Study of Triboelectric Effect - An applause for energy

Tiago João Lopes Leal (up201305730)

***Abstract*—It was studied the triboelectric series for PTFE, FEP, PVC, Cellulose and Copper relatively to Nylon 6.6. With patches of PTFE and Nylon 6.6 it was evaluated, with a load resistance ranging from from 100Ω to 1GΩ, the voltage mean and the power density. The maximum voltage was 3.07V and the power density was 0.009W/m^2. For an application example it was designed a latex glove with a patch of PTFE.**

I. Introduction

For a long time - dating the ancient Greek civilization - humans have observed the strange effect of charging electrically when rubbing a piece of amber and wool together. Following studies found this interaction was found also for pressing (usually generating a high voltage) and a multitude of different materials. The phenomena is called triboelectric effect and it's explained by the fact that when two surfaces of different materials tend to stick together because of the attraction between the different molecules. Because the electron transfer between molecules in the different materials is not immediately reversible (namely in insulators), the excess electrons in one type of molecule remain left behind, while a deficit of electrons occurs in the other. Leaving to steal electrons from the other contacting surface, having the first an excess negative charge, and the latter acquiring an equal positive charge (see 2a).

A. *Triboelectric series*

The triboelectric series is a table where it's organized the materials accordingly to their charge affinity, on the top there's the materials that tend to charge negatively and on the bottom those that tend to charge positively. This table can be used to chose materials that would generate the greatest voltage in the triboelectric - it's expected that the effect it's stronger the farther the materials are on the table - or to minimize static charging, avoiding corona discharges.

Material name	Charge affinity (nC/J)
Polytetrafluoroethylene (PTFE)	-190
Fluorinated ethylene propylene* (FEP)	~ -190
Polyvinyl chloride (PVC)	-100
Latex	-105
Copper	**
Paper (cellulose)	+10
Nylon, dry skin	+30
Hair, oily skin	+45

Table I: Triboelectric table. Adapted from: http://www.trifield.com/content/tribo-electric-series/ (consulted in 6th of March) *Estimated **It wasn't found an absolute value for copper just a position on the triboelectric series as being slightly negative

II. Experimental process

A. *Experimental Triboelectric Series*

Using the pressing apparatus (Figure 1) and Nylon 6.6 as a reference insulator material it were performed several cycles for each of the following materials: PTFE, FEP, PVC, cellulose and copper. The area of the samples was about $3cm^2$ and the voltage was measured in open circuit (Figure 2a) using a Tektronix oscilloscope .

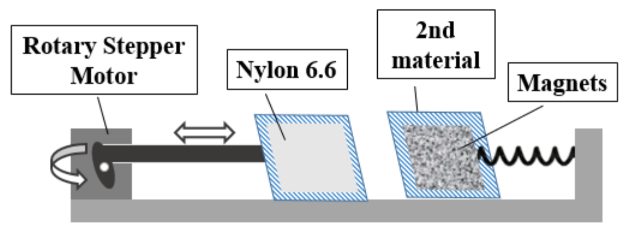


Figure 1: Pressing apparatus. It's composed by a rotary stepper motor that pushed and pulled periodically a rod attached to the surface that had a sample of Nylon 6.6 and some magnets. When it was closed to the other surface it would attract the second surface leaving them to clash and generate a high voltage signal. .

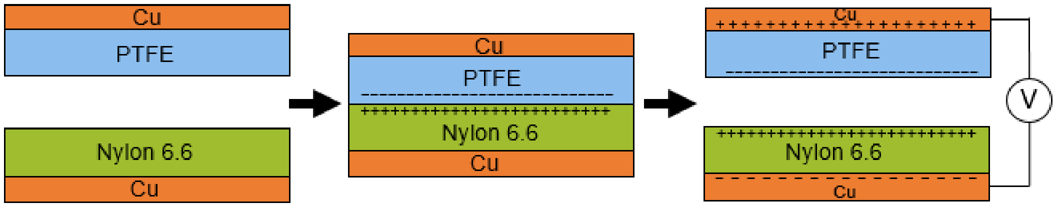
B. *Voltage vs Resistance Curve*

Using the insulators most distant in the triboelectric table (Table I), in this case, Nylon 6.6 and PTFE, it was performed a short circuit voltage measurement (Figure 2b) with the same apparatus as before (Figure 1).

