Soft hybrid dielectric elastomer generators

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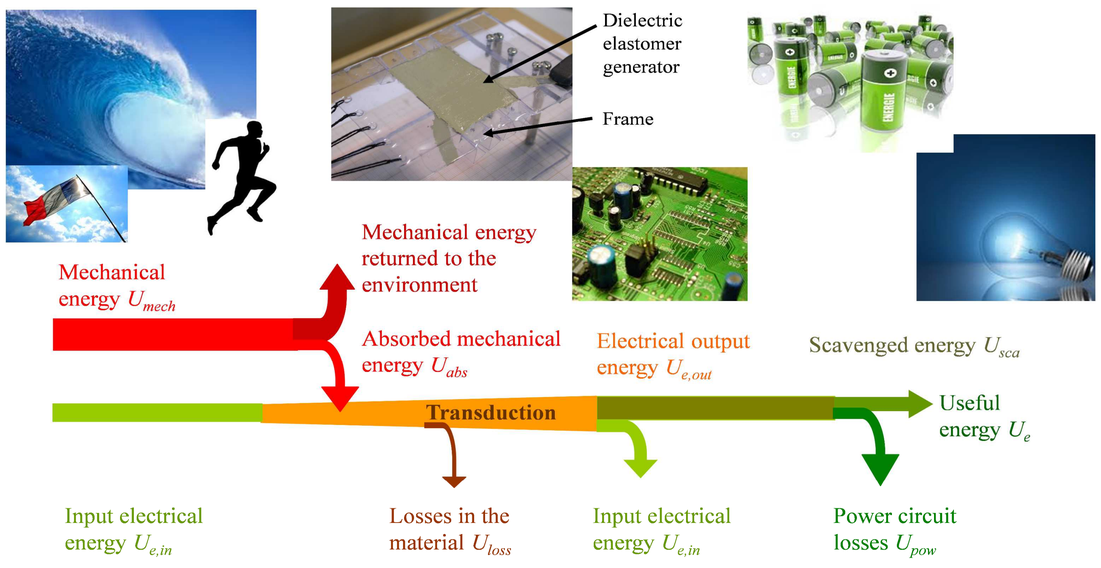
Objectives



Dielectric elastomer generators (DEGs) offer great potential for **soft applications involving fluid or human interactions**. These scavengers are electrostatic generators. They are light, compliant, have a wide-range of functions and develop an important energy density (0,834J.g^{-1}) under high bias voltage and high strain. Our research focus on:

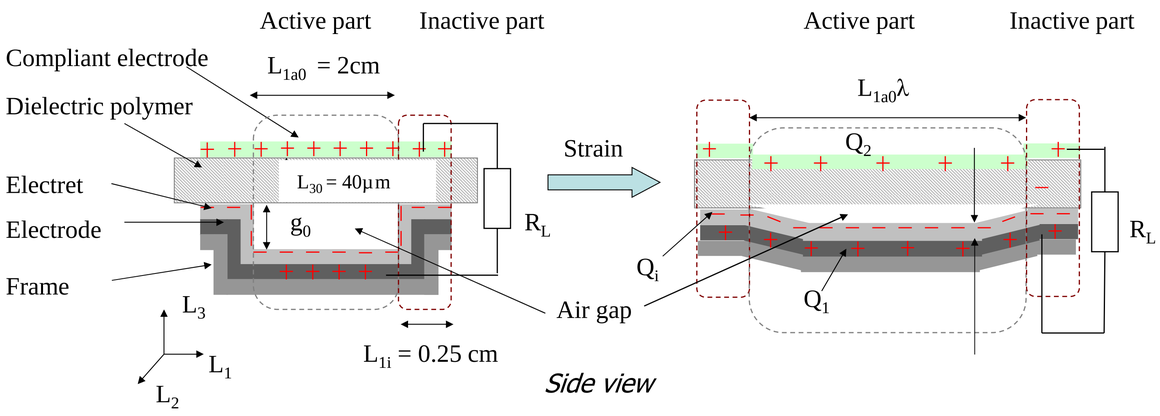
- **Mechanical and electrical characterization of materials**
- **Reliable electromechanical modelling**
- **New transducers based on electrets coupled with dielectric elastomer**

Concept of hybrid generator

The idea is to replace the external bias voltage by an electret in order to design a completely autonomous and lightweight generator. Various concepts of hybridization have been proposed.

