Harvesting energy from the fingertips using triboelectric films

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Abstract- Nowadays much effort has been devoted to produce affordable and clean energy to meet the worldwide needs. By using triboelectric nanogenerators (TENGs) for harvesting ambient mechanical energy based on the triboelectric effect such demands can be accomplished. In order to get the triboelectric series of six different materials an open circuit experimental apparatus was performed. The tendency of a material to acquire charge determines its place in the triboelectric series. Rating from low to high affinity, the obtained series was: PTFE, PVC, FEP, Cu, cellulose, Nylon 6.6. The results didn't really matched with the literature. After choosing the best triboelectric materials, a voltage and current measures were performed under a short circuit scheme. Unfortunately the voltage vs resistance plot shows a decreasing dependence, not in agreement with was expected. It was also plotted the power density vs resistance. Ignoring the first point, the system delivers a maximum power density for $100\,k\Omega$ reaching$0.1\,mW/m^2$. After all, by attaching a PTFE film to the keyboard and using the fingertips to text, one can deliver a mean open-circuit voltage of $0.222V$.

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I. Introduction

Over the past decades the development of society and the economy has substantially increased energy demands. Much research efforts have been devoted to harvest ambient energy to meet the worldwide needs. Nowadays, the electronic gadgets are following a general trend of miniturization, portability, and functionality. Currently, most of these autonomous devices use batteries for their power supply, but size limitations prevent long autonomy. For this reason, a large effort is ongoing to replace batteries with more efficient power sources in order to generate and store power at the micro-scale to improve autonomy and reduce the size of the devices.

Recently, the triboelectric effect has been utilized to obtain mechanical energy from irregular vibrations, sliding, and rotations, leading to the invention of triboelectric nanogenerators (TENGs). Based on the triboelectric effect coupled with electrostatic induction, TENGs have been used to harvest energy from a variety of applications.

The triboelectric effect occurs when materials (in most cases insulators) become electrically charged after they come into contact with another different material through pressing together or friction. This happens due to a chemical bond that is formed between some parts of the two surfaces, called adhesion, and as a result electrical charges move from one material to the other in a complicated way. The material that "steals" electrons from the other is said to have a stronger affinity for electrons (negative charge). After separation this material has a surplus of electrons and the meaning is that its surface will become negatively charged and in the same way the other material which lost electrons will become positively charged. How strongly matter holds on to its electrons determines its place in the triboelectric series (Figure 1). If a material is more apt to give up electrons when in contact with another material, it is more positive in the triboelectric series. If a material is more apt to "capture" electrons when in contact with another material, it is more negative in the triboelectric series. In order to get greater income in terms of energy, one can choose two materials with opposite polarities in the triboelectric series.

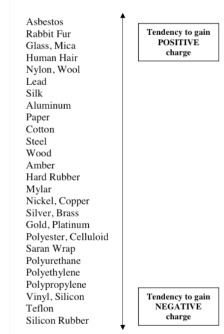

Figure 1. Triboelectric series [9]

Open-Circuit

The goal was to measure the triboelectric properties of six materials: Nylon 6.6, PVC, PTFE, FEP, Cu and Cellulose. Nylon 6.6 presents a greater electronic affinity, so we fixed Nylon 6.6 and simply varied the 2nd material. In order to measure the voltage between the materials an open-circuit configuration can be performed (Figure 2).

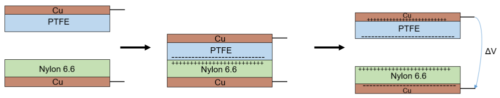

Figure 2. Schematic configuration for open-circuit measurements

Short-Circuit

One can also measure the voltage between a resistor using a short-circuit configuration (Figure 3). To measure the current flow between the materials a parallel load resistance was used (Figure 4).

