Improvement of a soft electrostatic generator: polarization with a triboelectric function

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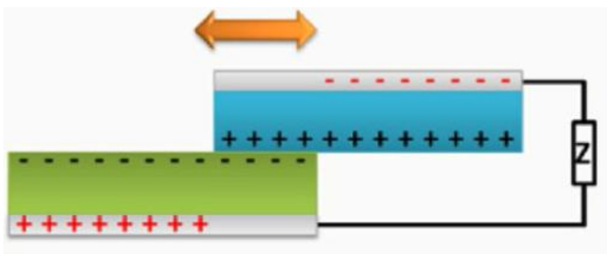
Abstract: Improvement of a soft electrostatic generator

Soft electrostatic generators (SEG), typically made of electroactive polymers like silicone, represent an efficient way to power up devices widely used in the IoT, including smart clothes, biomechanical energy harvesters or sensors. The principle of these generators is to exploit in an external circuit the electricity produced by a variation of capacity induced by a mechanical deformation of the SEG. The electrical charges available for this circuit have been in most cases previously brought through a high voltage supply (HVS). To get rid of the HVS and make the SEG autonomous in energy, we present an original solution based on a TENG (Triboelectric nano generator) approach used in a sliding mode. In order to develop and optimize the electrical response performance of the TENG to be coupled with our silicone-SEG, a test bench equipped with Trek electrostatic probes, a Keithley electrometer and a decade box has been designed. Thanks to this over-equipped bench, we have monitored the transfer of electrical charges between the two materials that form the TENG (copper, PET, PTFE.) over thousands of cycles in sliding mode. Modeling with a finite element model is underway to account for the observed mechanisms.

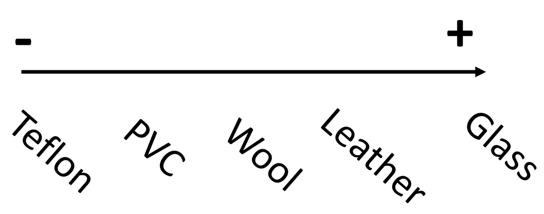
Design of a energy harvester

Triboelectric generator operating in sliding mode

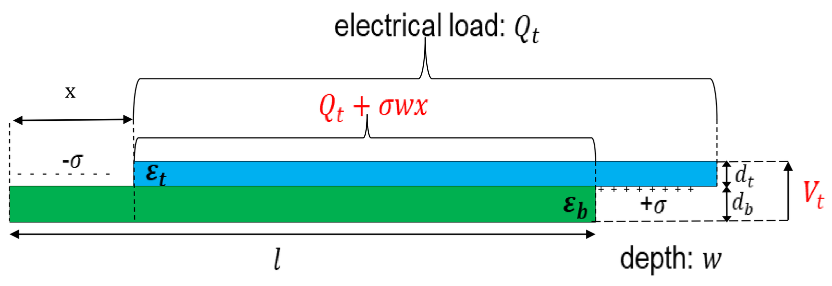


- Ease to fabricate
- Ease to integrate
- High power density potential

Triboelectric serie for material selection

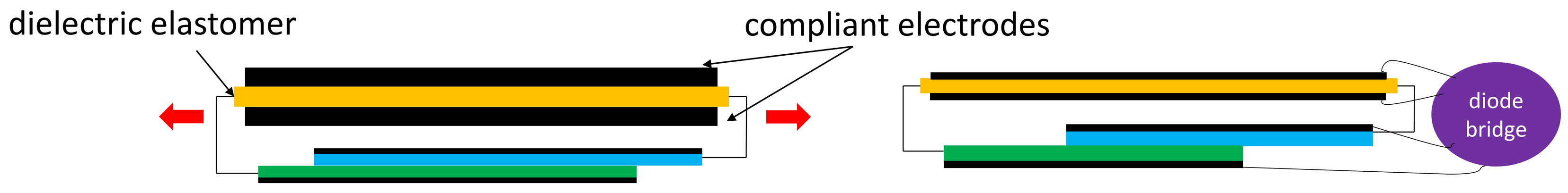


Theoretical analysis to predict the performance



$$V_t = \frac{Q_t+\sigma w x}{C_{var}}, \text{ avec } C_{var} = \varepsilon_0 \frac{w(l-x)}{\frac{d_t}{\epsilon_t}+\frac{d_b}{\epsilon_b}}$$

