INTEGRATING THE THERMOELECTRIC AND SENSING PROPERTIES OF PEDOT-BASED COMPOUNDS INTO SELF-POWERED DEVICES

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INTRODUCTION

ORGANIC THERMOELECTRICS

Queen Mary University of London

The Centre for Plastic Electronics

Imperial College London

Israel Journal of Chemistry
Official Journal of the Israel Chemical Society

Review

Thermoelectric Materials: A Brief Historical Survey from Metal Junctions and Inorganic Semiconductors to Organic Polymers

Prospero J. Taroni, Itziar Hoces, Natalie Stingelin, Martin Heeney, Emiliano Bilotti

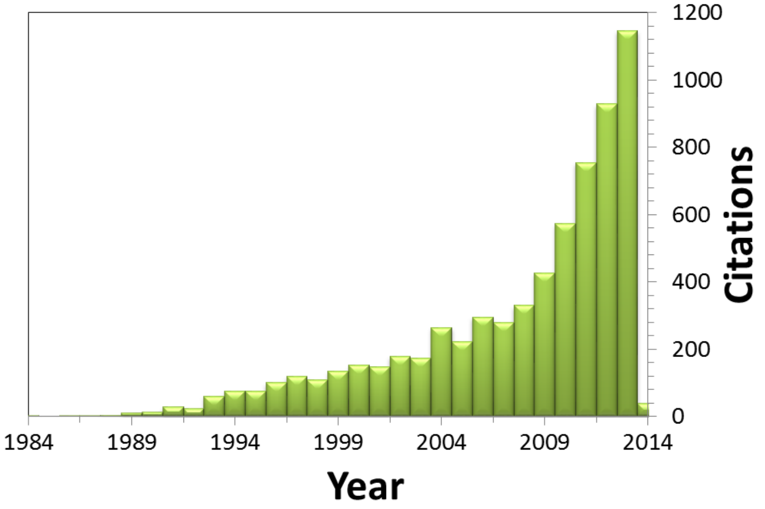
First published: 6 June 2014 Full publication history

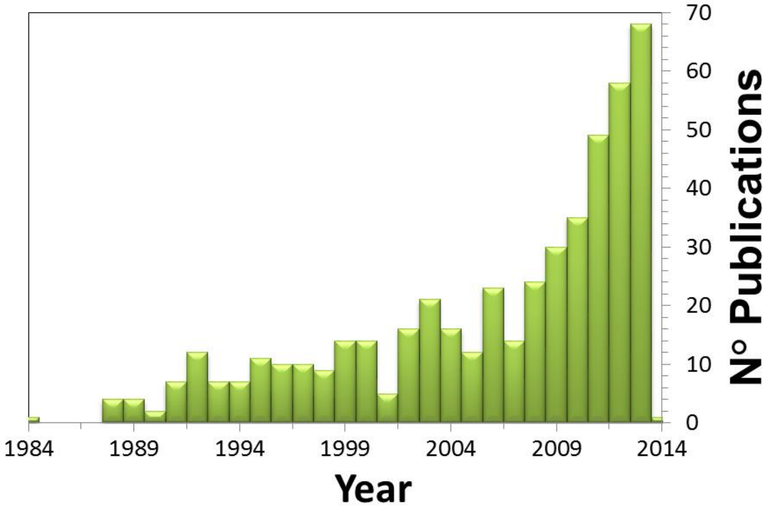
The first *European Conference on Thermoelectrics* in 1988 had **no mention on organic materials** in their proceedings.

According to the **Thomas Reuter Web of Science** citation report for the term **'organic thermoelectric*'** (last three decades) the interest has grown exponentially.

The potential advantages :

- **lower cost**
- **relative abundance**
- **possibility for large area deposition.**
- **However, their use is limited to lower-temperature applications.**





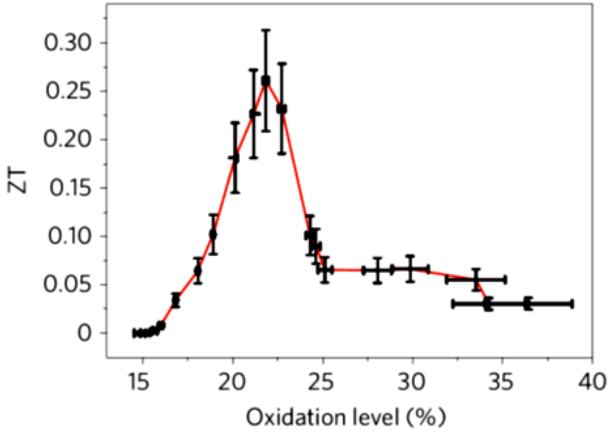
SIGNIFICANT PROGRESS FOR *P*-TYPE ORGANIC THERMOELECTRIC MATERIALS

nature materials 2011 LETTERS
PUBLISHED ONLINE: 1 MAY 2011 | DOI: 10.1038/NMAT3012

Optimization of the thermoelectric figure of merit in the conducting polymer poly(3,4-ethylenedioxythiophene)

Olga Bubnova[1], Zia Ullah Khan[1], Abdellah Malti[1], Slawomir Braun[2], Mats Fahlman[2], Magnus Berggren[1] and Xavier Crispin[1]*

The accurate control of the oxidation level in poly(3,4-ethylenedioxythiophene) (PEDOT) combined with its low intrinsic thermal conductivity ($\lambda = 0.37\ \mathrm{W\,m^{-1}\,K^{-1}}$) yields a $ZT = 0.25$ at room temperature that approaches the values required for efficient devices.

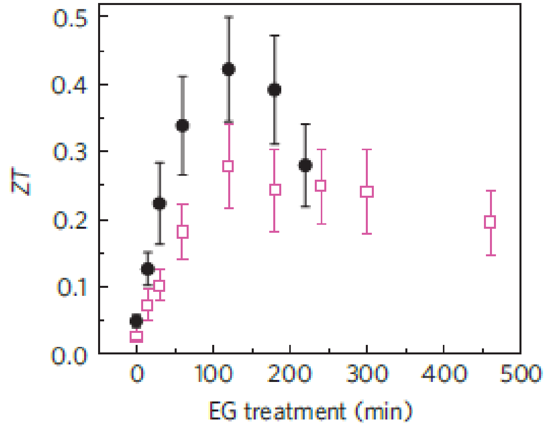


nature materials 2013 LETTERS
PUBLISHED ONLINE: 5 MAY 2013 | DOI: 10.1038/NMAT3635

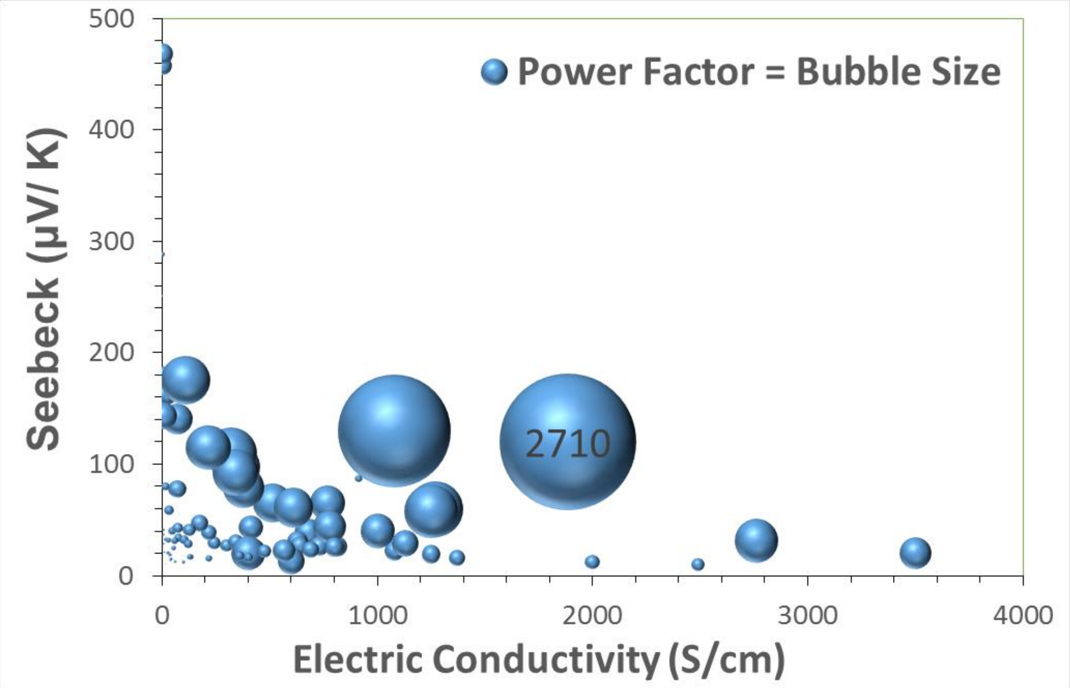
Engineered doping of organic semiconductors for enhanced thermoelectric efficiency

G-H. Kim[1], L. Shao[1], K. Zhang[1] and K. P. Pipe[1,2]*

Reducing dopant volume is found to be as important as optimizing carrier concentration when maximizing *ZT* in OSCs. Implementing this strategy with the dopant poly(styrenesulphonate) in poly(3,4-ethylenedioxythiophene), we achieve $ZT = 0.42$ at room temperature.