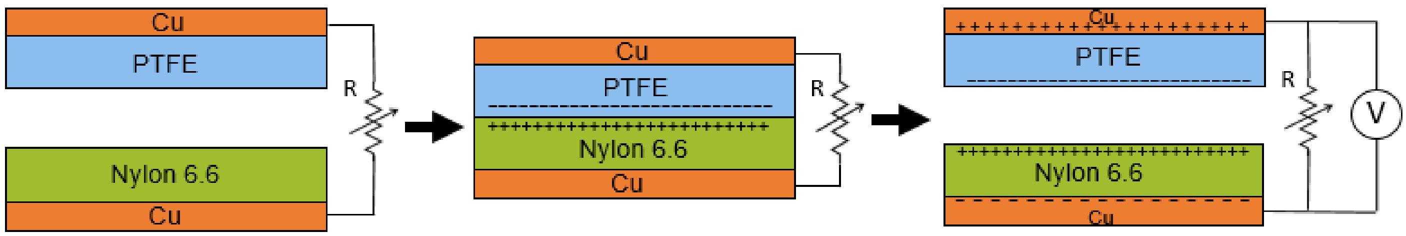
Due to the fact that the effect if force dependent it was designed another set up so that the force of the impact was greater generating higher peaks of voltage and current, but because the it was needed to be hitting the materials by human labor it would lead to a non consistent parameter that could mess with the data.

C. *Application*

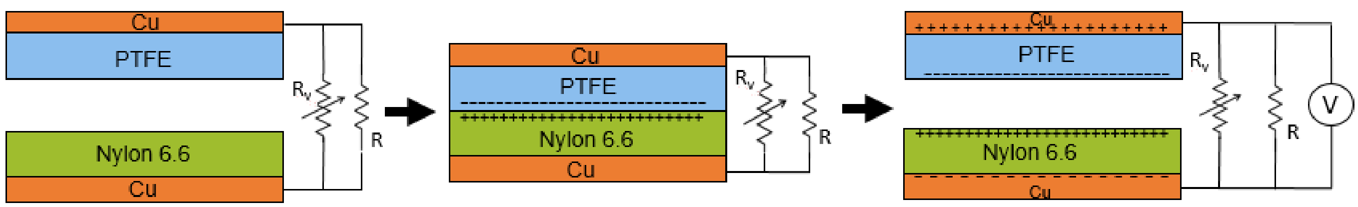
The last part of this study was to create a triboelectric nanogenerator (TENG) in order to generate electricity. It was designed a single-electrode glove that had a patch of PTFE (Figure 3), supported by a electrode of copper. When a finger or the palm touched the patch it would induce a voltage peak measured in short circuit.



(a) Open circuit measurement.



(b) Short circuit measurement.



(c) Short circuit for measurement of current

Figure 2: Schemes of the measurements for voltage and current.

Figure 3: Glove with the PTFE patch.

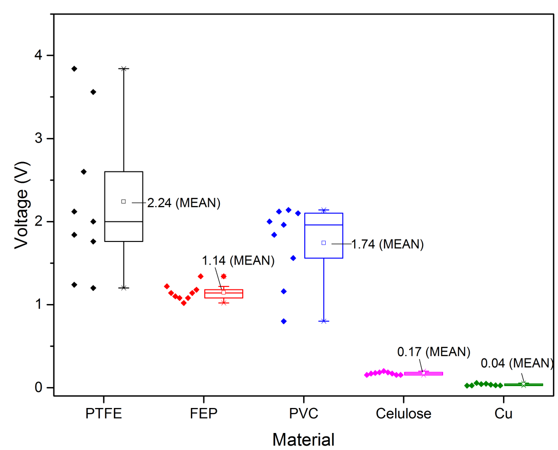


Figure 4: Box plot of the voltage values for the studied materials.

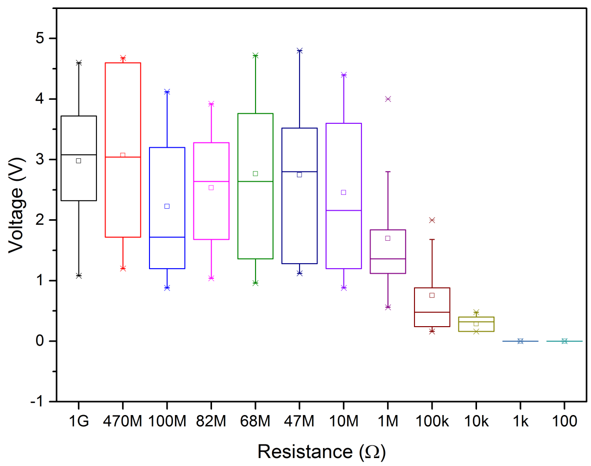
III. Results and Discussion

Apart from FEP, the data gathered (Figure 4) is consistent with what was expected from the tabled data (Figure I).

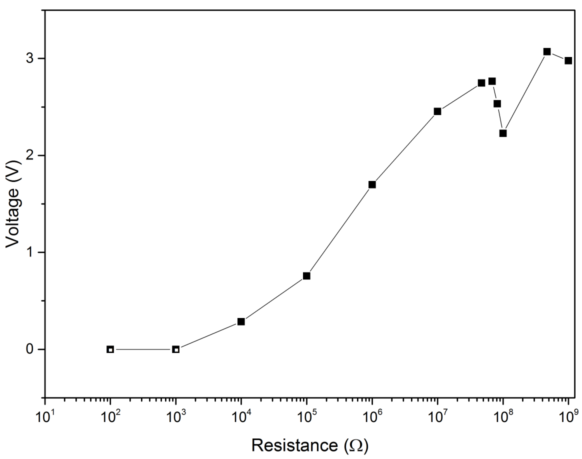
For FEP, cellulose and copper the voltage values are quite precise although for copper the uncertainty is on the same order of magnitude of the voltage value (see Table II) so a better apparatus may be needed to measure in greater detail for this material. For the copper it was expected a low voltage value because between metals there isn't a big difference in charge affinity, maybe because of the rapid motion of conduction electrons that cancel the small charge accumulated.