Integration in our hybrid structures: the triboelectric generator polarizes a dielectric elastomer generator (DEG)



Energy gain of the system:

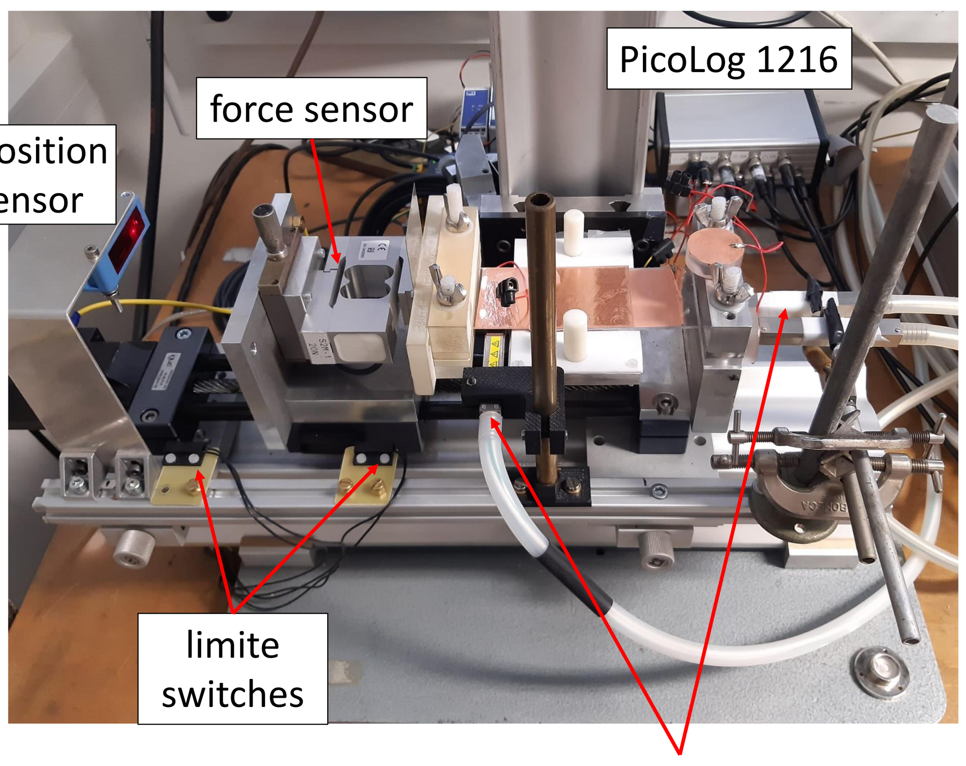
$$W_{rec} = \frac{1}{2}(C_{min}V_{max}^2 - C_{max}V_{min}^2)$$

Scavenged energy proportional to the square of the input (polarized) voltage

Test bench setup

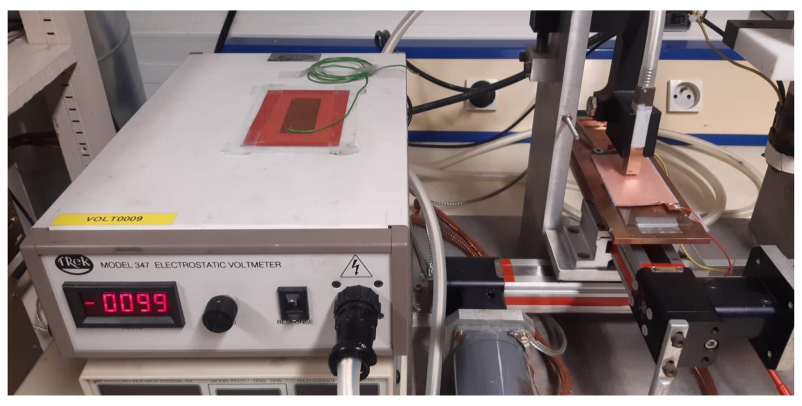
Translation length: 60 mm
Maximum speed: 500 mm/s
Width of samples: <55 mm
Length of samples: <60 mm

