum power obtain was 6,68 mW, corresponding to a resistance of $10 M\Omega$.[2]

The results obtain were satisfactory, although some values are not coherent with the rest. The fact that the area of contact

[1]This current is very small, therefore it was used an amplifier.

[2]The values can be compared since both plates had the same area.

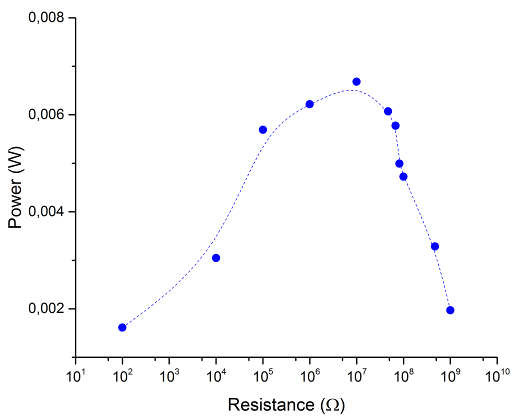

Figure 6. Power of the device, for different load resistor values.

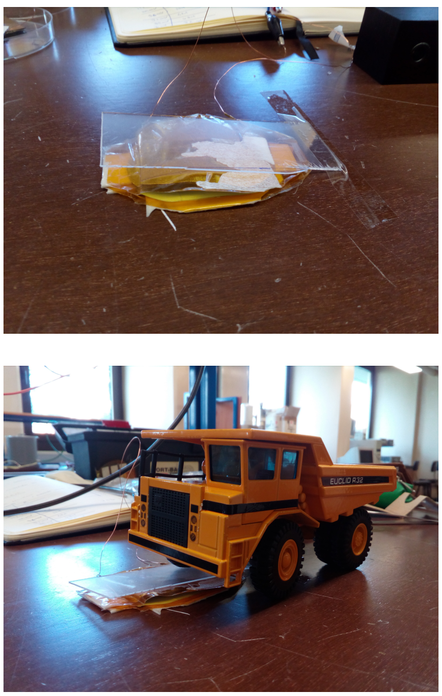

Figure 7. Prototype of a road speed reducer.

is not always the same, and that the short-circuit current is very small, can justify the variations and the errors of the results.

D. Prototype for a road speed reducer

In order to explore the possible applications of a triboelectric generator, it was made a prototype of a road speed reducer. The idea is to use the exerted force by the a car to produce energy to power the street lightning, for example.

The prototype consisted of films of PTFE and Nylon, placed in two opposite pieces of Kapton, glued to each other (in a closed shell shape, but flexible), and a hard plastic ramp, as shown in figure 7. Everything had to be perfectly placed to make sure that the films only touched when the car was on the ramp.

The maximum tension obtained was above 400 mV, but it was noted that the fastest the car was, the more efficient was the device, contradicting the fundamental principal of a speed reducer.

Using the same basis, it would be possible to put it on doors to take advantage of the knocking. This idea was tested and higher tensions were achieved.

V. Conclusion

It's evident that the triboelectric effect is very promising, but in order to achieve its maximum potential, it is extremely necessary to study the most effective conditions in terms of the different materials used, their areas and time of contact.

In the near future, it will be possible to use the movements of the human beings and their daily life, to feed their need for energy, even for the tiniest device.

References

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