Rolling Energy

Simão Sá

31/03/2017

Abstract

The sucessful harvesting of all energy wasted in everyday processes and activities of the human kind is increasingly more important. As part of the answer, triboelectric nanogenerators present themselves as a low cost, high adaptability solution for the harvesting of mechanical motion waste energy. In this paper the relative position of six materials in the triboelectric series is confirmed. For the most efficient pair of materials, the pair that generated the biggest potential difference, a voltage and current dependencie on the load resistance was obtained and a power dependencie on the resistence was calculated. A power of $1\mu W$ was obtained for a load resistance of $10^6\Omega$, this may not be the best value for the resistance, but it is in the same order of magnitude. A novel device to harvest energy from the shafts of engines was projected and the concept was tested, an output voltage of 2 volts was achieved.

Keywords:Triboelectrics, Energy harvesting

1 Introduction

Humanity is reaching times where the sucessful harvesting of all energy available is of uttermost importance in order to satisfy our needs. The truth is that oil will run out and fusion energy is still in its early steps. In the meantime we as a species need to develop ways to harvest all the energy we can, this is where triboelectric materials come in! This type of materials can harvest energy from motions that would otherwise be wasted. In a future where electronics is increasingly smaller and has low power needs, triboelectrics might be of use to power such electronic devices. These structures are light and small making them ideal for many applications, in the low frequency regime they are more efficient than electromagnetic generators finally they are simple and low cost to manufacture. Triboelectric nanogenerators harvest energy based on the coupling of triboelectric and electrostatic effects. It happens when two materials (mostly insulators) become electrically charged after they are put in contact (friction, pressure...). The cause is a complicated process called adhesion where a chemical bond between the two surfaces is established in some places and, as a result a flow of electrons between the materials appears. These charges flow from the material with less affinity for electrons to the material with a stronger affinity for electrons, creating a surplus of negative charge in this surface (negatively charged surface), the other surface will have a surplus of positive charge resulting in a positively charged surface, as such a potential diference is created.The affinity for electrons can be seen in the triboelectric series Fig1.1. To obtain better income of energy the materials should be chosed such that they are located in opposite poles of the series.

2 Experiment and results

2.1 Apparatus

In order to make all the measurements, an in-house made apparatus was used. It consists of two parts. First the setup from Fig 2.1, where triboelectric films are glued and, using magnets, a rotary stepper motor and a spring, a movement of sucessive collision and separation is achieved. This is conected to the computer via an Arduino. The second part consists

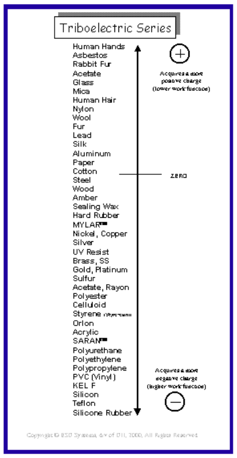


Figure 1.1: Triboelectric series

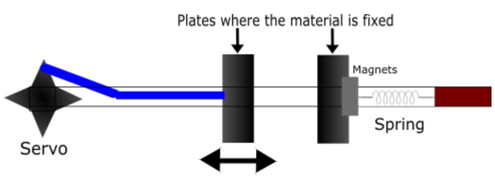


Figure 2.1: Setup used to make the motion

of a circuit board that will allow us to change the resistance that is in parallel with the triboelectric materials (ranging from 100Ω to $1\text{G}\Omega$) and make voltage and current measurements (using an osciloscope conected to the computer), which is also conected to the computer via an Arduino. All of this is automated using LabView.

.

2.2 Initial tests

We had an array of materials to choose from: Nylon 6.6, PVC, PTFE, FEP, Cu and Celulose.

In order to choose the materials to our application, a test was performed, an open circuit measure, without resistance in parallel, of all the pairs of materials. This was a proof that the triboelectric series is correct since the two materials who are most apart in the series are Nylon and PTFE and, as such, we expected them to be the most efficient, our expectations were

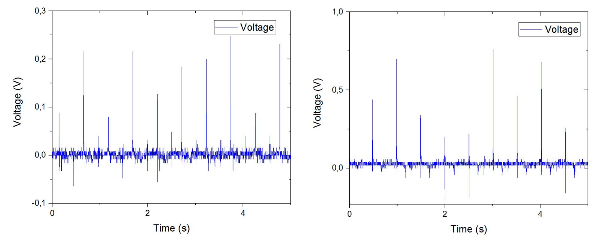


Figure 2.2: Two configurations: PTFE-PVC (above) and Nylon-PTFE (below), as expected the Nylon-PTFE performs better (seen by the height of positive peaks)

correct.

