Soft Dielectric-Generators (SDG) for Energy Harvesting and Sensors

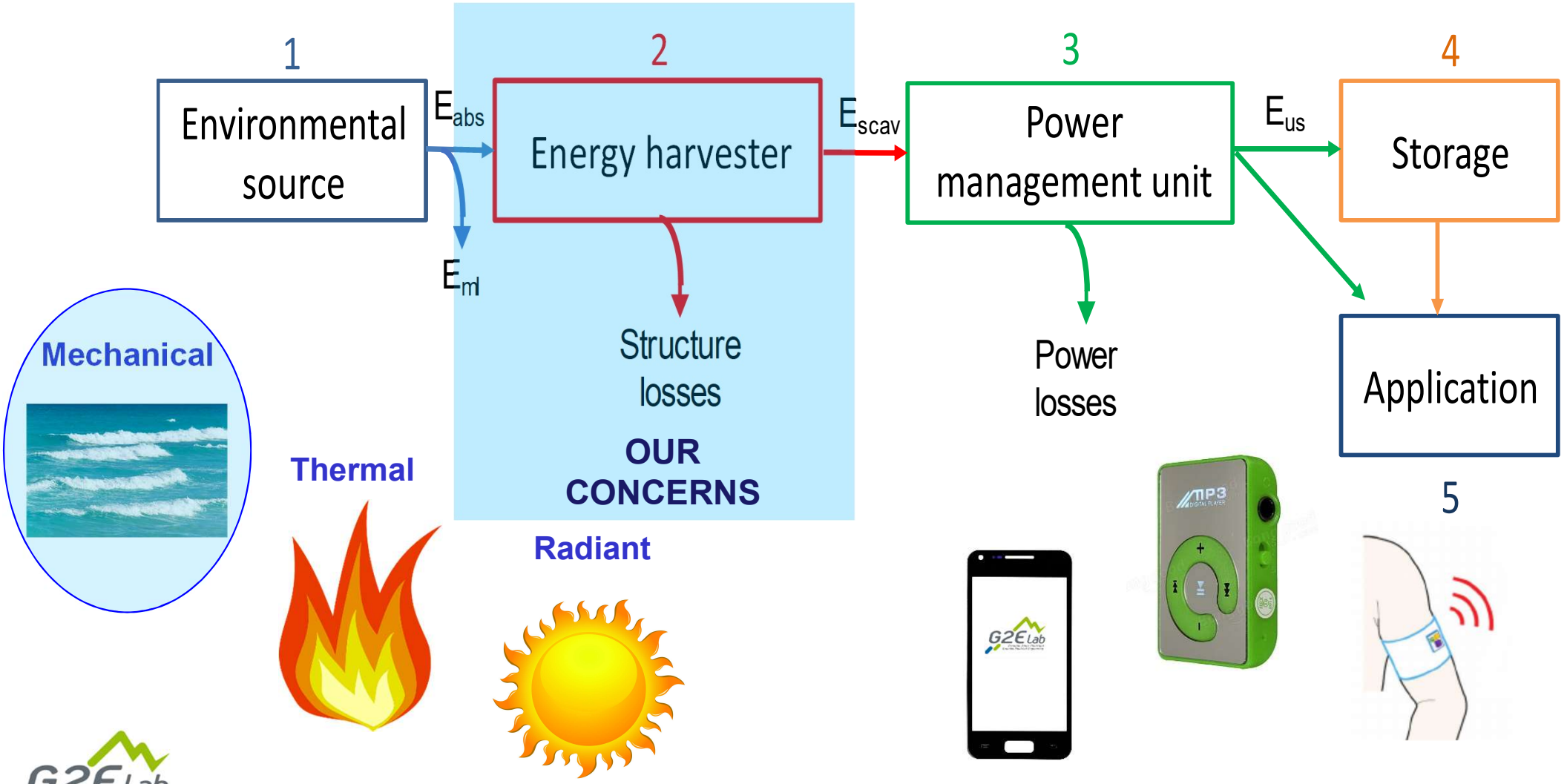
A. Sylvestre, C. Jean-Mistral, S. Basrour, D. Bellet, J. Bai

OUTLINE

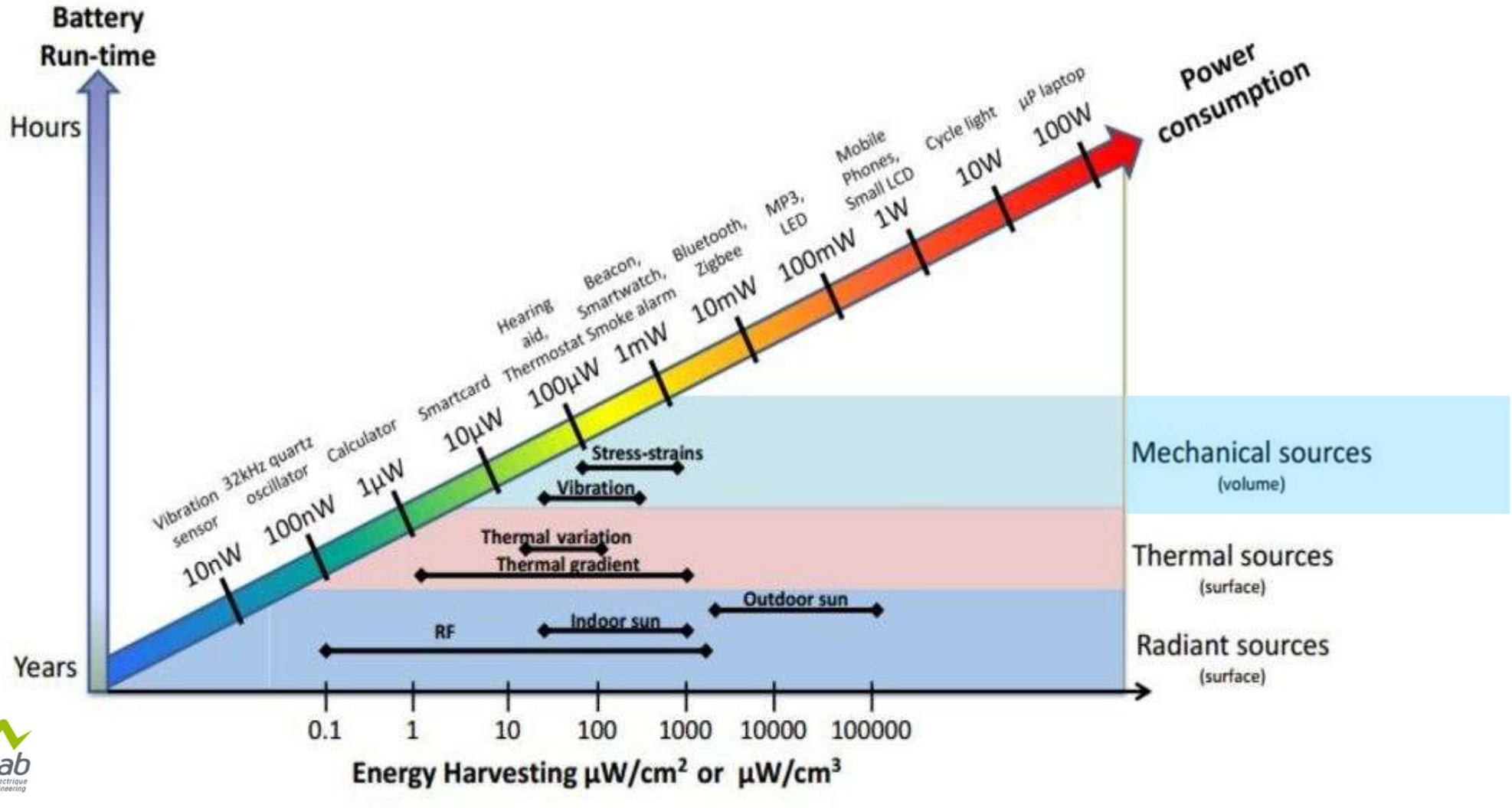
1. Positioning and originality of the study
2. SDG for wearable applications
3. SDG as piezoelectrets generators
4. SDG for wave energy converters (WEC)
5. Conclusion

SDG = Soft Dielectric-Generators

Positioning and originality of the study : our concerns



Positioning and originality of the study : our concerns



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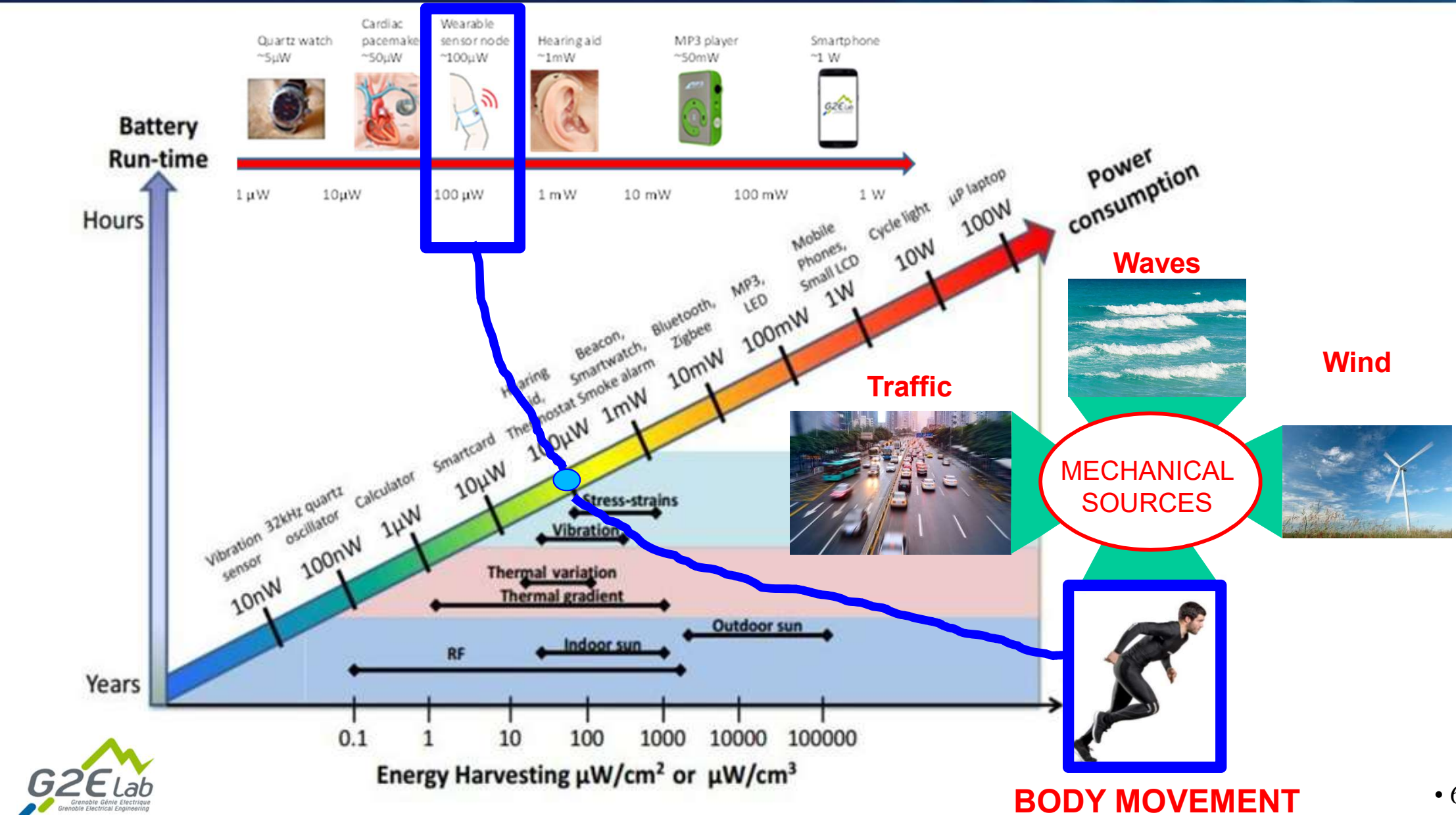
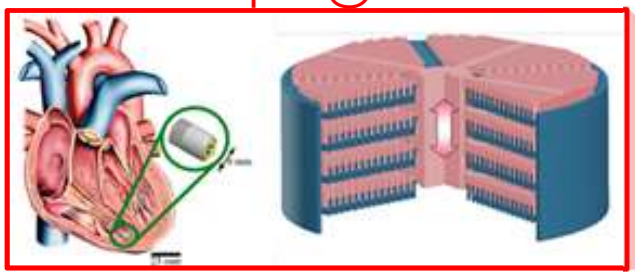
SDG = Soft Soft Dielectric-Generators