Electret mode

In the « electret mode », the scavenger has the same operating principle as a classic electret generator : re-arrangement of charges through a load due to variations in the capacitance of the structure.



Governing equations:

$$mL_{1a0}\frac{\partial^2\lambda}{\partial t^2} = -\left[2\frac{L_{20}L_{30}}{\lambda}\left(C_{10}+2C_{20}(I_1-3)+3C_{30}(I_1-3)^2\right)\left(\lambda^2-\frac{1}{\lambda^2}\right)\right]+\left[\frac{\partial}{\partial\lambda}\left(\frac{Q_2^2}{2C_{eq}}\right)\right]+F_{ext}$$

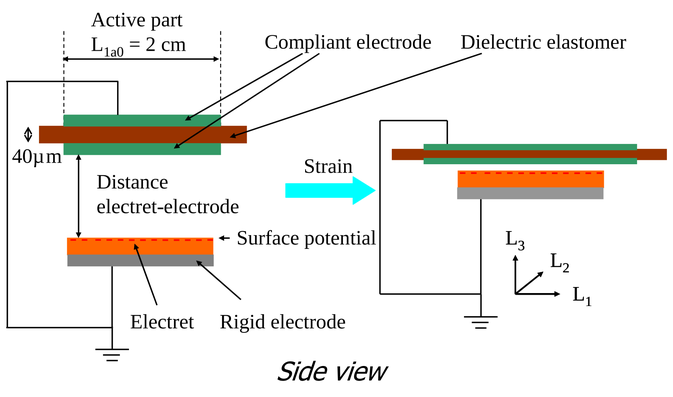
$$\frac{\partial Q_2}{\partial t} = \frac{V}{R}-\frac{Q_2}{R.C_{eq}}$$

Output average power: $$P_{out} = \frac{1}{t_2-t_1}\int_{t_1}^{t_2} R\left(\frac{\partial Q_2}{\partial t}\right)^2 \partial t$$

Dielectric mode

The electret is used as an electrostatic source to polarize the dielectric elastomer.

Main electric field



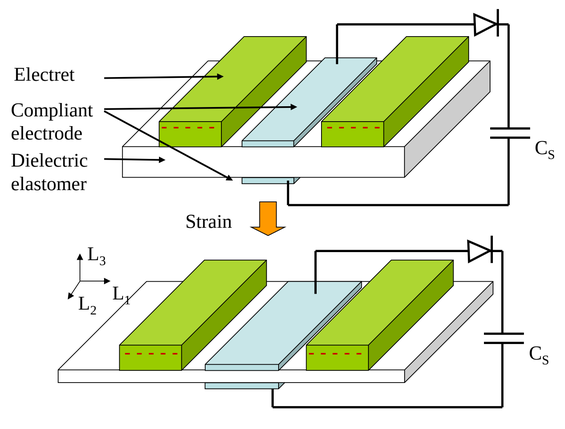
Governing equation:

$$mL_{1a0}\frac{\partial^2\lambda}{\partial t^2} = \frac{L_{20}L_{30}}{\lambda}\left[-2(C_{10}+2C_{20}(I_1-3)+3C_{30}(I_1-3)^2(\lambda^2-\frac{1}{\lambda^2})+\frac{Q^2}{\varepsilon_0\varepsilon_r\lambda^2L_{1a0}^2L_{20}^2}+f_{ext}\right]$$

Scavenged energy per cycle (electrostatic generator): $$E_{pro} = \frac{1}{2}(C_DV_D^2-C_CV_C^2)$$