LITERATURE REVIEW: ‘ORGANIC THERMOELECTRIC COMPOSITES*’



Best Power Factor for *p*-type composite:

LbL

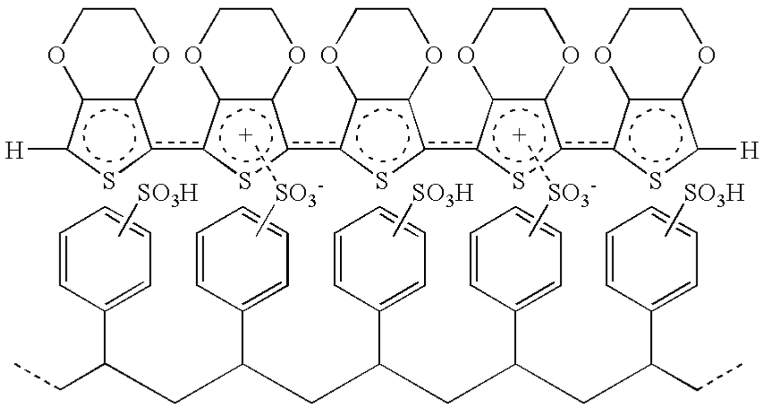
Polyaniline/ Graphene-PEDOT:PSS/ Polyaniline/ DWCNT-PEDOT:PSS

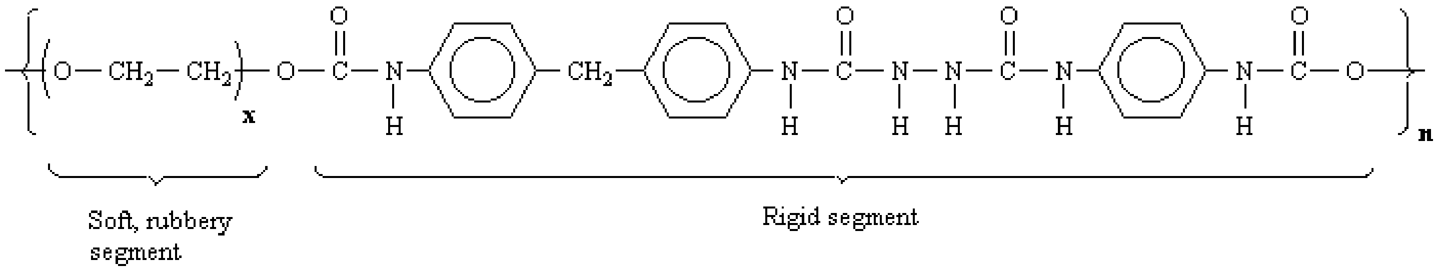
Cho, C. et al., Adv. Energy Mater. 6, (2016)

- **Highest Seebeck coefficient** for ***p*-type** materials were reported between **400 and 500 uV/ K**, but they did not generate the highest PF.
- **Highest electrical conductivity** were between **2500 and 3500 S/ cm**, but they did not generate the highest PF.
- **Best power factor** was generated by moderately high electric conductivities and Seebeck coefficients between **1000 – 2000 S/ cm and 100 – 200 uV/ K**, respectively.

MOTIVATION:

To combine the electrical properties of PEDOT:PSS with the mechanical properties of Spandex



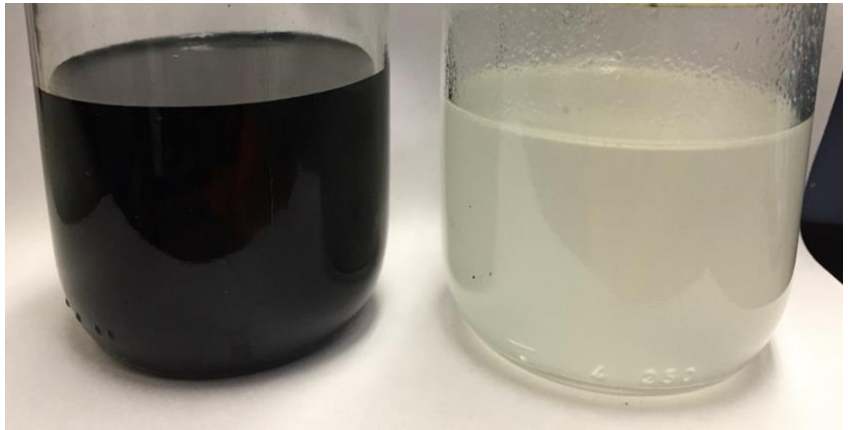


PEDOT:PSS
Clevios PH1000

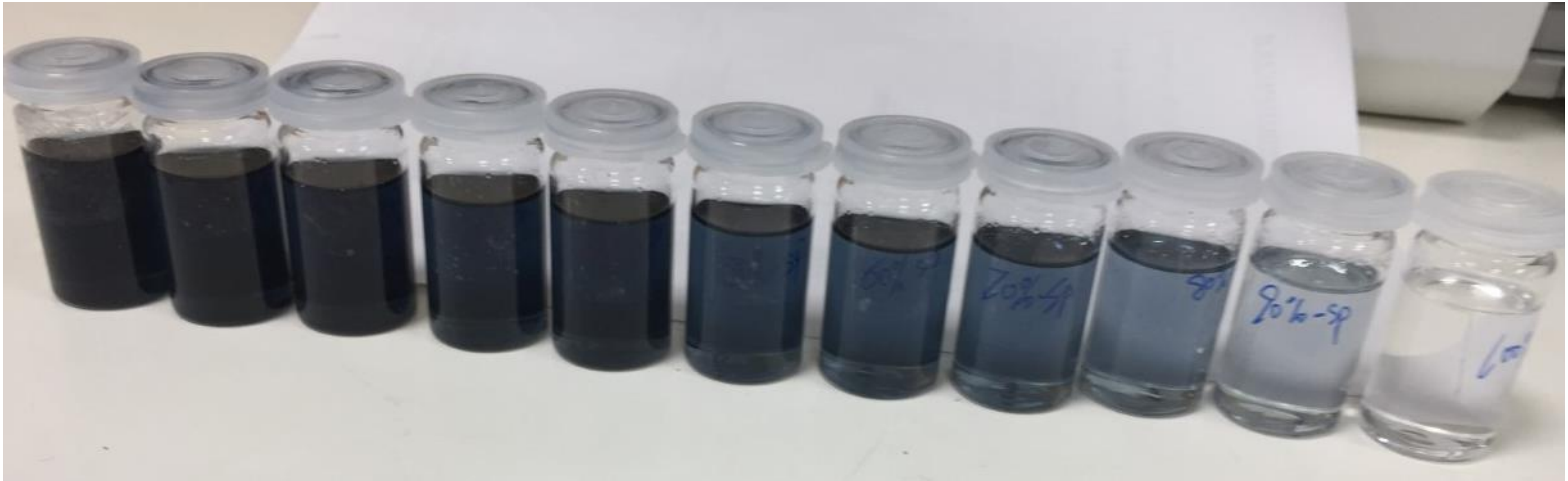
SPANDEX
Lycra ® Invista

METHOD:

Fabrication of PEDOT:PSS/ Spandex composite.