SDG for wearable applications



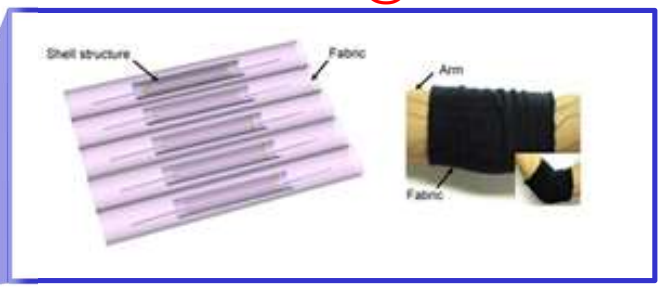
SDG for wearable applications soft polymers

20 µW @ 1-2 Hz



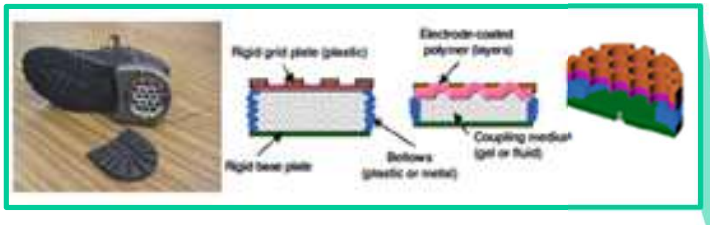
M. Deterre *et al., J. Phys. Conf. Ser.*, vol. 476, no. 1, p. 012039, 2013

0.21 mW @ 0.8 Hz



A. Khaligh *et al. IEEE Trans. Ind. Electron.*, vol. 57, no. 3, pp. 850–860, Mar. 2010.

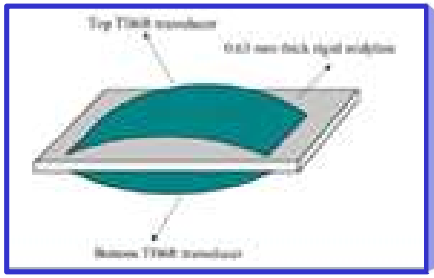
0.8 W @ 1 Hz



100 µW @ 0.8 Hz

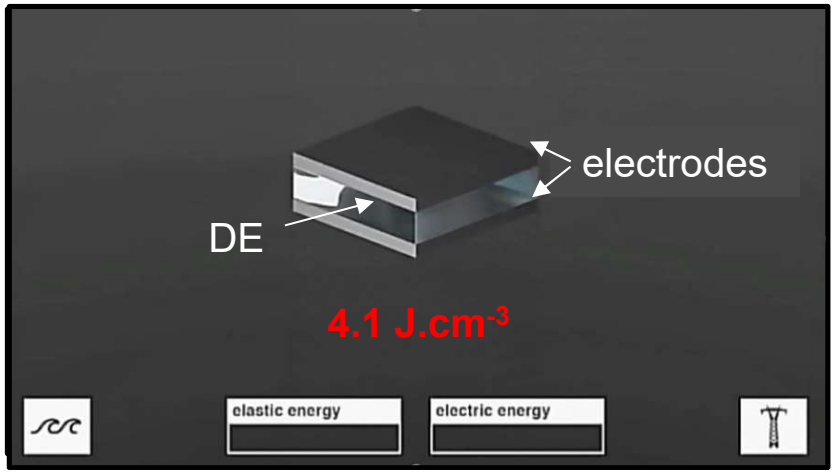
C. Jean-Mistral, PhDthesis, Université Joseph-Fourier - Grenoble I, 2008.

5.8 mW @ 0.9 Hz



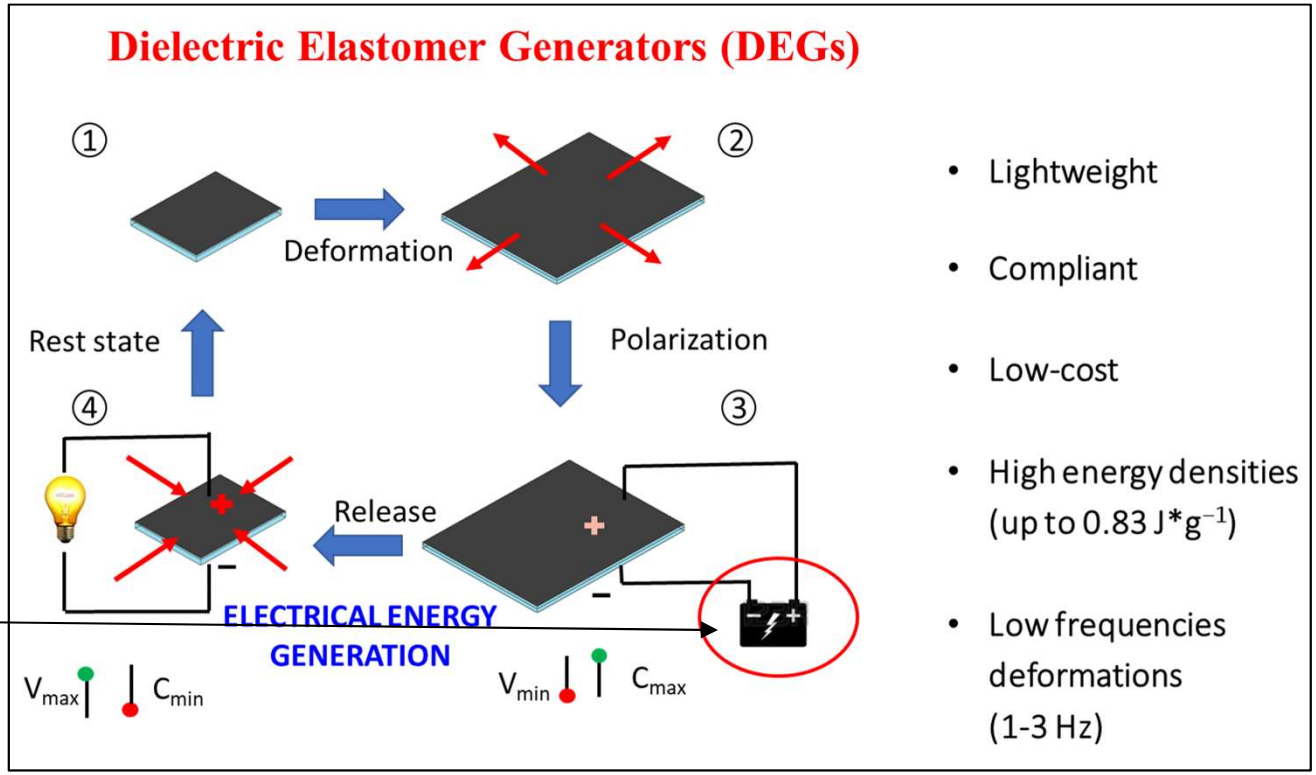
R. D. Kornbluh *et al.*, EAPAD, 2011, vol. 7976, p. 797605.
N. S. Shenck *et. al. IEEE Micro*, vol. 21, no. 3, pp. 30–42, May 2001.

SDG for wearable applications

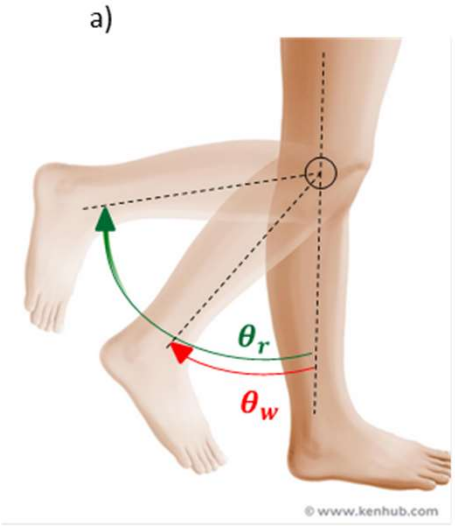


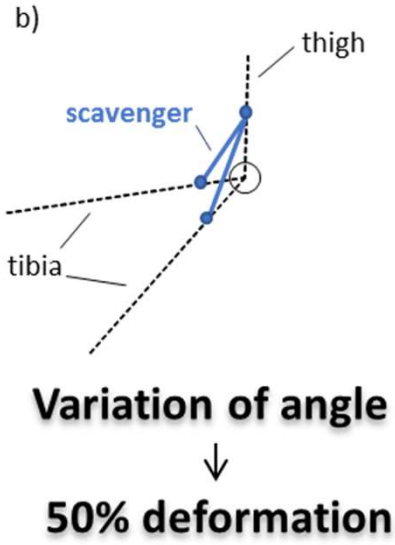
Dielectric elastomers generators (DEGs)

High-Voltage Supply



SDG for wearable applications





Variation of angle

↓

50% deformation

DEGs

- Lightweight
- Compli…
- …gy density
- …igh efficiency
- Low cost

High external polarization source

Realization of hybrid devices for human body energy harvesting at knee level

↓

Elimination of the external polarization source

↓

Increase energy density and lifetime, decrease encumbrance

SDG for wearable applications

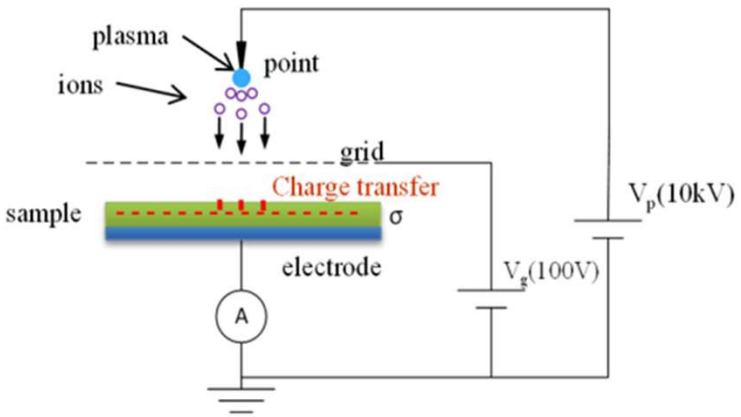
How to replace the external high voltage source?