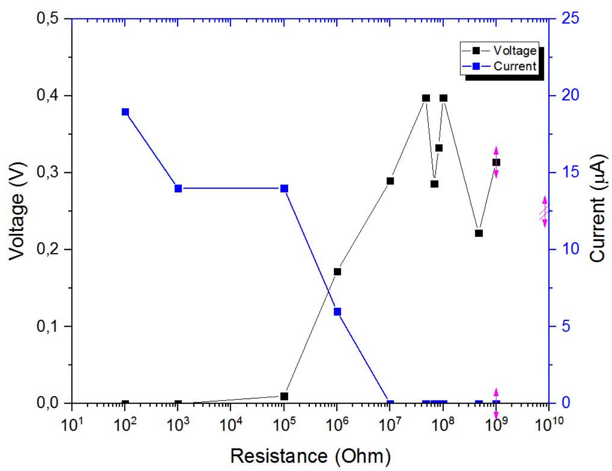
2.3 Best pair measurements

From all of our combinations we arrived at the conclusion that Nylon-PTFE was the most efficient, so we measured it in a short circuit configuration which means that we conected both films with a resistance and measured the voltage in its terminals. To measure the current, a second load resistance was used in parallel and through the voltage mesurement in that resistance we calculated current using Ohm's law.

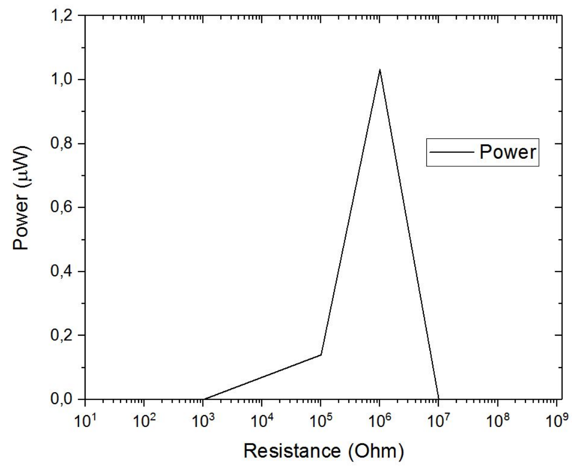
We obtained a graph Fig 2.2(a) for the voltage and the current as a function of the resistance. From here we can obtain the ideal resistance for the system just by looking at the generated power (Fig 2.2(b)). It was determined that this resistance is between $10^5\,\Omega$and $10^7\,\Omega$. In the graph this isn't obvious since the steps are of one order of magnitude at a time, after this it was nedeed an extensive search for the best resistance in this interval. We obtained a maximum power of $P = 1\mu W$ which is rather less than reported in literature, although, given the circumstances of the experiment which was made as a proof of concept, this result is normal, since this experiment is one that needs a lot of control in order to properly function and deliver high power.

2.4 Real world application

There are a lot of things in the world that spin. If we think about it, all motors start with a spinning



(a)



(b)

Figure 2.3: Voltage and current as a function of resistance and power as a function of resistance

motion. This has a lot of potential energy built into it, imagine that we could connect a small device (Fig 2.4) consisting of a wheel coated with PTFE (green) that would turn in association with the motor shaft (grey) and would roll on a surface made of separated patches of Nylon (blue). At high rotations the rotating motion is very simillar to an impact and we can have a constant flow of energy leaving the device. The same principle can be adapted to all cilinders moving within a cilinder, floaters can be made using this principle, as they rotate the create energy that could light up a small led for navigation of some sort.

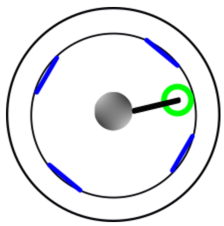


Figure 2.4: Depiction of our basic application

We designed a simple set of two cilinders, one coated with nylon and the other with a patch of aluminum glued to it, then made them spin rapidly by hand and observed $\triangle V \cong 2.1V$, higher than our setup experiments.

Figure 2.5: Our simple apparatus

3 Conclusion

During this short experiment we were able to sort out some materials of the triboelectric series and see how they perform in conjuction with one another, the triboelectric series was confirmed. We performed various measurements to the sample and obtained the depencies of voltage and current in a load resistance. With this the power dependance was calculated and was observed that the higher power output($P = 1\mu W$) takes place between $10^5 \Omega$ and $10^7 \Omega$. A new application for harvesting of spinning motion energy was devised and a output voltage of 2 volts was achieved.

4 References

[1] Cátia R.S. Rodrigues, Carla A.S. Alves, Joel Puga, André M. Pereira, João O. Ventura, "Triboelectric driven turbine to generate electricity from the motion of water", Nano Energy 30, 379–386, 2016.

[2]Z.L. Wang, J. Chen, L. Lin, "Progress in triboelectric nanogenerators as a new energy technology and self-powered sensors", Energy Environ. Sci. 8 (8), 2250–2282, 2015.

[3] Hulin Zhang , Ya Yang , Yuanjie Su , Jun Chen , Katherine Adams , Sangmin Lee , Chenguo Hu , and Zhong Lin Wang , "Triboelectric Nanogenerator for Harvesting Vibration Energy in Full Space and as Self-Powered Acceleration Sensor", Adv. Funct. Mater 24, 1401–1407, 2014.

[4] Feng-Ru Fan, Zhong-Qun Tian, Zhong Lin Wang, "Flexible triboelectricgenerator!", Nano Energy 1, 328–334, 2012.