Material name	Voltage Mean (V)
PTFE	2.2±0.9
FEP	1.14±0.09
PVC	1.7±0.5
Cellulose	0.17±0.02
Cu	0.04±0.01

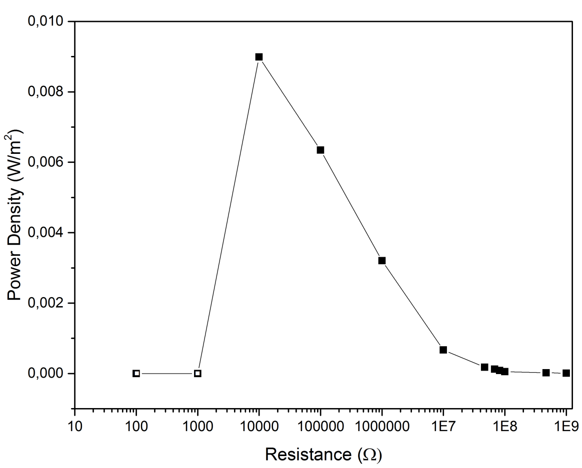
Table II: Mean of peaks of tension gathered.



(a) Voltage distribution for each resistance measured.



(b) Voltage measured in relation with the resistance.



(c) Power density in relation with the resistance.

Figure 5: Output voltage and power density for the rotary stepper motor with Nylon 6.6 and PTFE. Note: for 1kΩ and 100Ω the values were very close to our maximum sensitivity so they were estimated.

It was investigated the performance of our samples (Nylon 6.6 and PTFE) when applied to a variable load resistances (from 100Ω to 1GΩ). Apart for some resistances, namely 100MΩ, 82MΩ, 68MΩ, it's observable that the voltage increases with the resistance load. When values of resistance are above the 1GΩ generally the circuit starts to operate as if it is an open circuit, dropping the current close to zero.

The power density, that is an important parameter for electricity production, had a maximum around 1kΩ of 0,009W/m^2 a really low value comparing with the first papers with triboelectric nanogenerators (TENG) that in 2012 had 3.67W/m^2.

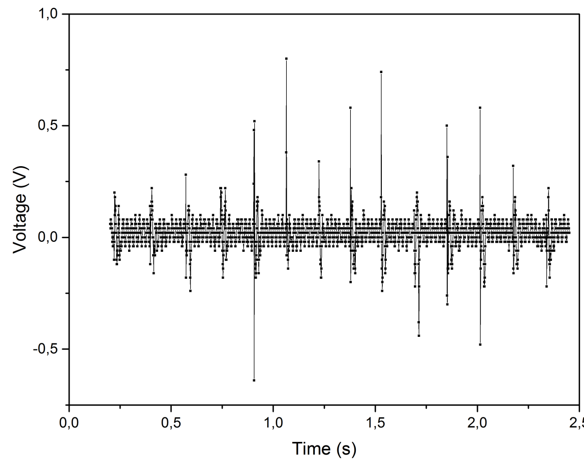


Figure 6: Output voltage for the glove application.

Lastly, wearing a latex glove previously prepared with the insulator patch it was obtained a voltage mean of 0.518V with the highest value being 0.8V.

It wasn't possibly to evaluate the current because it was just too low for our equipment to measure. This comes also from the experiment restrictions, being the triboelectric effect, when pressed, a instantaneous process makes harder to work with the voltage signal received in order to remove some noise and increase resolution.

IV. Conclusion

It was possible to observe the triboelectric effect on a range of different materials. Although it was not possible to measure current, the voltage vs resistance curve obtained corresponded to the expected.

Regarding the TENG in order to understand better if this would be a good electric generator it should be done an analysis of the power density.

For the future it's suggested to improve the existing set up so that a stronger impact could be applied, given the fact that this effect if force dependent.

References

[1] Rodrigues, C. R.; Alves, C. A.; Puga, J.; Pereira, A. M. & Ventura, J. O. Triboelectric driven turbine to generate electricity from the motion of water Nano Energy, 2016, 30

[2] Wang, Z.; Chen, J. & Lin, L. Progress in triboelectric nanogenerators as a new energy technology and self-powered sensors Energy Environ., 2015, 2250-2282

[3] Wang, S.; Lin, L. & Wang, Z. Nanoscale-triboelectric-effect enabled energy conversion for sustainable powering of portable electronics Nano Letters, 2012, 12, 6339-6346