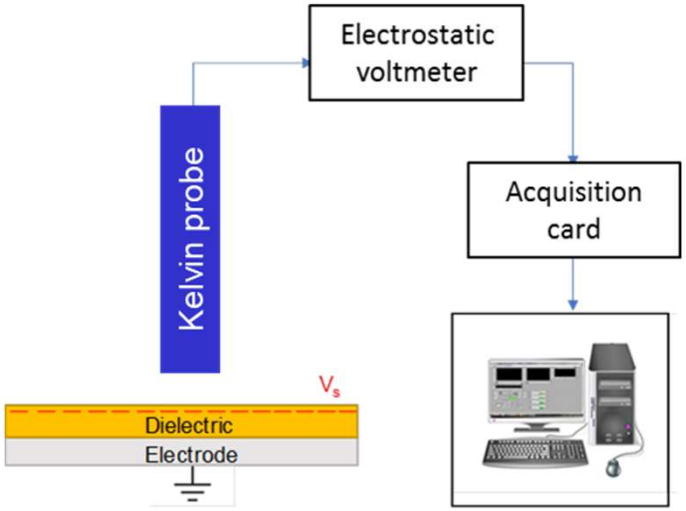
↳ By using an **electret** polymer

How to obtain an electret and how to test its performance?

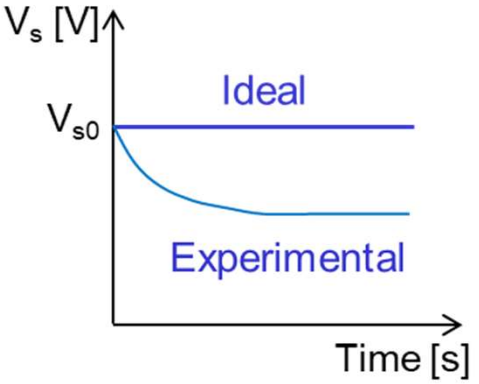
Experimental techniques

Corona discharge



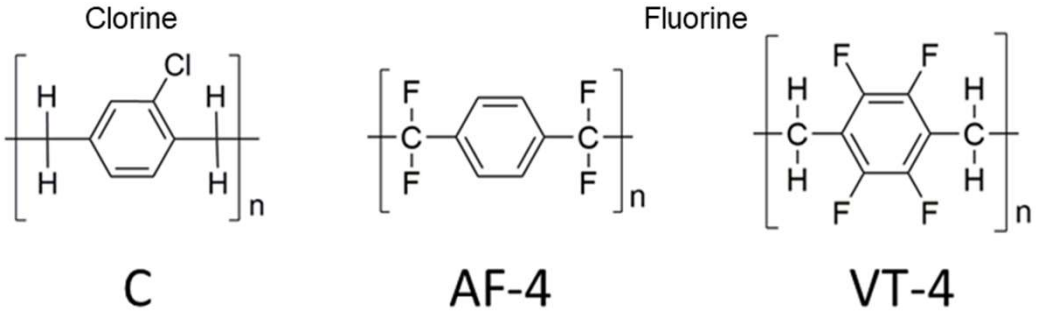


Surface Potential decay (SPD)

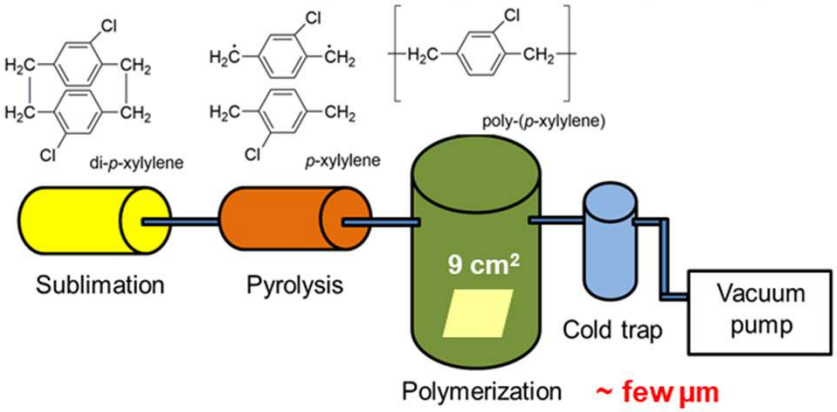


Choice of electret polymer

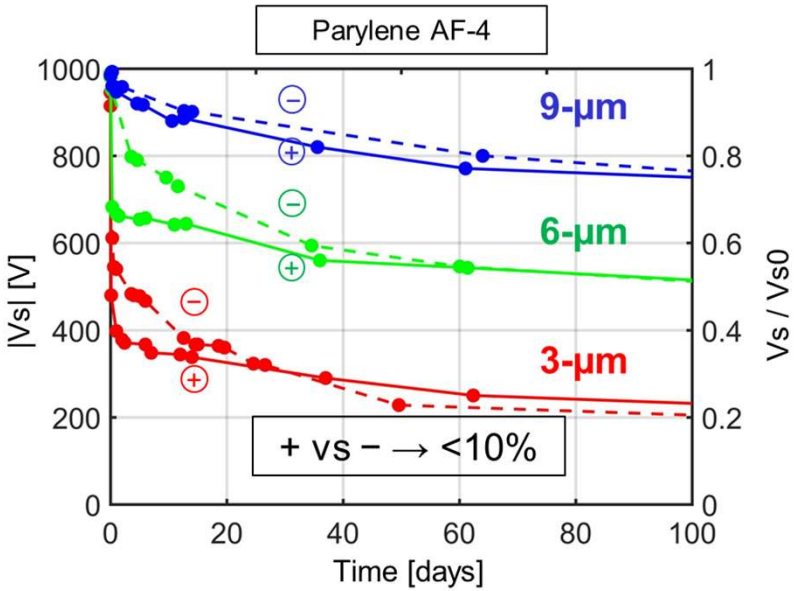
Three Parylene variants

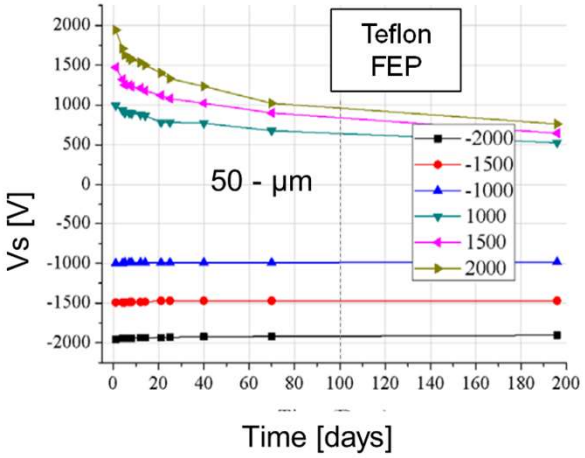


Chemical vapor deposition (CVD)



Results on AF4 parylene

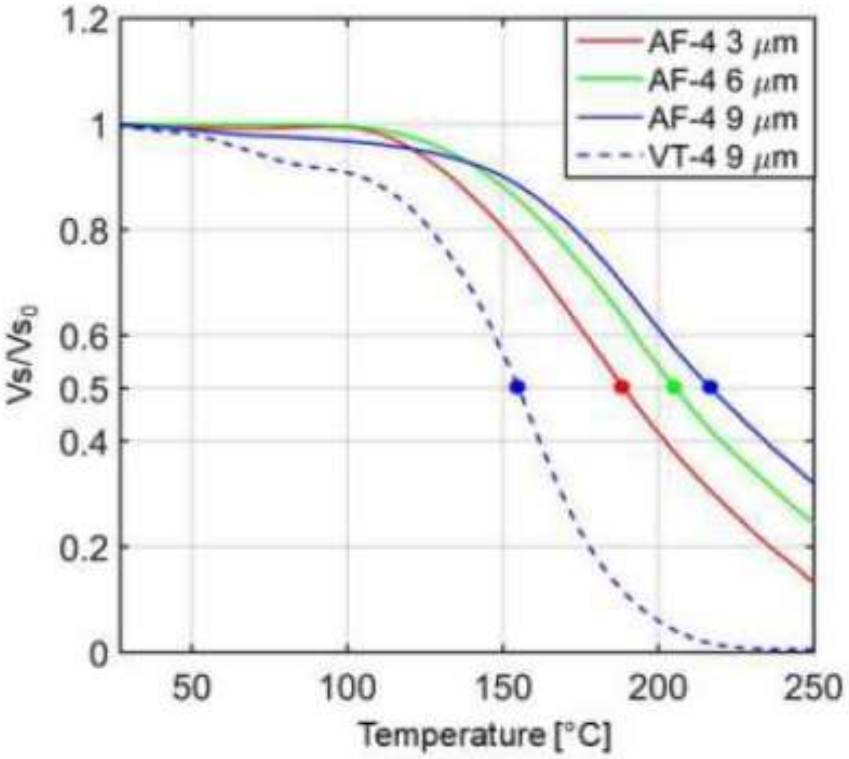




Vu-Cong et.al, *Smart materials and structures* 22.2 (2013): 025012.

SDG for wearable applications

PARYLENE AF4



C. Lagomarsini *et al*. J. Appl. Polymer Sci. Under review.

A VERY GOOD ELECTRET!