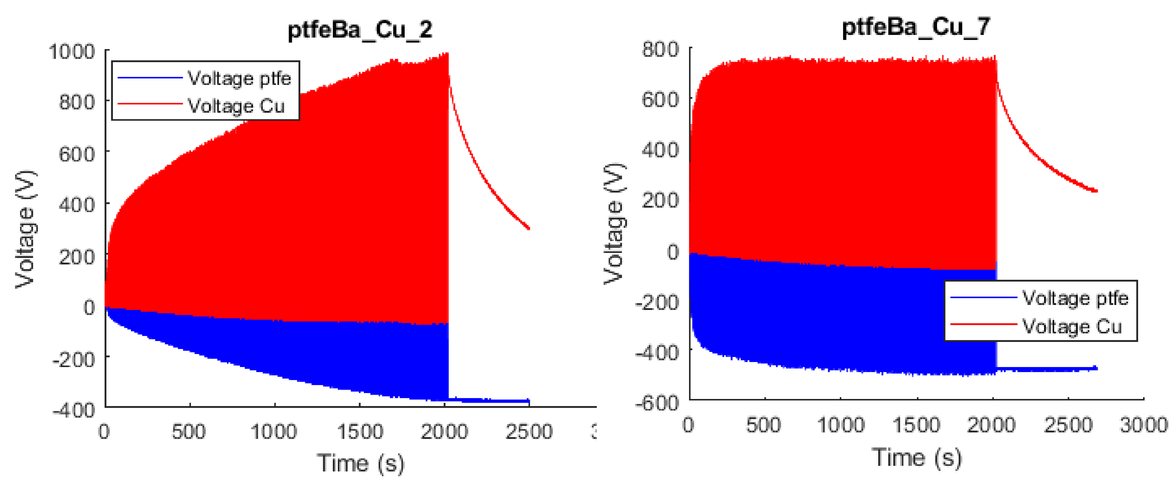
Acquisition frequency: 1 kHz
Acquisition time: 5400 s
Resistor range: 1 MΩ - 1.6 GΩ



electrostatic probes

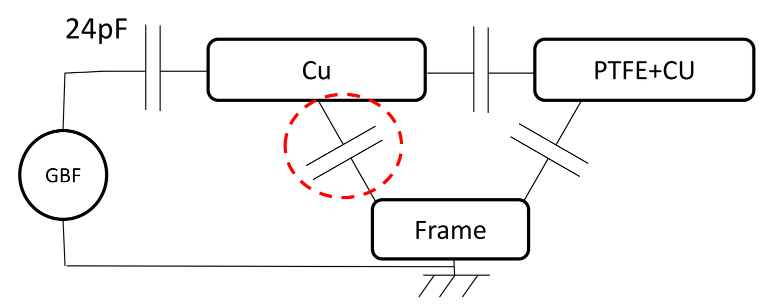
Trek 347 electrostatic voltmeter: ±3 kV ; 3 V accuracy

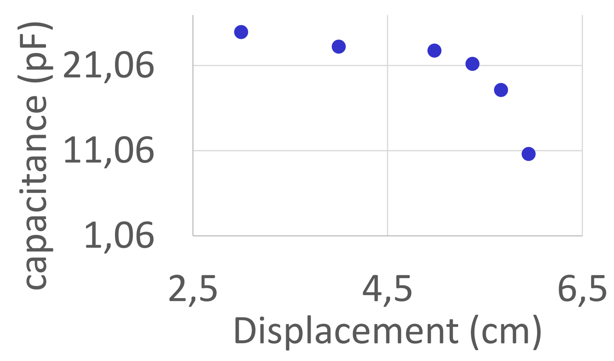




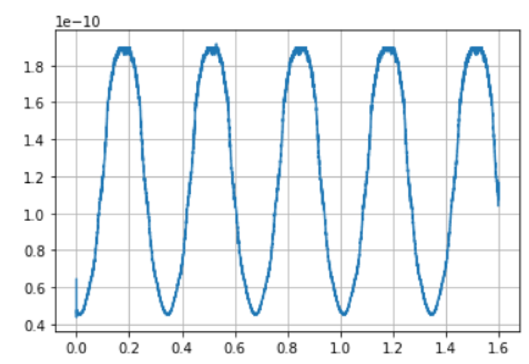
Influence of past experiments of the sample on its electrical response