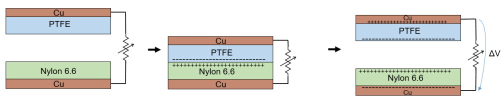

Figure 3. Schematic configuration for open-circuit measurements

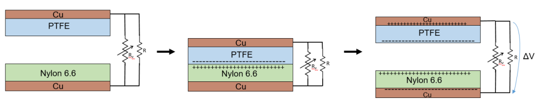

Figure 4. Schematic configuration for current measurements

Application

Here, according to the triboelectric series, human skin has a high positive affinity. Hence by choosing a high negative affinity material like PTFE one can harvest biomechanical energy as a self-powered tactile sensor system for the computer keyboard.

II. Experimental details

The triboelectric materials were used in a film form, in wich on one of the sides was placed a cooper foil tape that acts as the electrode.

The apparatus used consists of a rotary stepper motor and a spring with magnets attached to its tip, as illustrated in figure 5. The triboelectric films are glued to the collision system as illustrated in Figure . The motor is powered through an Arduino connected with a computer. For the short-circuit configuration, a printed circuit board with several resistances, ranging from 100 Ω to 1 GΩ, was used. This was also connected to an Arduino, in order to automatize the process with LabView.

Finally, for the keyboard application, we simply attached the PTFE film to the "Enter" key (Figure 6), and measure the voltage in an open-circuit configuration.

III. Results and discussion

To find the triboelectric voltage in all the configurations of the experiment it was used an oscilloscope to measure the voltage peaks. The mean value delivers the voltage associated with the respective measure. As sketched in Figure 7, we got from low to high open-circuit voltage: PTFE, PVC, FEP, Cu, cellulose, Nylon 6.6. According with the triboelecric series[8] it sould have gotten PTFE, FEP, PVC, Cellulose, Cu, Nylon 6.6. We suspect that the samples were not at their best conditions. Also, the contact area between the two films isn't exactly the same throughout the experiment. Some films may have a larger contact are than others, and that may explain the results.

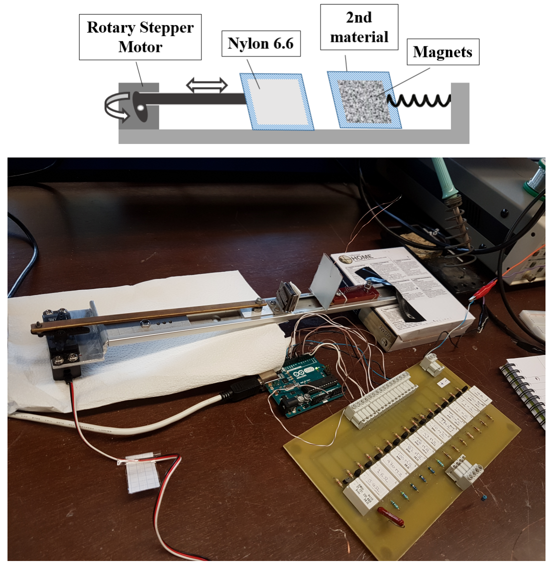

Figure 5. Device mechanism for pressing the two materials

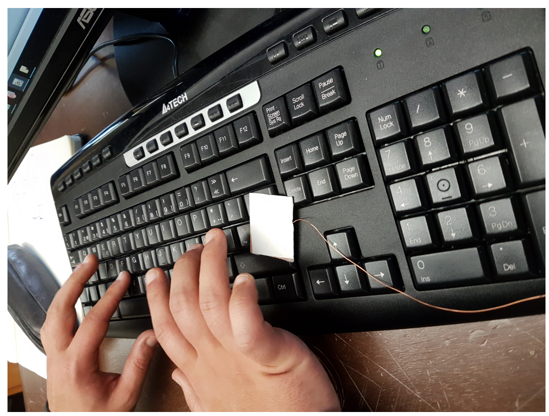

Figure 6. Application using fingertips to tap a keyboard revested with PTFE

In order to study the performance of our TENG, we measured its output when connected to variable load resistances, ranging from 100 Ω to 1GΩ. We choose PTFE-Nylon6.6, because it was the pair that delivers a higher voltage. For the current measurement a load resistance of $R = 10\,\Omega$ was choosen. Thus, once known the contact area the samples, $A \sim 3.5cm$, one can estimate the power density of the TENG. Figures 8 and 9 shows the voltage and power density dependence with the load resistance (variable). Notice that voltage tend to decrease with increasing load resistance, not as expected. According to literature[1] , the potencial output has the reverse trend. Still, it is possible to verify the same