Applied Polymer SCIENCE

Jan. 2019

Annealing for the improvement of the capabilities of parylene C as electret

A. Kachroudi,[1] C. Lagomarsini,[1] V. H. Mareau,[2] A. Sylvestre[1]

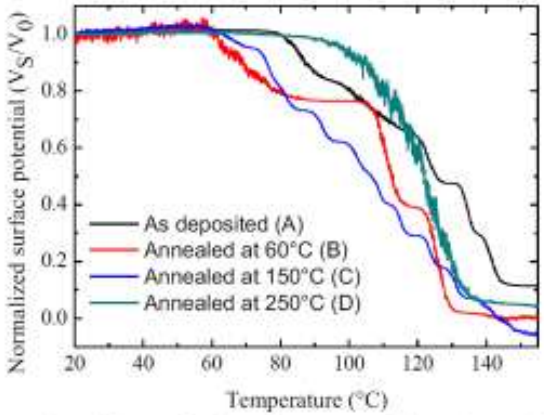
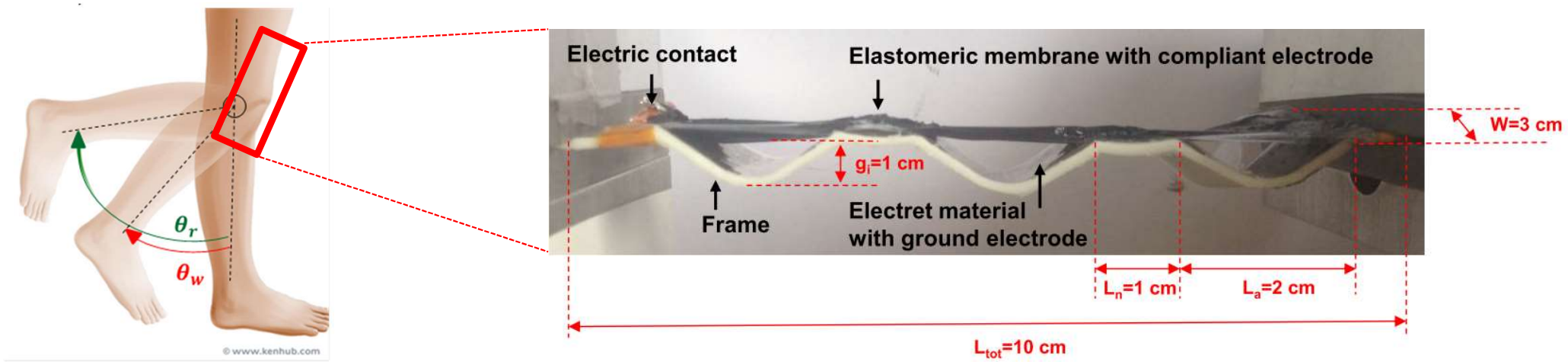
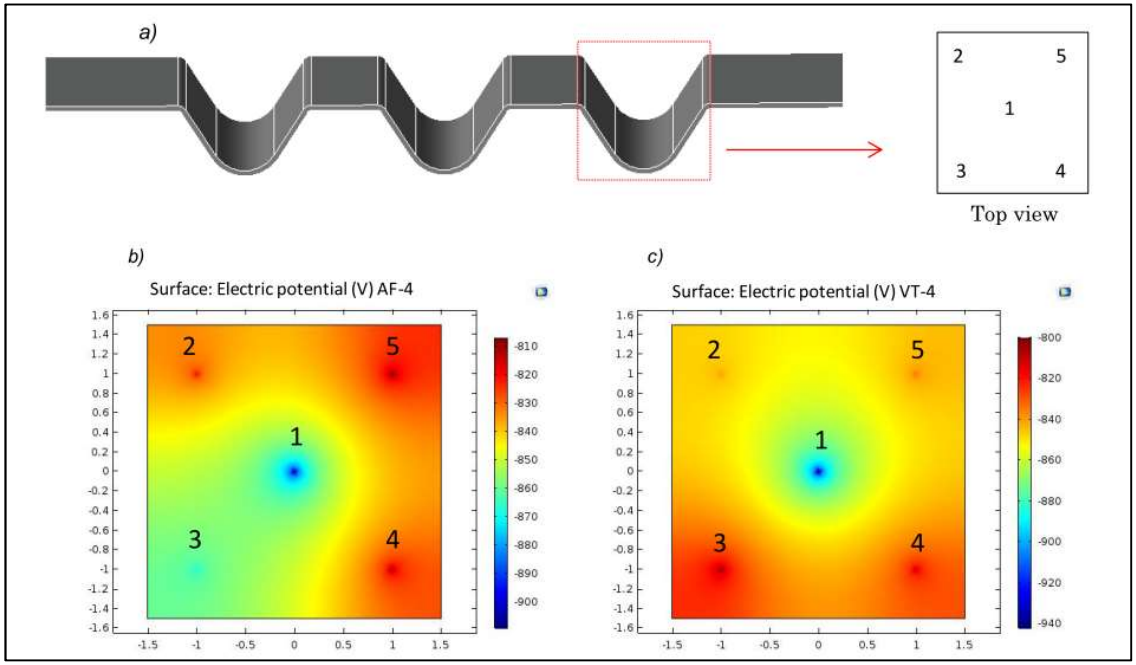


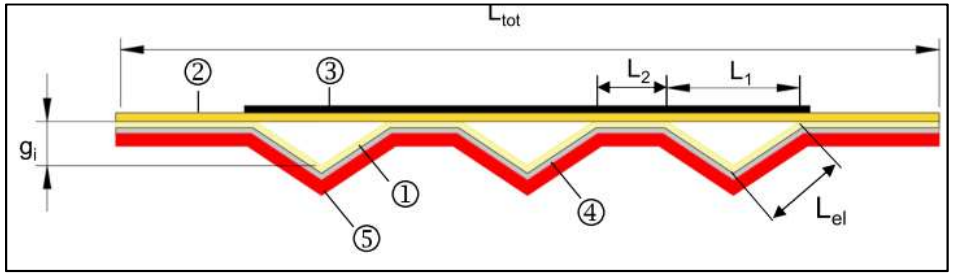
Figure 11. Thermally stimulated surface potential decay (TSSPD) for electret parylene C. [Color figure can be viewed at wileyonlinelibrary.com]