Edge mode

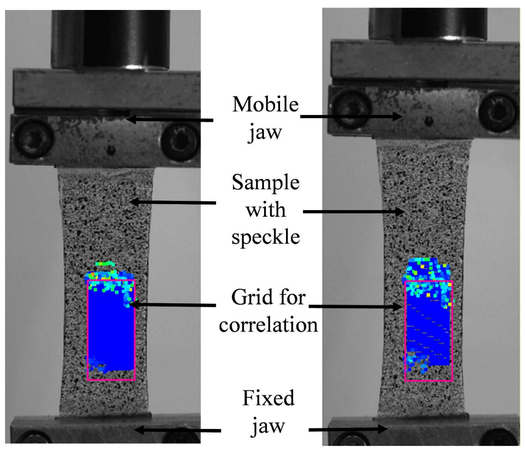
Peripheral electric field



Material Characterization

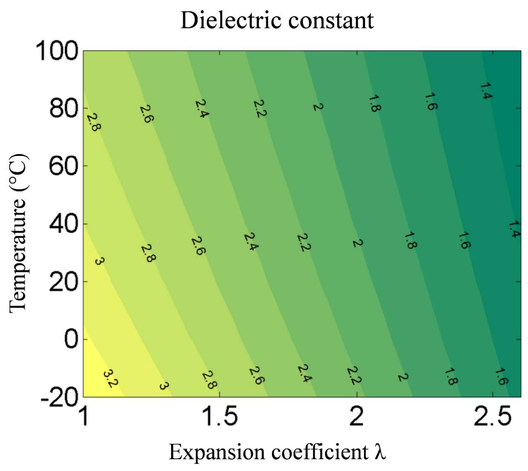
Silicone Polypower (PDMS Wacker RT 625):

Video-extensometry:



Hyperelastic laws with a viscous part. Empirical laws function of strain rate and temperature.

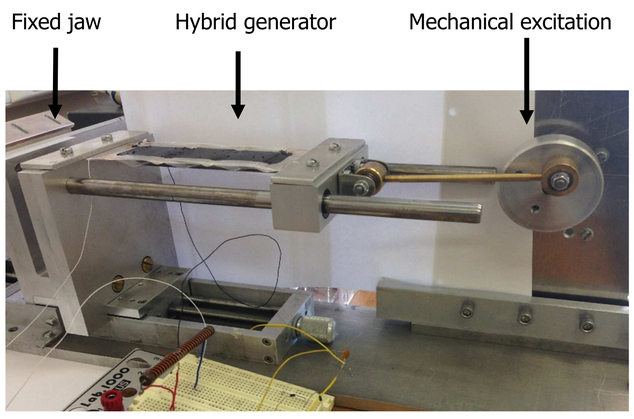
Dielectric spectrometry:



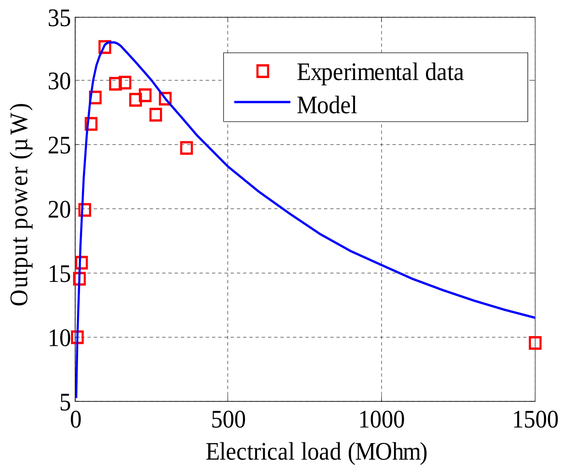
Empirical laws function of frequency, temperature, pre-stress and nature of the electrode.

Tests of a structure in electret mode

Structure of 9cm per 2.5cm made of silicone Polypower and Teflon electret charged up to -1000V (Corona discharge), strain of 50% at 1Hz.



Output voltage accross electrical load R is recorded thanks to an electrostatic voltemer.



→ Scavenged energy density of 0.55mJ.g^{-1}.

Conclusions

- Hybrid transducer: generator without bias voltage. Modelling and optimization of various operating mode.
- Design of a soft hybrid generator in electret mode. 33µW is scavenged. Promising scavenged energy density up to 1.42mJ.g^{-1}.

Jean-Mistral C, Vu-Cong T, Sylvestre A 2012 Advances for Dielectric Elastomers Generators: Replacement of high voltage supply by electret *Appl. Phys. Lett.* **101** 162901

Vu-Cong T, Jean-Mistral C, Sylvestre A 2012 Electrets substituting external bias voltage in dielectric elastomer generators: application to human motion *Smart Mater. Struct*. **22** 025012

Vu-Cong T., Jean-Mistral C. and Sylvestre A., "New operating limit for applications with electroactive elastomer: Effect of the drift of the dielectric permittivity and the electrical breakdown", Proc. SPIE 8687 1S (2013)