Measurement of the parasitic capacitance between copper and frame





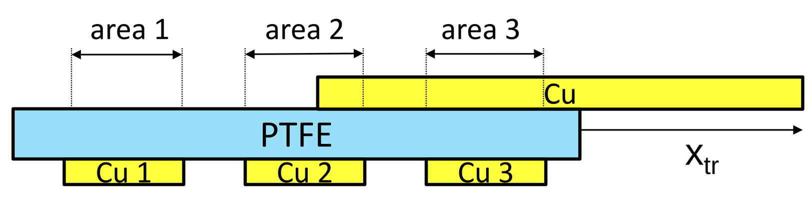
One parasitic capacitance up to 25pF

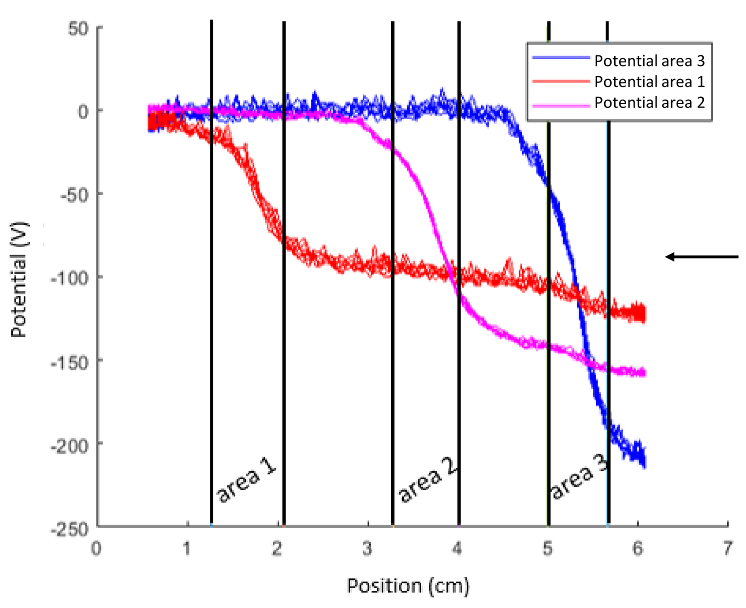


Dynamic measurement of capacitance of a TENG (in F)
Min value: 44 pF
Max value: 192 pF