0% - 100% MIXTURES OF SPANDEX WITH PEDOT:PSS



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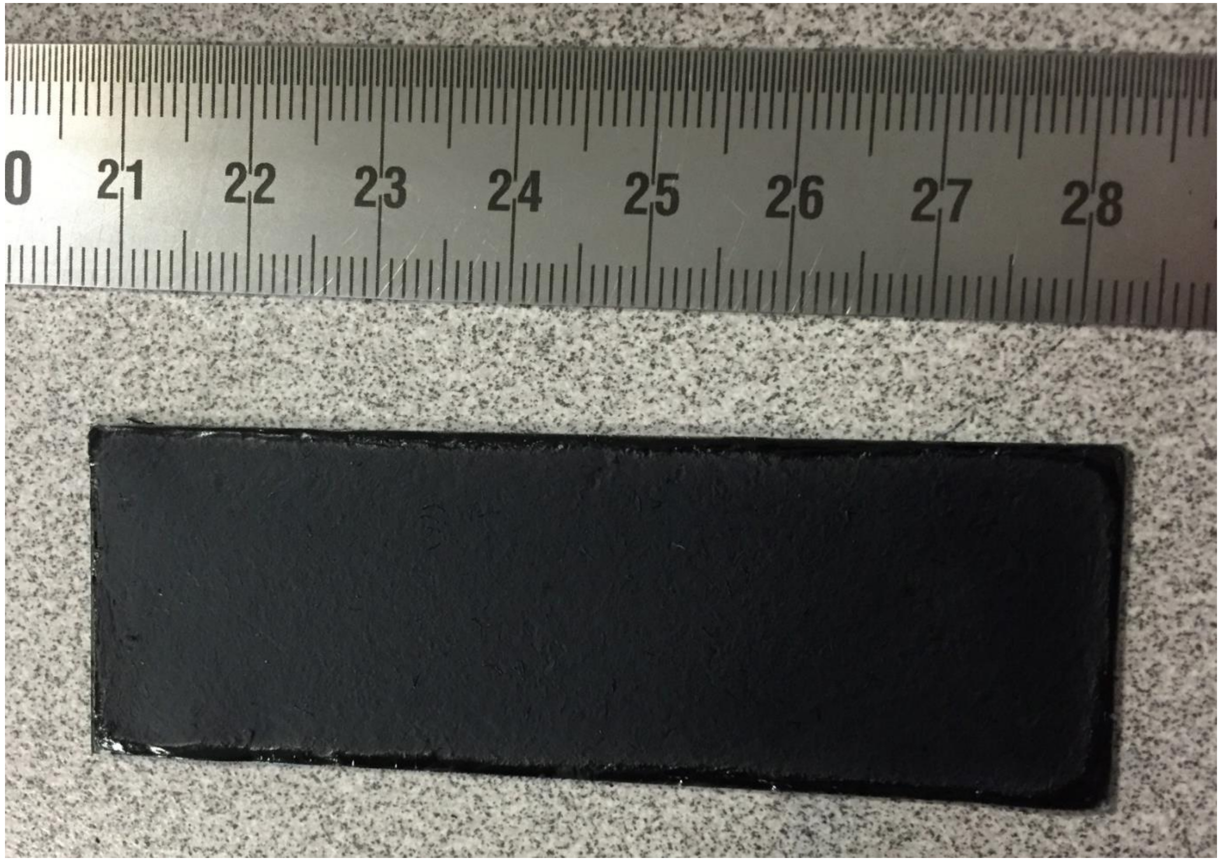
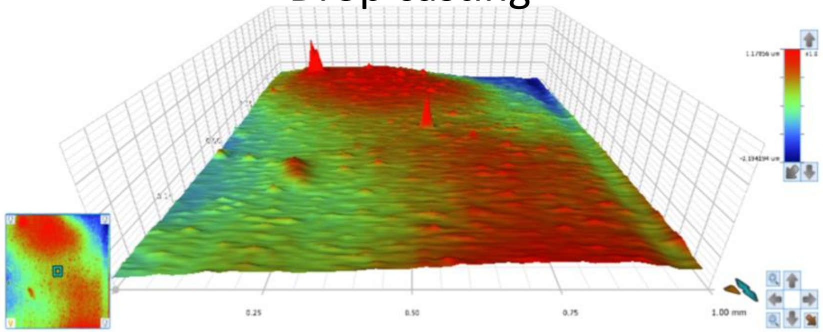
DROP-CASTED FILMS