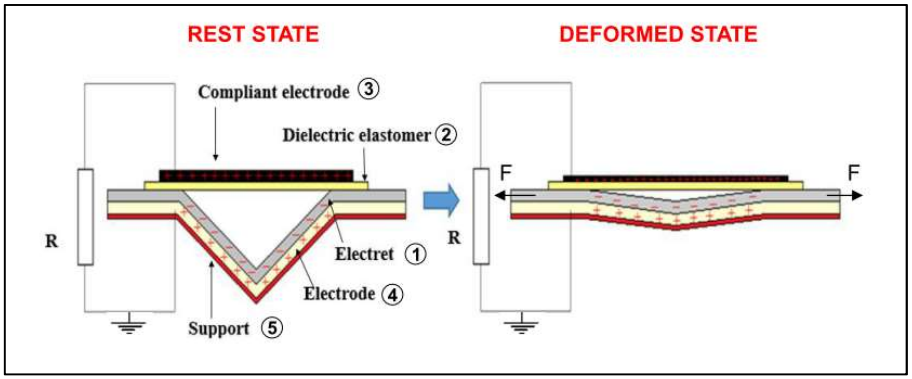
Low cost solution…
but less successfull

SDG for wearable applications



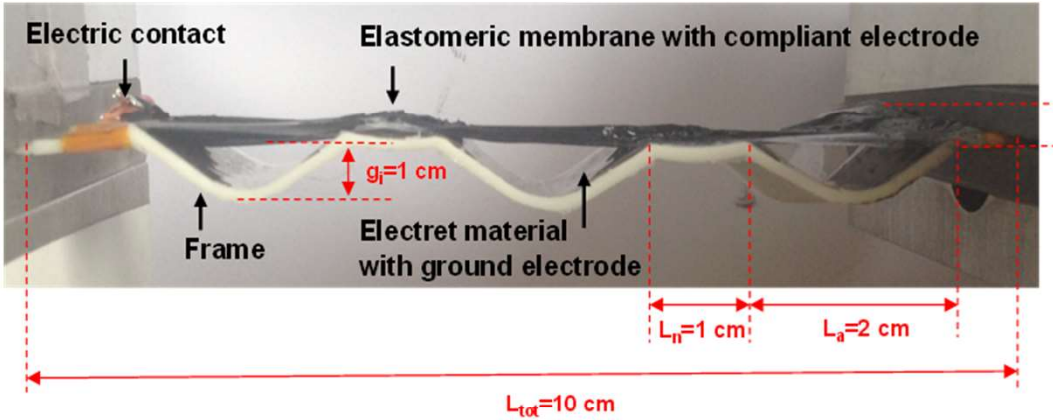


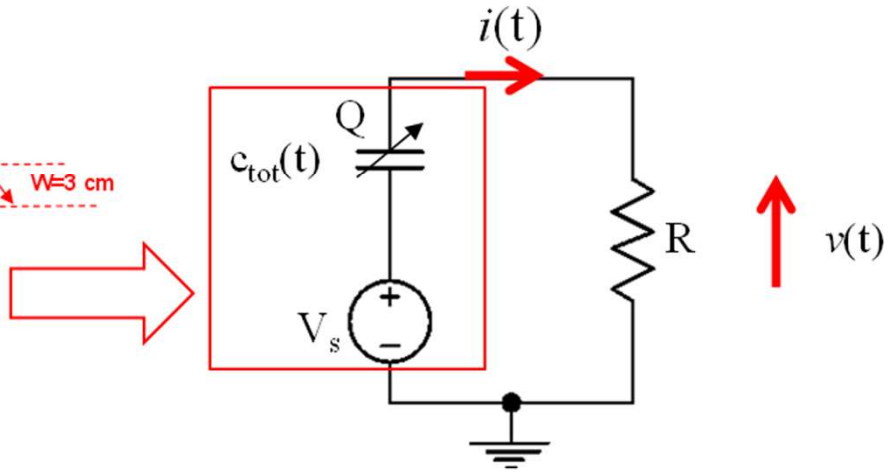




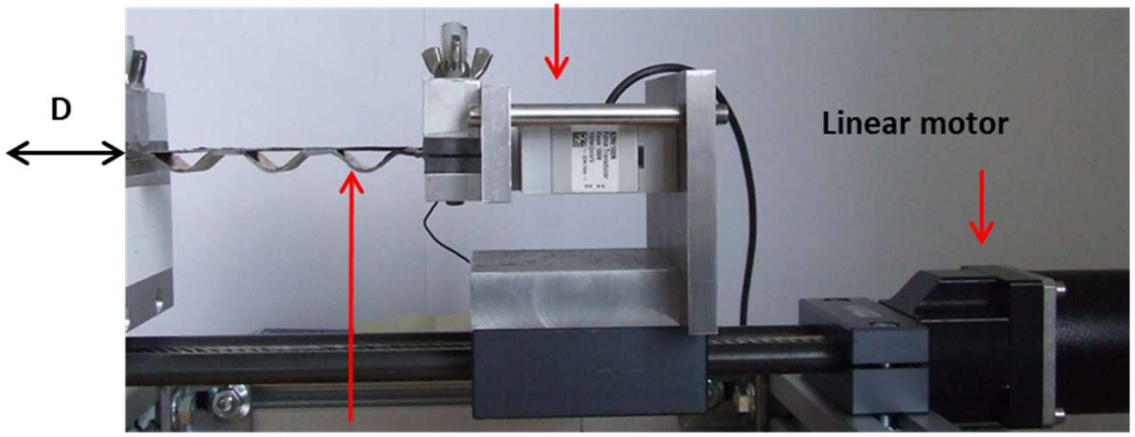
SDG for wearable applications

Experimental validation



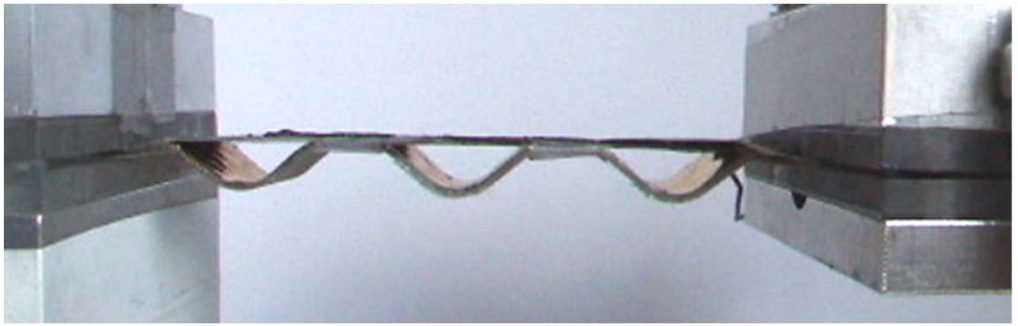


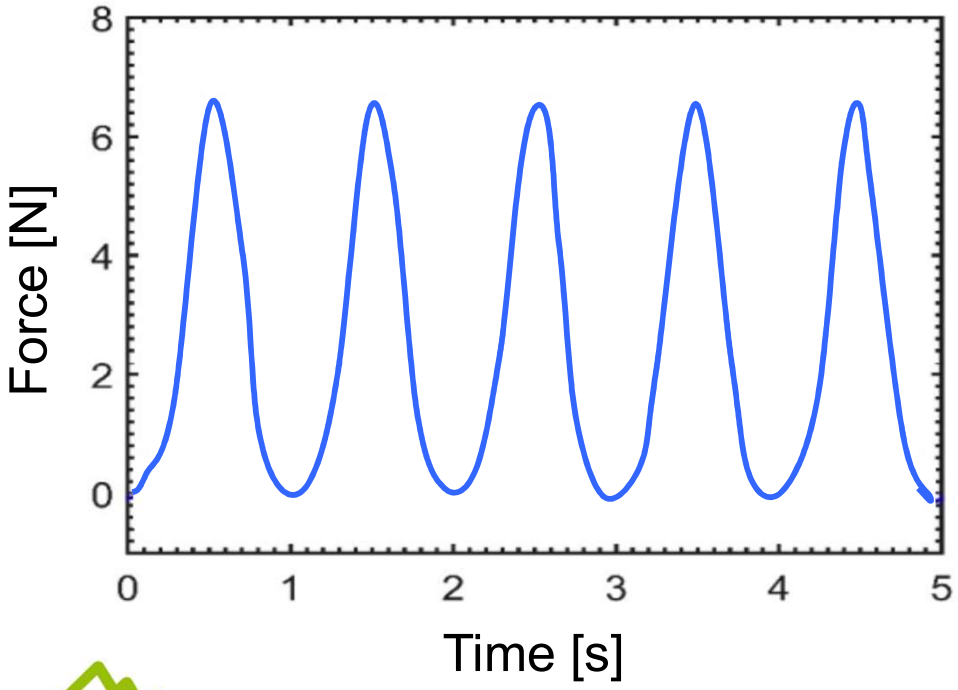
Force sensor

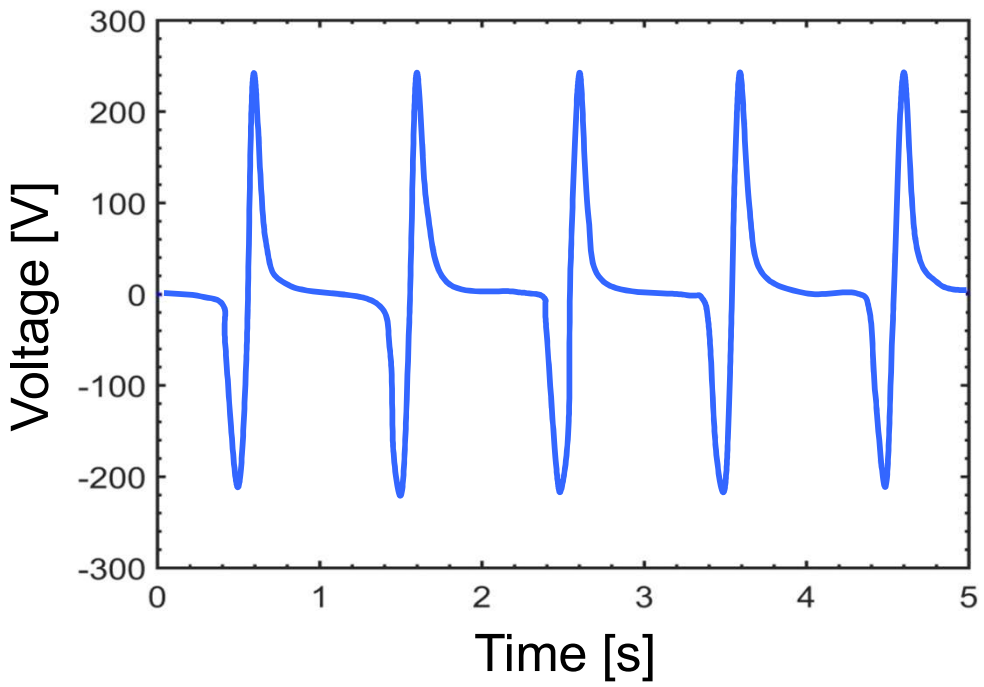


$$\begin{cases} i = \dfrac{\partial Q}{dt} = \dfrac{V_s}{R} - \dfrac{Q}{RC_{tot}} \\ P_{avg} = \dfrac{1}{t_2 - t_1}\displaystyle\int_{t_1}^{t_2} R\left(\dfrac{\partial Q}{dt}\right)^2 \partial t \end{cases}$$

SDG for wearable applications



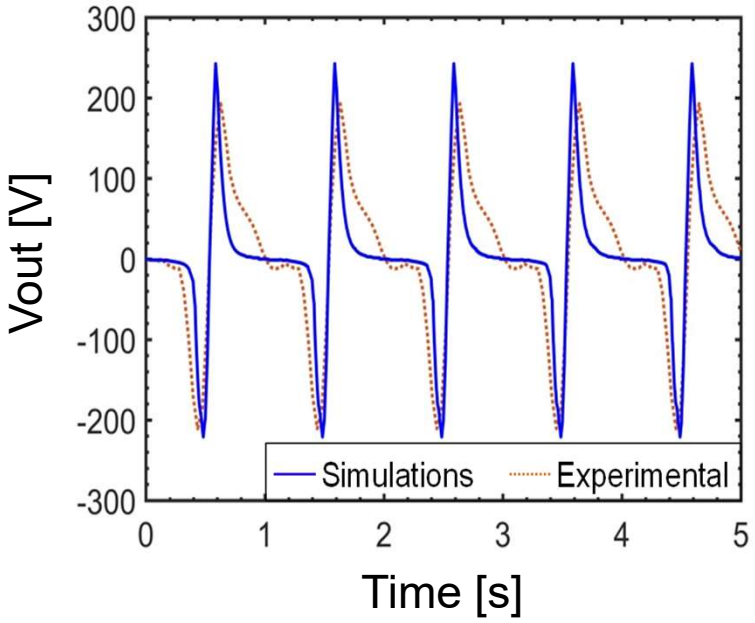


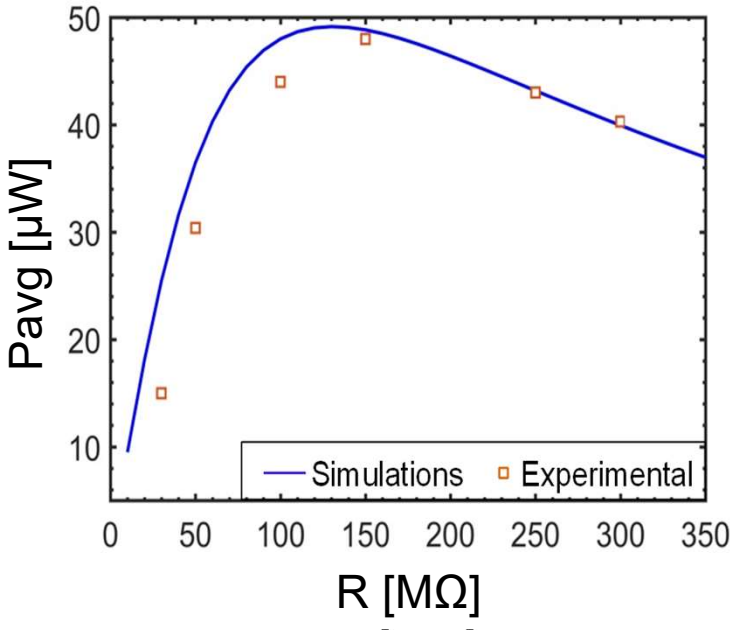


SDG for wearable applications

Experimental validation

Final air gap= 100 µm





F_{max} = 7 N
(no additional effort by the user)

$Pout = 49\ \mu W$

IOP Publishing
Smart Materials and Structures
Smart Mater. Struct. **28** (2019) 104003 (13pp)
https://doi.org/10.1088/1361-665X/ab3906

Optimization of an electret-based soft hybrid generator for human body applications

AUG. 2019

Clara Lagomarsini[1,2], Claire Jean-Mistral[2], Stéphane Monfray[3] and Alain Sylvestre[1]

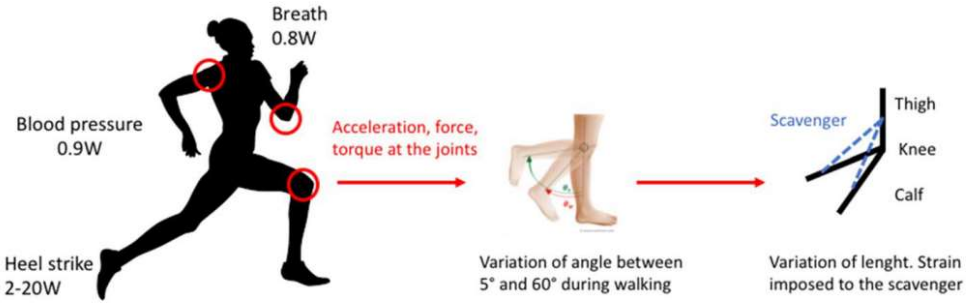


Figure 1. Available lost mechanical energy located on human body and localization of our scavenger.

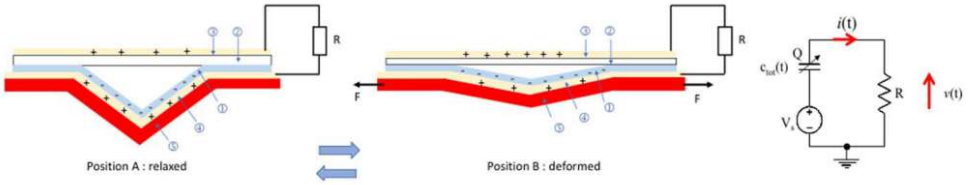


Figure 2. Operating principle of a hybrid structure and equivalent electrical circuit.

2.2 mJ/g

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Smart Mater. Struct. **28** (2019) 035003 (12pp)
https://doi.org/10.1088/1361-665X/aaf34e

Hybrid piezoelectric–electrostatic generators for wearable energy harvesting applications

FEB. 2019

Clara Lagomarsini[1,2], Claire Jean-Mistral[2], Giulia Lombardi[1,2] and Alain Sylvestre[1]

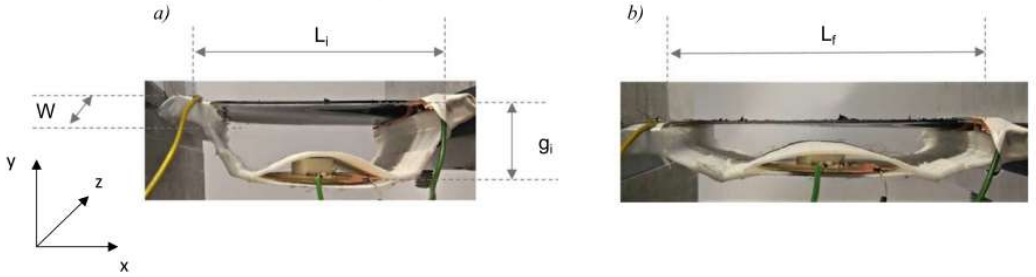

Figure 7. Experimental PZT-based prototype in the rest (a) and deformed (b) configuration.