TENG in open circuit and with resistor load

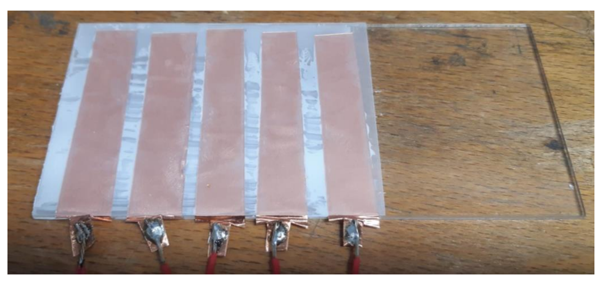
Three copper electrodes in open circuit



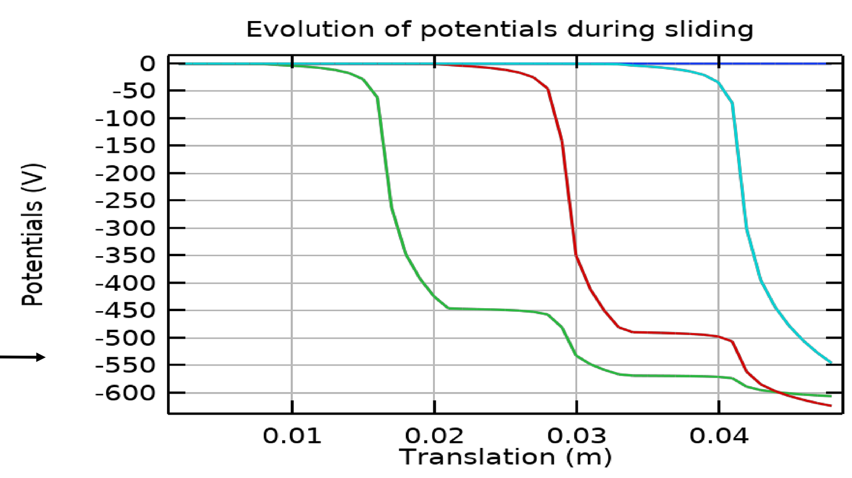


experiments

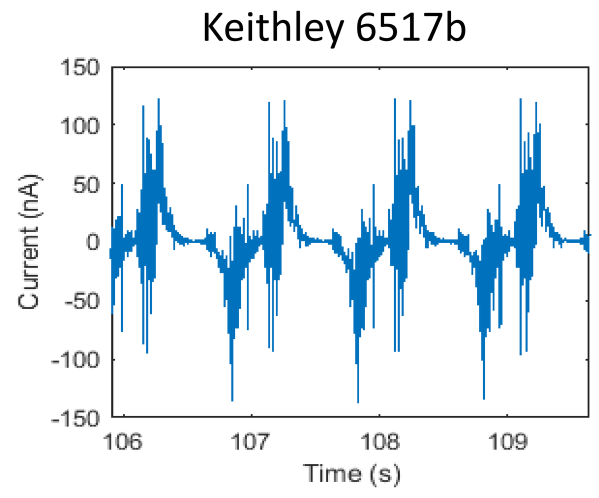
Comsol simulation



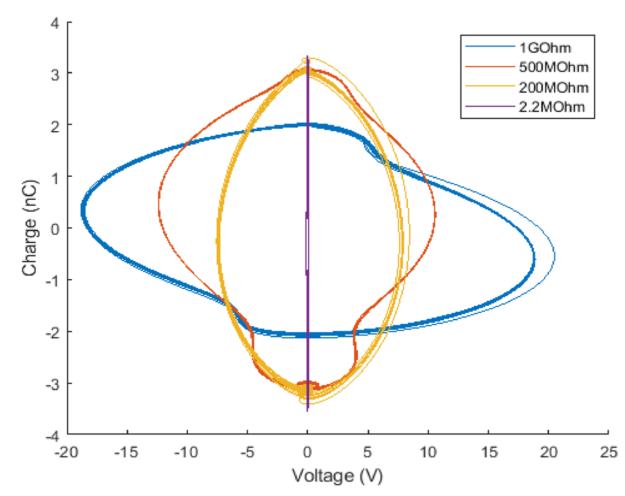
Example of device



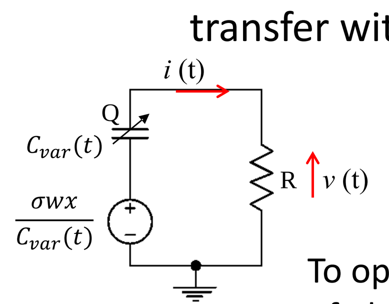
Unfiltered current measured with Keithley 6517b



Computations with Matlab

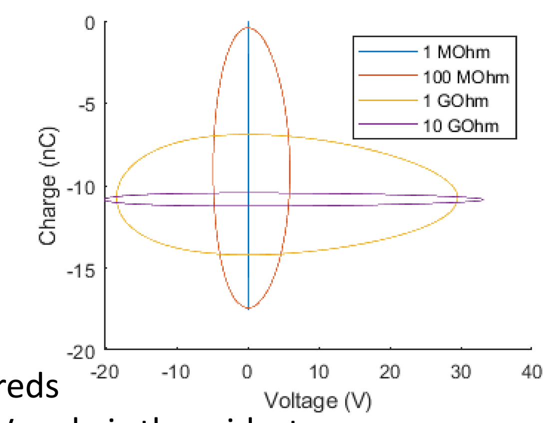


Use of QV cycles to compare power transfer with different loads



$$\begin{cases} i = \frac{\partial Q}{dt} = \frac{V_s}{R} = \frac{Q}{RC_{var}} \\ P_{avg} = \frac{1}{t_2-t_1}\int_{t_1}^{t_2} R\left(\frac{\partial Q}{dt}\right)^2 \partial t \end{cases}$$

Matlab simulations



To optimize the power transfer, a load of few hundreds of ohms is required as the area described by the QV cycle is the widest

Synthesis - Conclusions

- Measurement of non-negligible parasitic capacitance between the copper film and the frame compared to the capacitance of the TENG: importance of the environment in these measurements.
- Non uniform charge density identified by experimental results that suggest promoting larger friction strokes rather than larger width for developing devices.
- Good accordance between experimental and simulated QV cycles. Be careful that the uniform load consideration of the simulations does not affect the power estimation
- Power managment units remain to be tested to charge fixed capacitors at first, then SEGs. Half-wave diode rectifiers are the best candidates .
- The triboelectric phenomenon is better and better understood, even if behind apparent easy experiments remain real challenges to obtain repeatable and interpretable measurements.

References

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