Better electric conductivity compared to spray coating

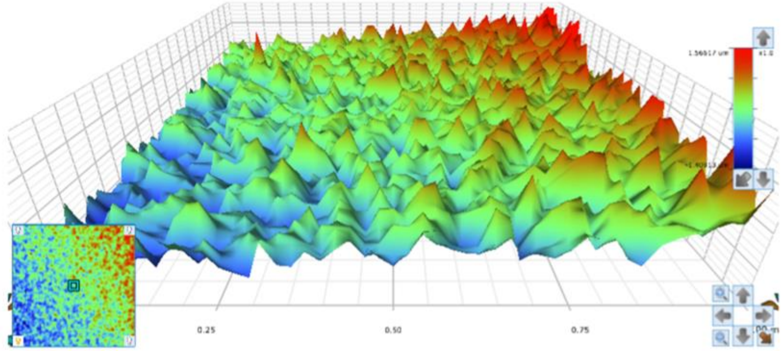


3D images - 1 x 1 cm

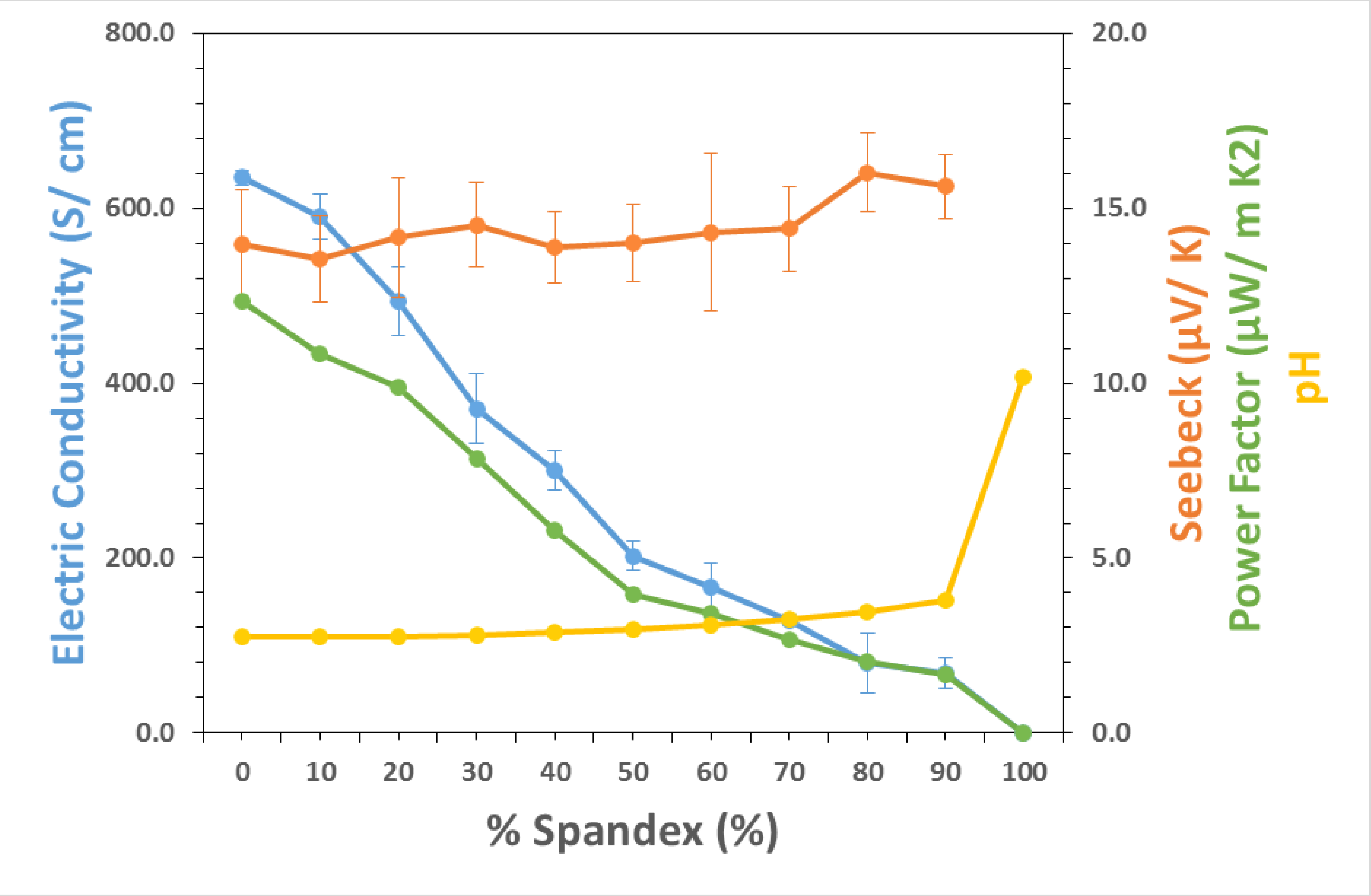
Drop casting



Spray coating



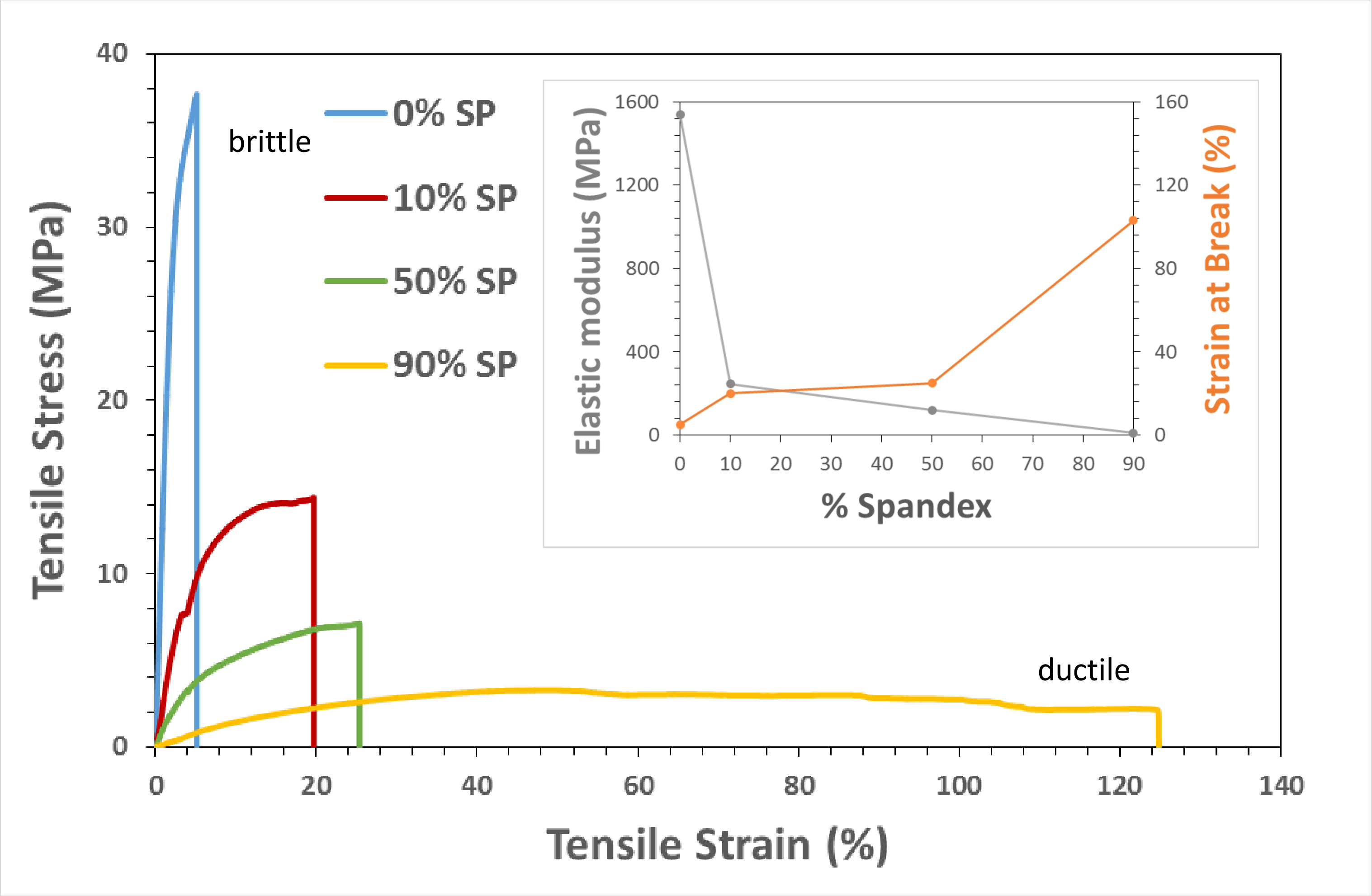
THERMOELECTRIC CHARACTERISATION OF PEDOT:PSS/ SPANDEX COMPOSITES



- The electric conductivity decreases with increased concentration of Spandex, but remains relatively high due to solvent treatment.

- The Seebeck coefficient is not significantly affected by increased concentration of Spandex.