17 µJ @ 1 Hz

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Another approach : piezoelectrets

Contents lists available at ScienceDirect

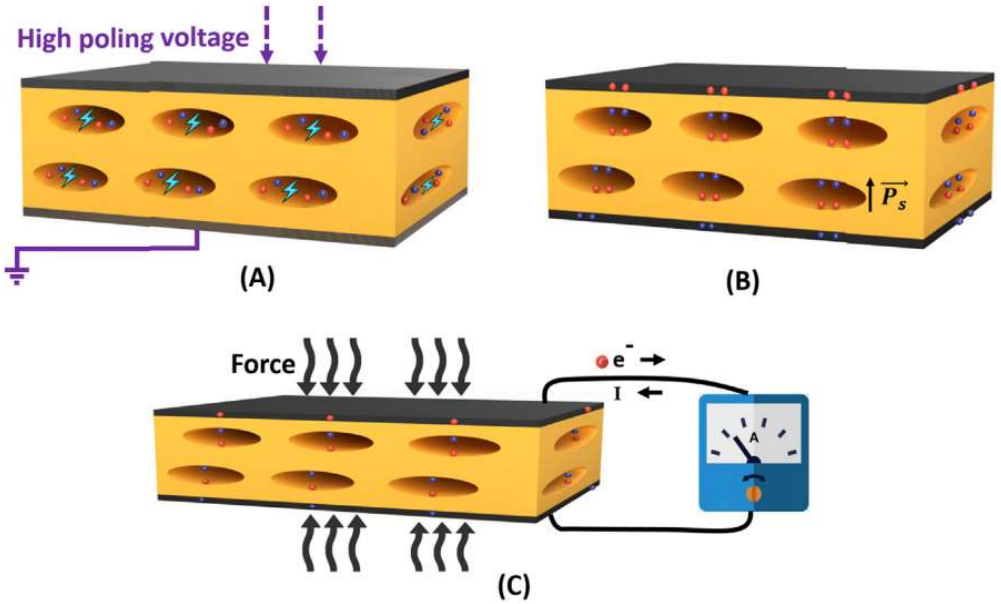
2019 Nano Energy

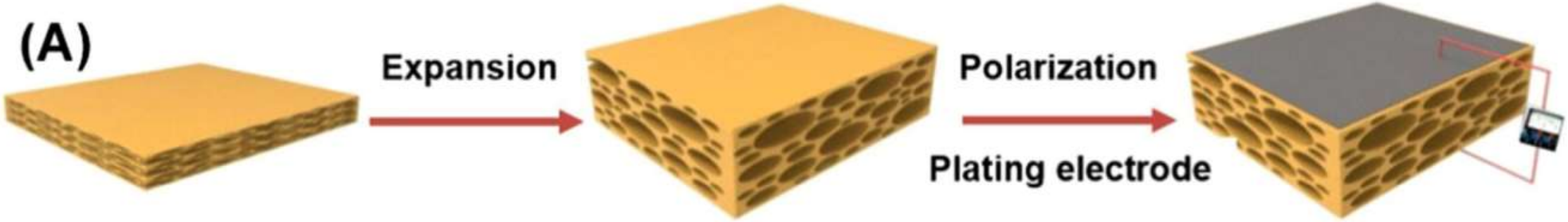
journal homepage: www.elsevier.com/locate/nanoen

Review

Ferroelectret materials and devices for energy harvesting applications

Yan Zhang[a,b,*], Chris Rhys Bowen[a], Sujoy Kumar Ghosh[c], Dipankar Mandal[c,f], Hamideh Khanbareh[a], Mustafa Arafa[d], Chaoying Wan[e]





Our prototype of piezoelectrets

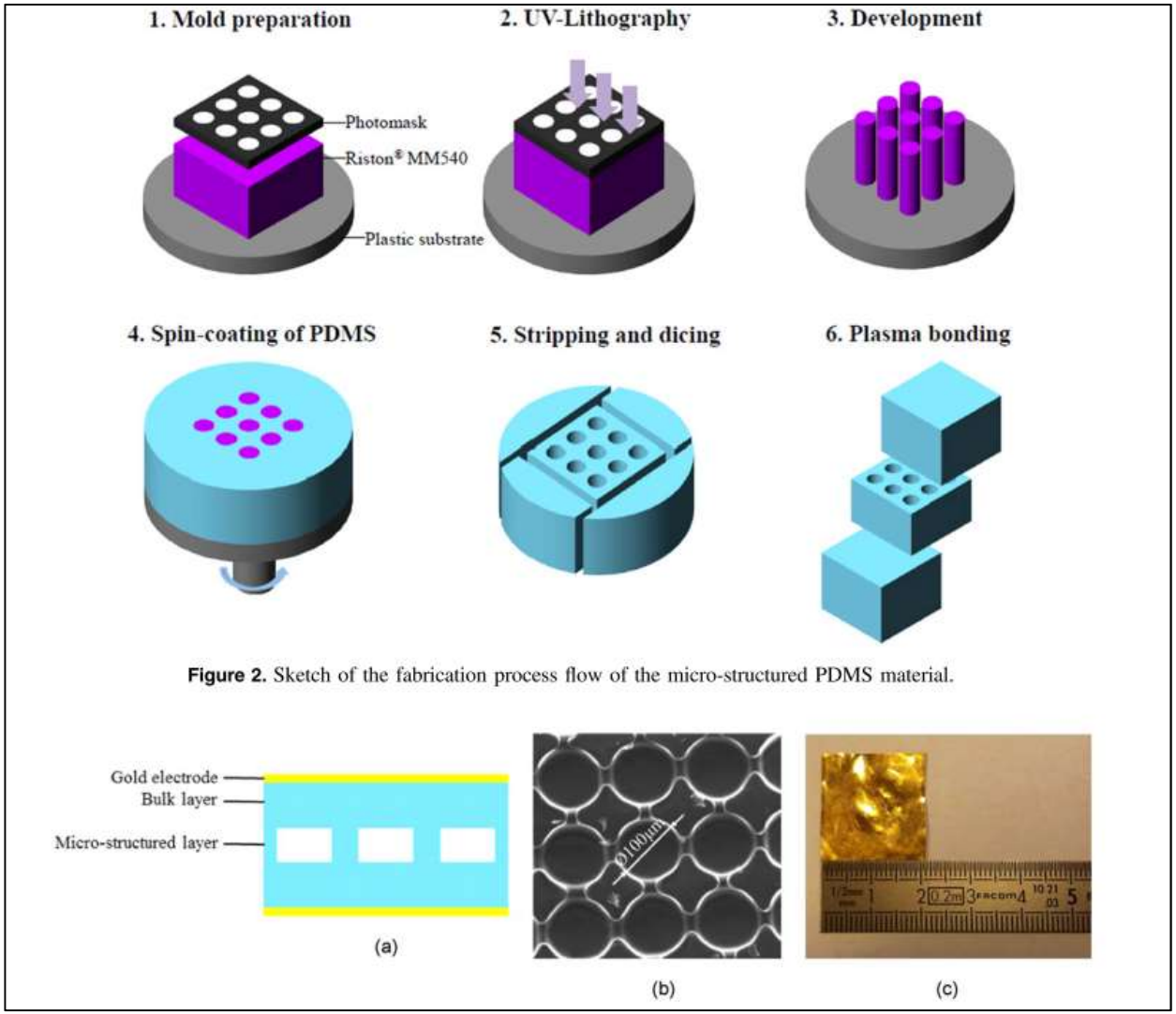


Figure 2. Sketch of the fabrication process flow of the micro-structured PDMS material.

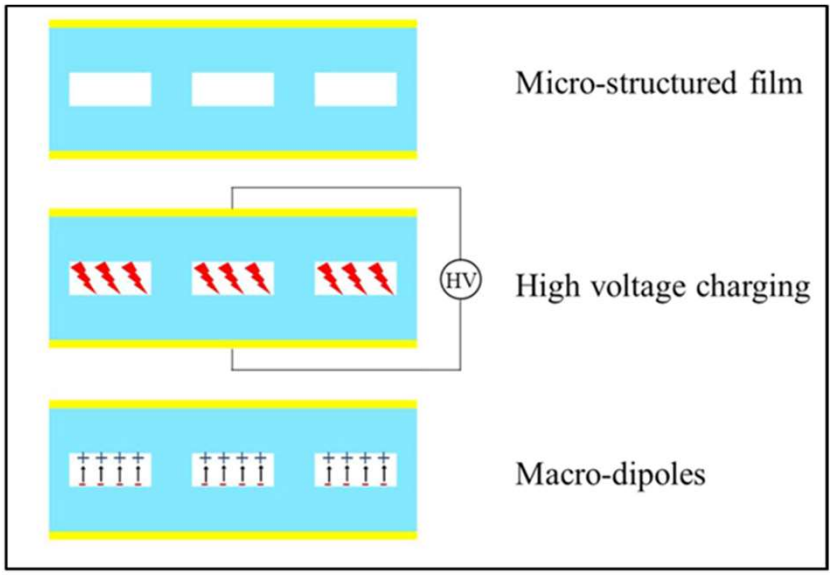
IOP Publishing — Smart Materials and Structures
Smart Mater. Struct. **24** (2015) 125013 (15pp) — doi:10.1088/0964-1726/24/12/125013

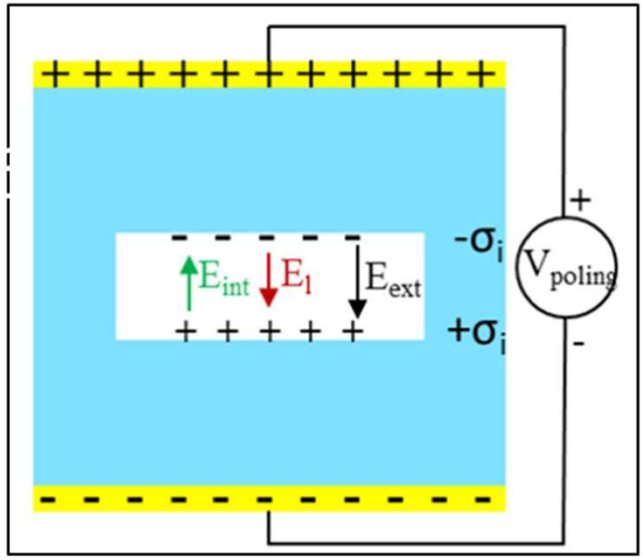
Dielectric properties modelling of cellular structures with PDMS for micro-sensor applications

2015

Achraf Kachroudi[1,2,3], Skandar Basrour[1,2], Libor Rufer[1,2], Alain Sylvestre[4] and Fathi Jomni[3]

Creation of dipoles : 'breakdown' of cavities
Large piezoelectric coefficient





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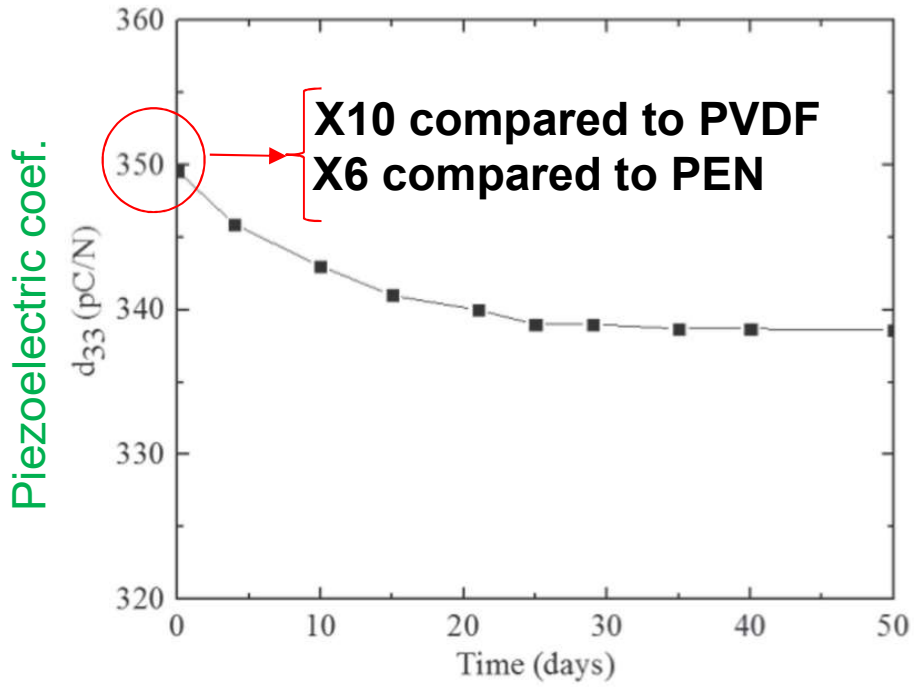
Smart Mater. Struct. 25 (2016) 105027 (14pp)
Smart Materials and Structures
doi:10.1088/0964-1726/25/10/105027