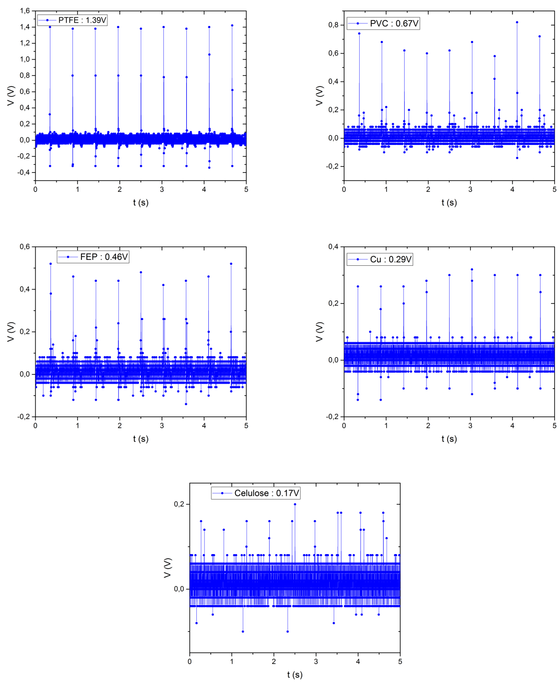

Figure 7. Open-circuit voltage for PTFE,PVC,FEP,Cu and Celulose

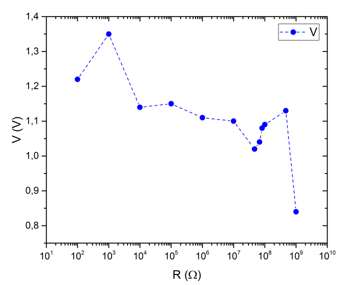

Figure 8. Measured output voltage of the TENG

behaviour for the power density. However, rejecting the first point, we observed that the largest power output takes place for , $R \approx 100\,k\Omega$.

Regarding to the keyboard application, the same procedure as before was performed, leading to a mean voltage output of V=0.222 V (Figure 10). Experimental data point out that one can get reasonable output values, given the not so great conditions that was carried out the experiment.

IV. Conclusions

In this four hours laboratory experiment, the triboelectric proprieties of six different materials in film form were studied. Methods such as open-circuit and short-circuit were performed. The obtained triboelectric series was: PTFE, PVC, FEP, Cu, cellulose, Nylon 6.6. It didn't matched with what was excpeted. Voltage and Current dependence on a load resistance was investigated. Despite the voltage output

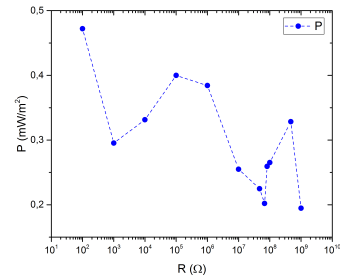

Figure 9. Power density of the TENG

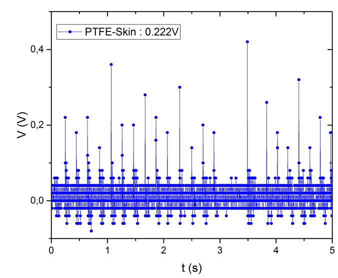

Figure 10. Measured output voltage of the application

decrease with increasing load resistance, we observed that the largest power output takes place for , $R \approx 100\,k\Omega$.

For future application, a keyboard coated with PTFE could deliver reasonable values for powering a wireless keyboard for instance.

References

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[8] https://www.trifield.com/content/tribo-electric-series/

[9] http://people.virginia.edu/~ral5q/classes/phys6263/fall15/Lab01.pdf