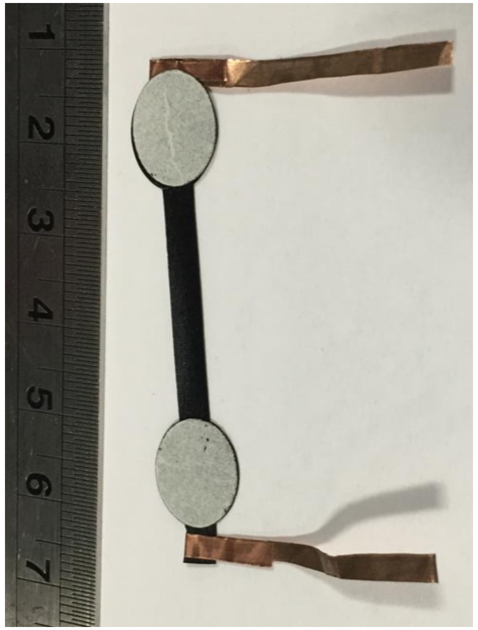
TENSILE PROPERTIES OF COMPOSITES

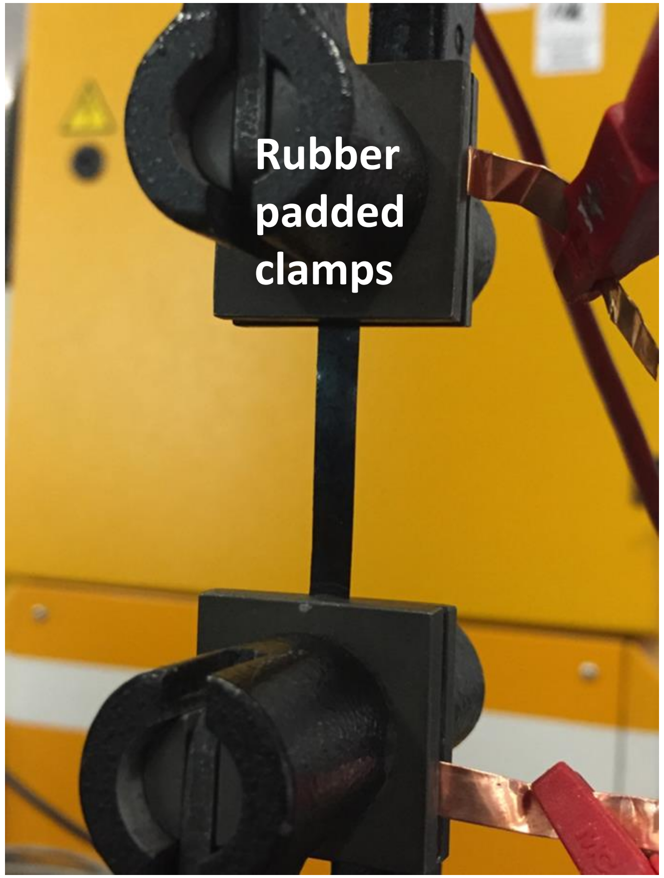


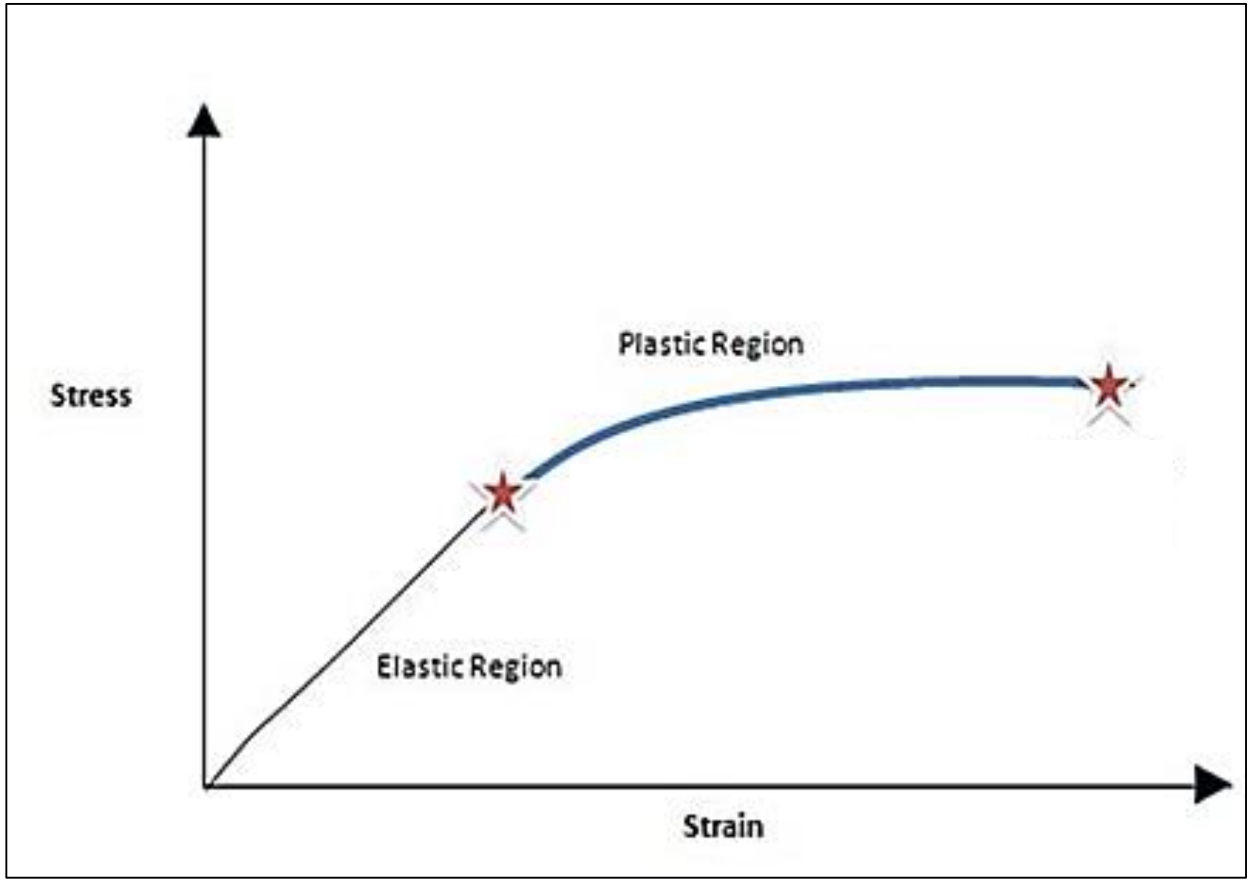
- The strain at break (%) increases with increased concentration of Spandex.
- The elastic modulus decrease with increased concentration of Spandex.

CYCLIC TEST: STRAIN SENSING WITH APPLIED VOLTAGE AND MEASURED CURRENT.

$$R = \frac{V}{I}$$







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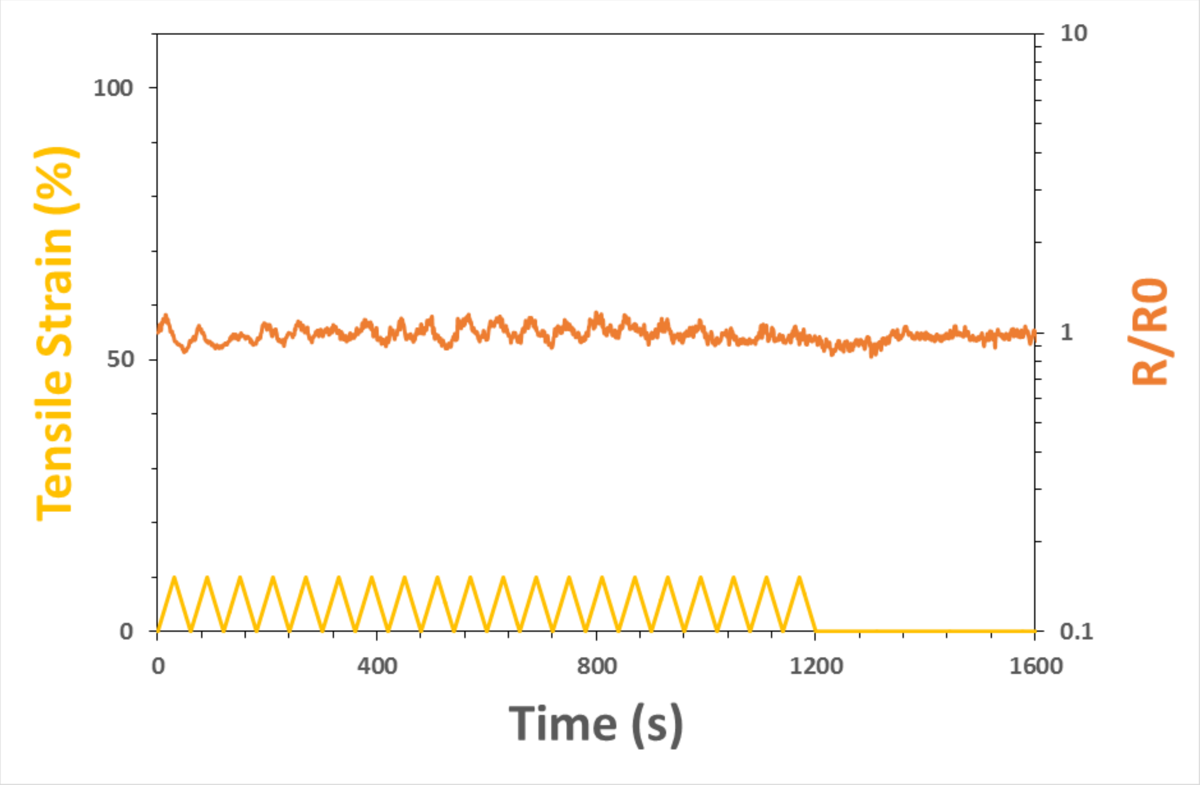
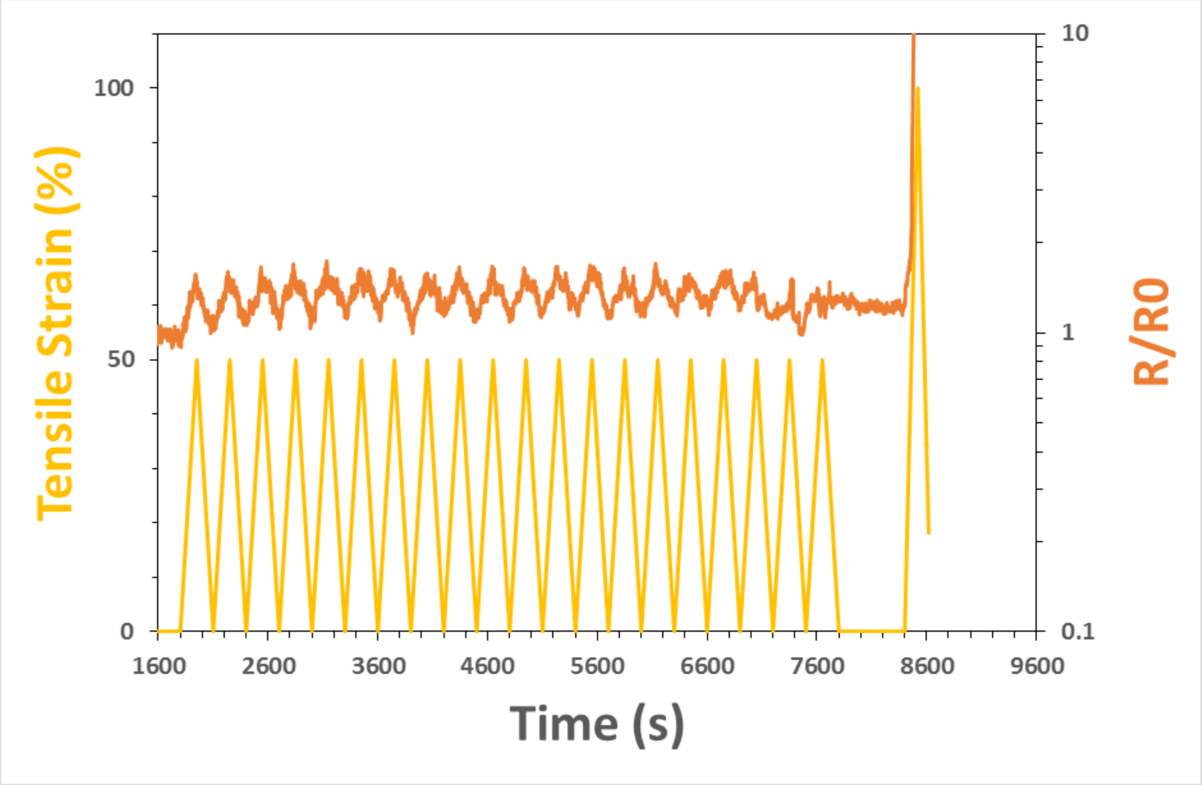
CYCLIC TEST, 90% SPANDEX AFTER EG BATH