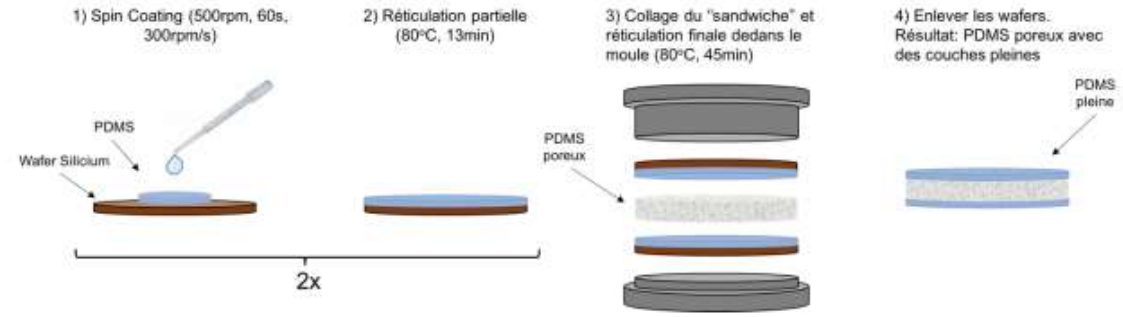
Micro-structured PDMS piezoelectric enhancement through charging conditions

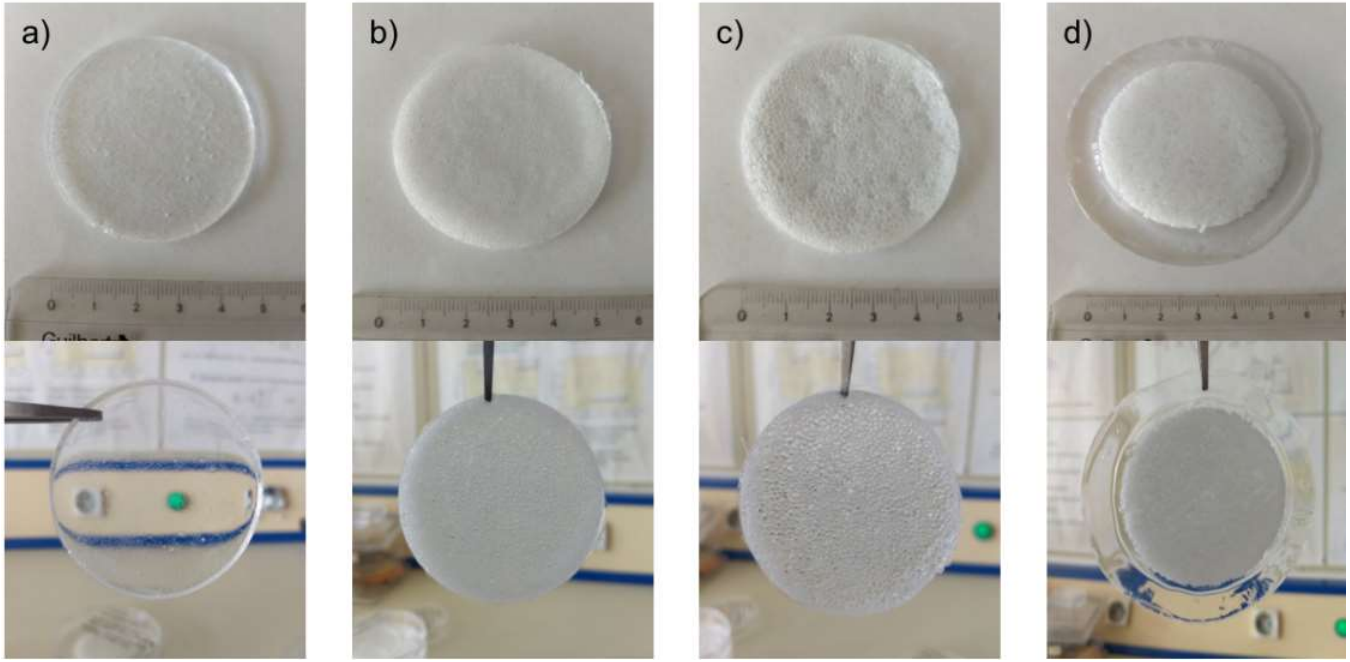
2016

Achraf Kachroudi[1,2,3], Skandar Basrour[1,2], Libor Rufer[1,2], Alain Sylvestre[4] and Fathi Jomni[3]



A soft, low-cost and simple piezoelectret





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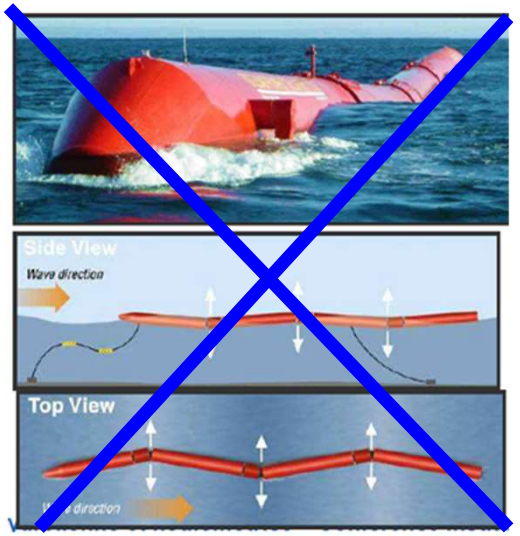
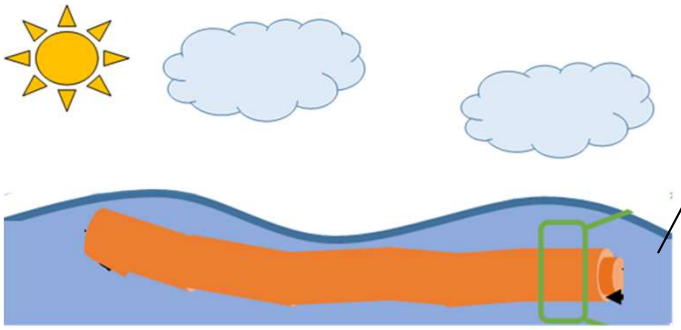
SDG for Wave Energy Converters (WEC)



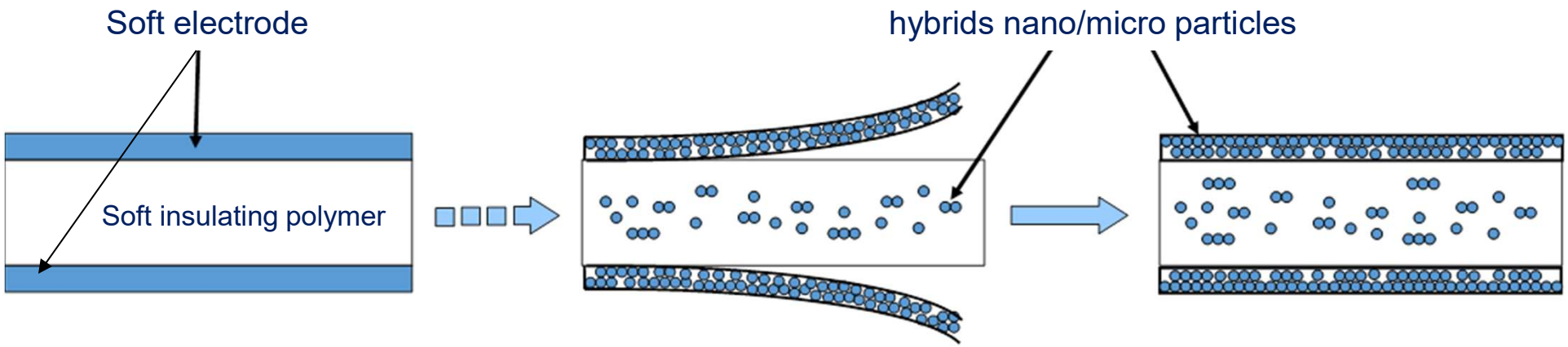
Pelamis



Wave Energy Converter (WEC) of SBM Offshore 2010

P_{out} = 2 W

SDG for Wave Energy Converters (WEC)



$$T_m = \varepsilon_0 \varepsilon' E^2$$

mechanical

electrical

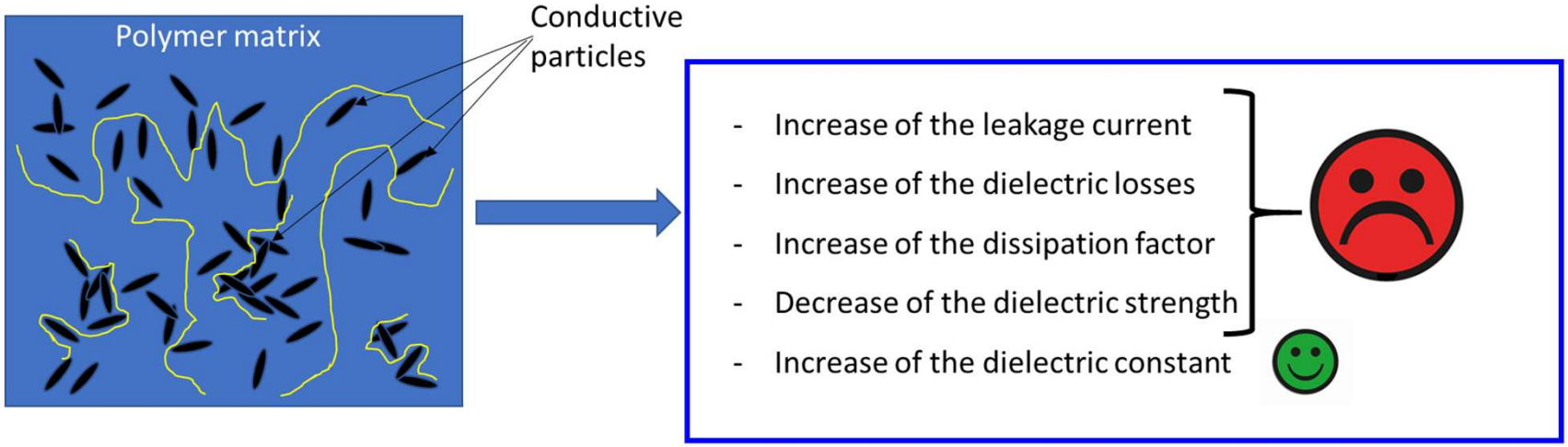
ε'= dielectric constant

↳ PDMS soft polymer: $\varepsilon' = 3$

PDMS = Polydimethylsiloxane

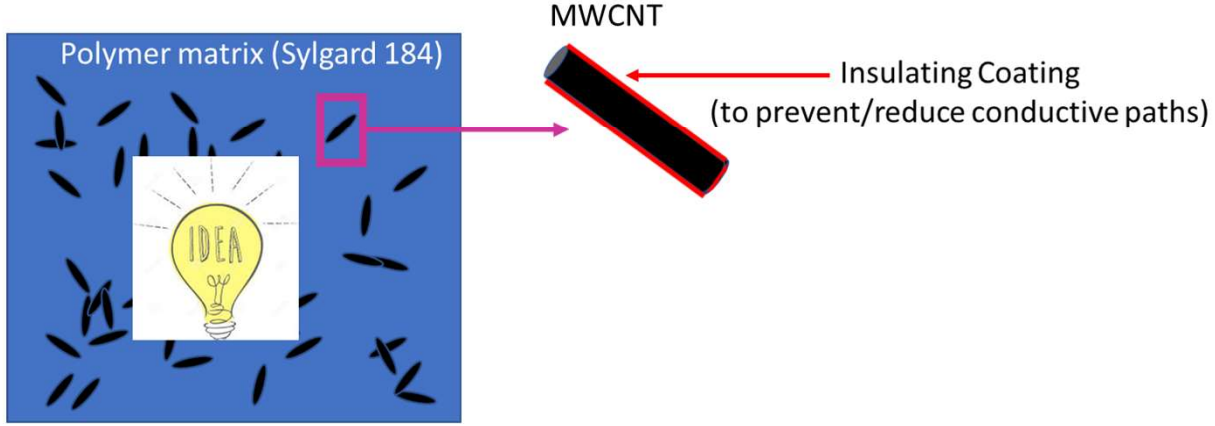
SDG for Wave Energy Converters (WEC)