CYCLE 1 – 10% STRAIN



CYCLE 2 – 50% STRAIN



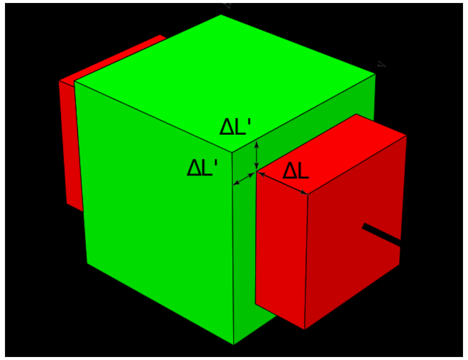
THE EFFECT OF GEOMETRIC FACTORS ON RESISTANCE (50% STRAIN)

DERIVED FROM POISSON'S RATIO

[PDF] Stress-Strain Behavior of Thermoplastic Polyurethane - Massachuset...
web.mit.edu/cortiz/www/Jerry/TPU_final.pdf ▾
by HJ Qi - Cited by 267 - Related articles
The stress-strain behavior of TPUs demonstrates strong hysteresis, time ... It is hence reasonable to assume the Poisson's ratio ν ranges from 0.48 to 0.50.

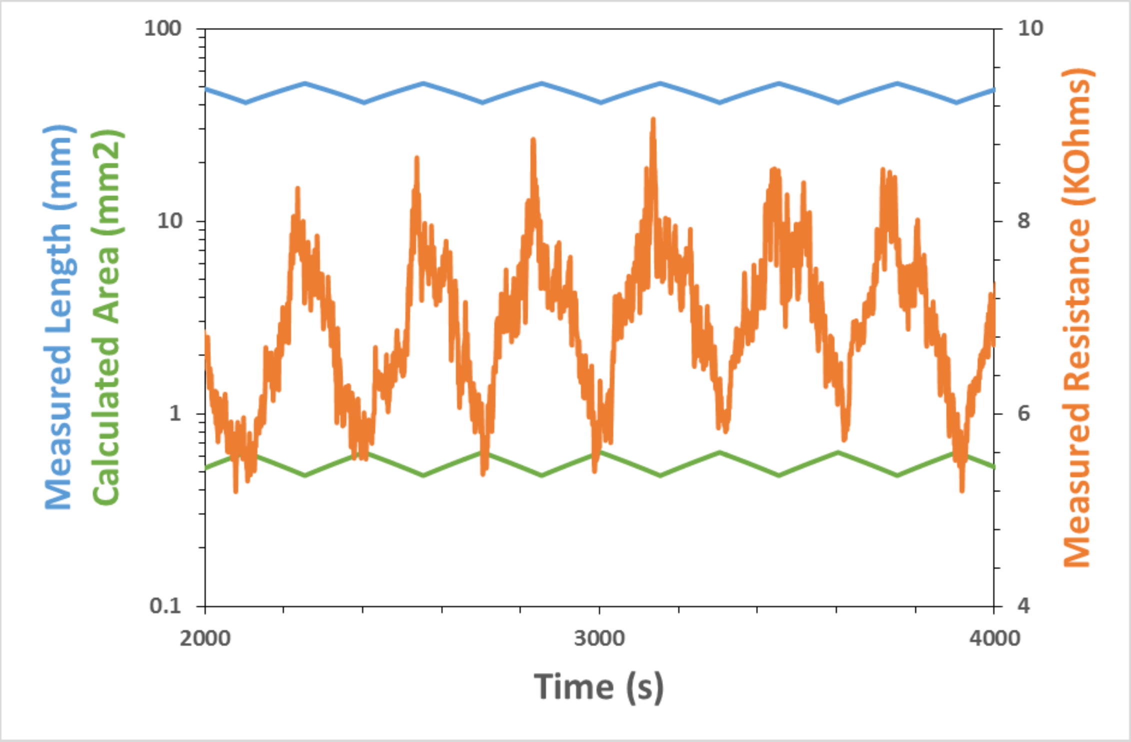
$$W = W_0\left(1 - \left(0.5 \times \frac{Extension}{L_0}\right)\right)$$

$$T = T_0\left(1 - \left(0.5 \times \frac{Extension}{L_0}\right)\right)$$



$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area



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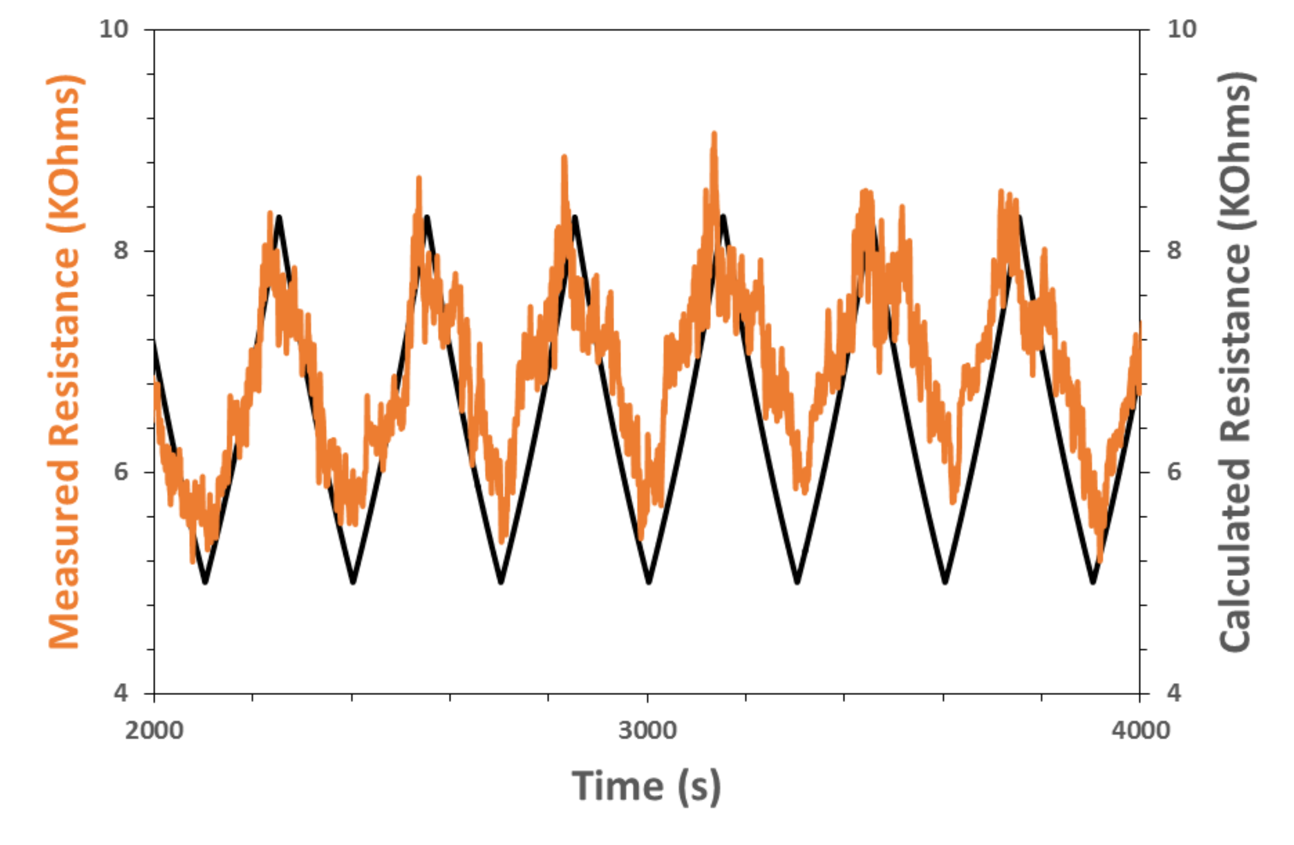
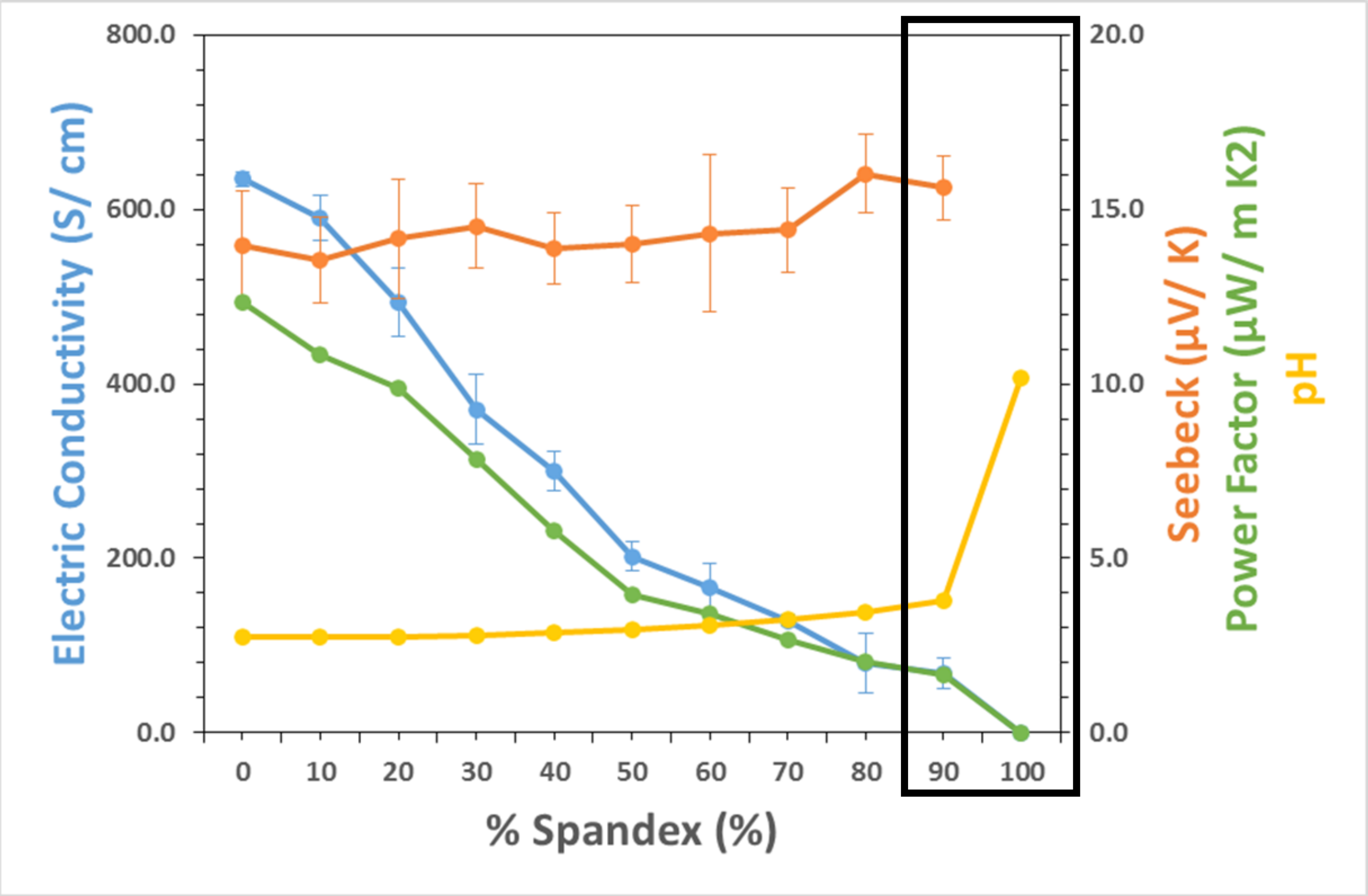
THE EFFECT OF GEOMETRIC FACTORS ON RESISTANCE (50% STRAIN)

- The sample did not recover its length very quickly, so at the minimal extension point, the measured resistance corresponds to a slightly stretched sample.
- The calculated resistance still very close to the measured resistance, so there is no indication of significant changes in the resistivity during extension.
- Variation of resistance with cycle is likely to be due to geometric factors only.



IMPROVING THE SENSITIVITY TO STRAIN

- The use of a lower concentrations of PEDOT to Spandex – **sensitivity not only affected by geometrical factors, but also to changes in resistivity due to a closer proximity to percolation.**