For these applications : stretching of polymers (typ. >50% of their nominal position) → Silicone rubbers { Dielectric Constant = 3

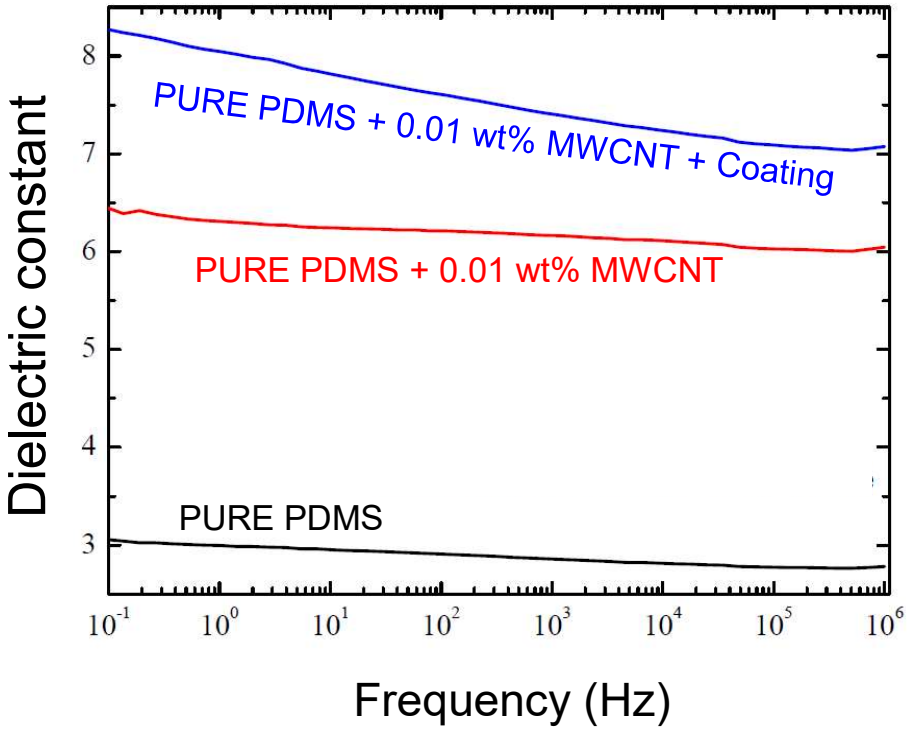


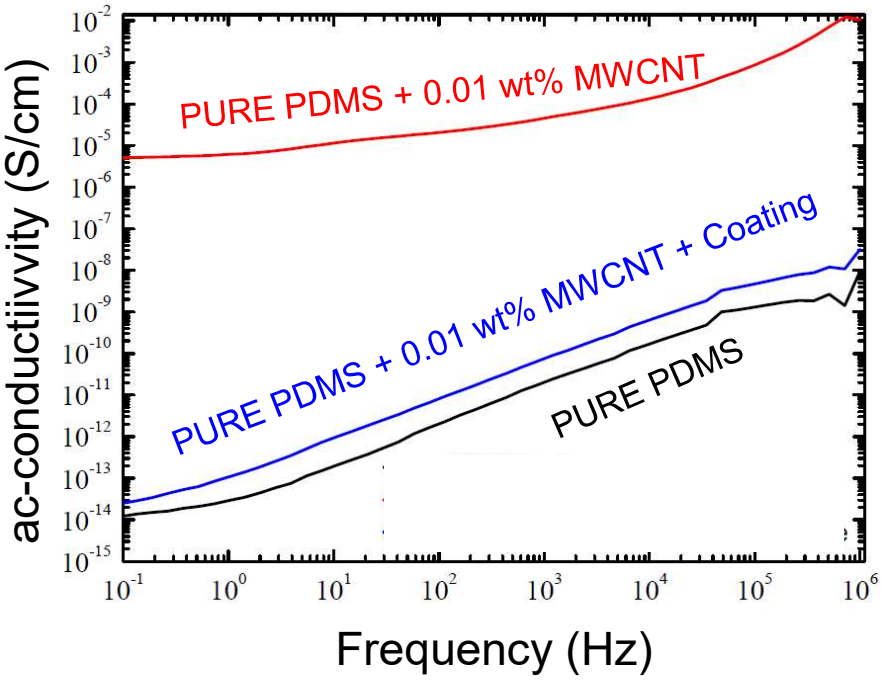
Main drawbacks: Favorable conductive paths

THE SOLUTION?



Dielectric performance

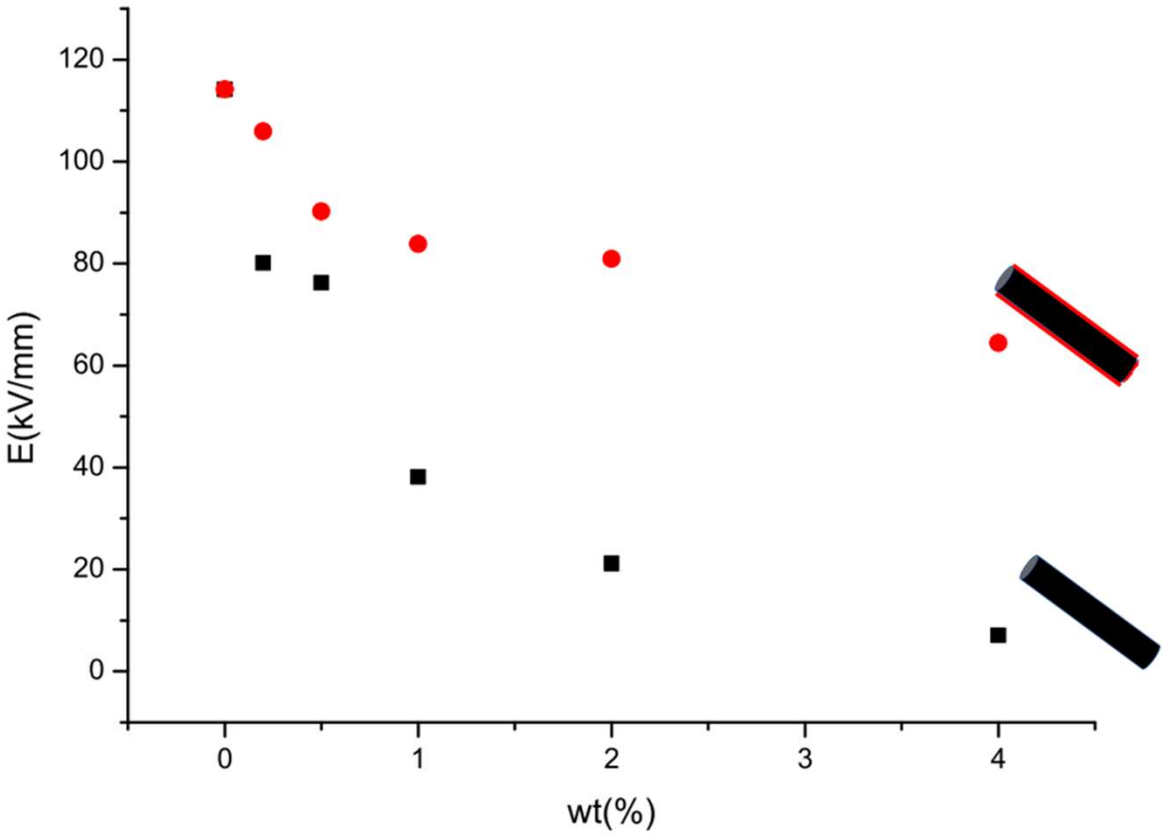


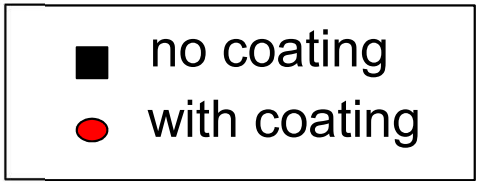


Interest of a parylene coating to prevent electrical conduction

SDG for Wave Energy Converters (WEC)

BREAKDOWN VOLTAGE : influence of the coating





Interest of coating to limit breakdown voltage degradation

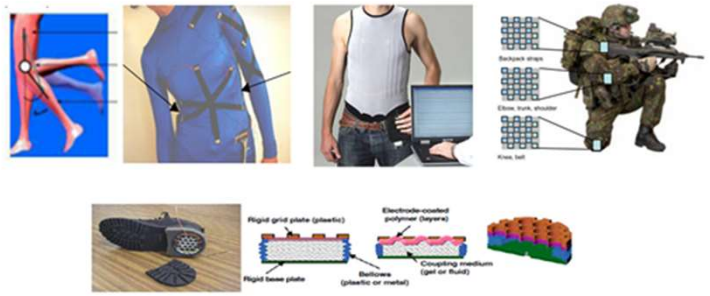
OUTLINE

1. Positioning and originality of the study
2. SDG for wearable applications
3. SDG as piezoelectrets generators
4. SDG for wave energy converters (WEC)
5. Conclusion

SDG = Soft Dielectric-Generators

CONCLUSION: Can we imagine living in a world surrounded by electroactive polymers?

SMART CLOTHES

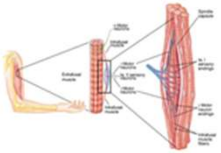


GENERATORS FOR HYBRID VEHICLES

PUBLIC LIGHTING

ELECTROACTIVE POLYMER APPLICATIONS

ARTIFICIAL MUSCLES



HAPTIC SCREEN

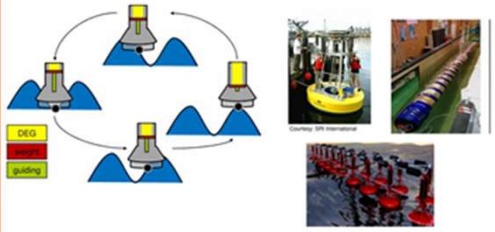
CHALLENGE

Créer LOCALEMENT une vibration ou une texture particulière sur un écran ou un clavier.

POSSIBILITÉS AVEC DES EAP

Tablettes Braille reconfigurables

SEE FARM OF ELECTRICITY



AUTONOMOUS BIOCOMPATIBLE GENERATORS