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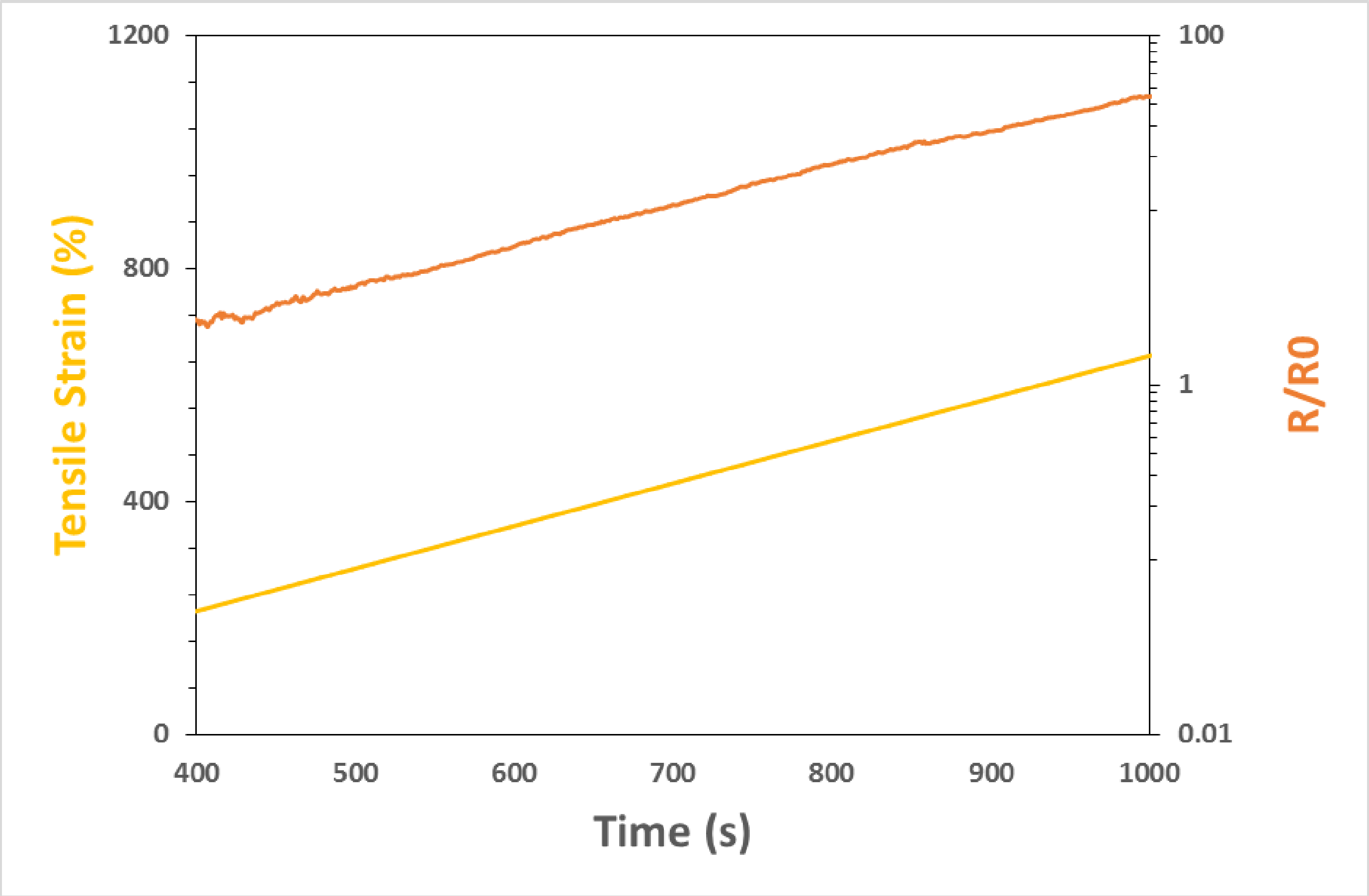
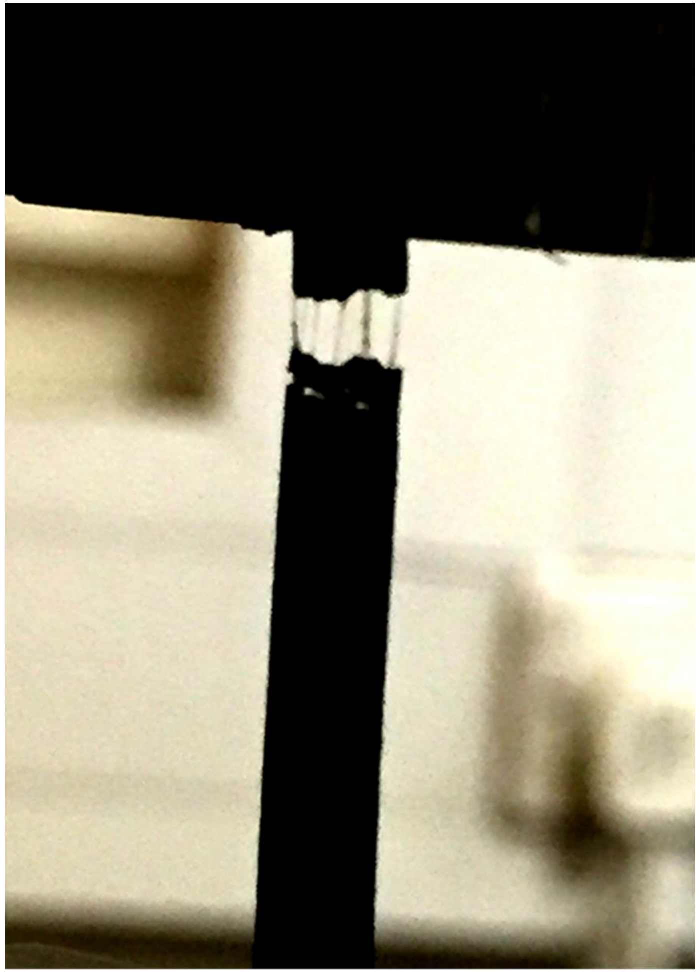
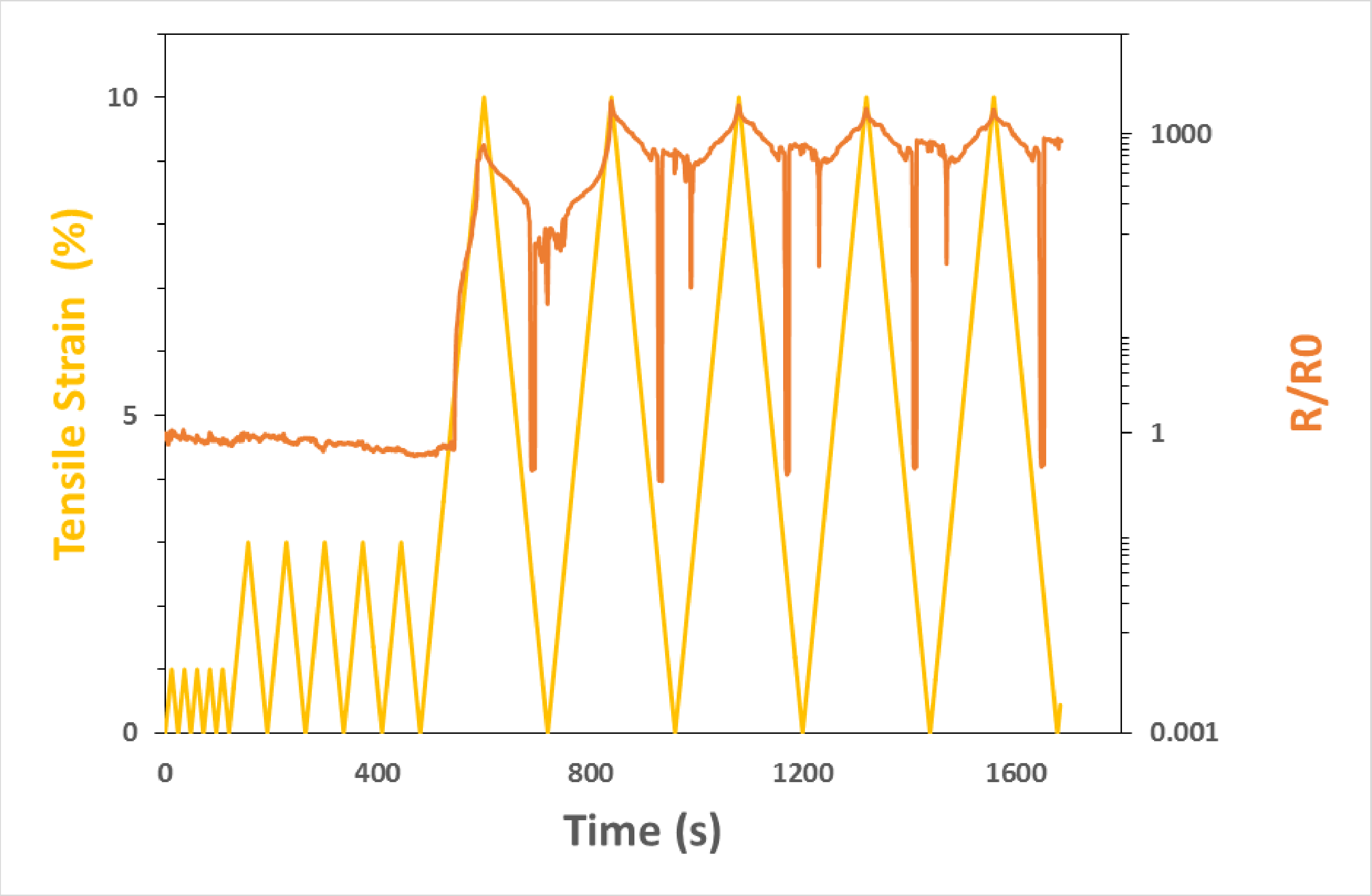
IMPROVING THE SENSITIVITY TO STRAIN

A higher strain % may also generate higher sensitivity.

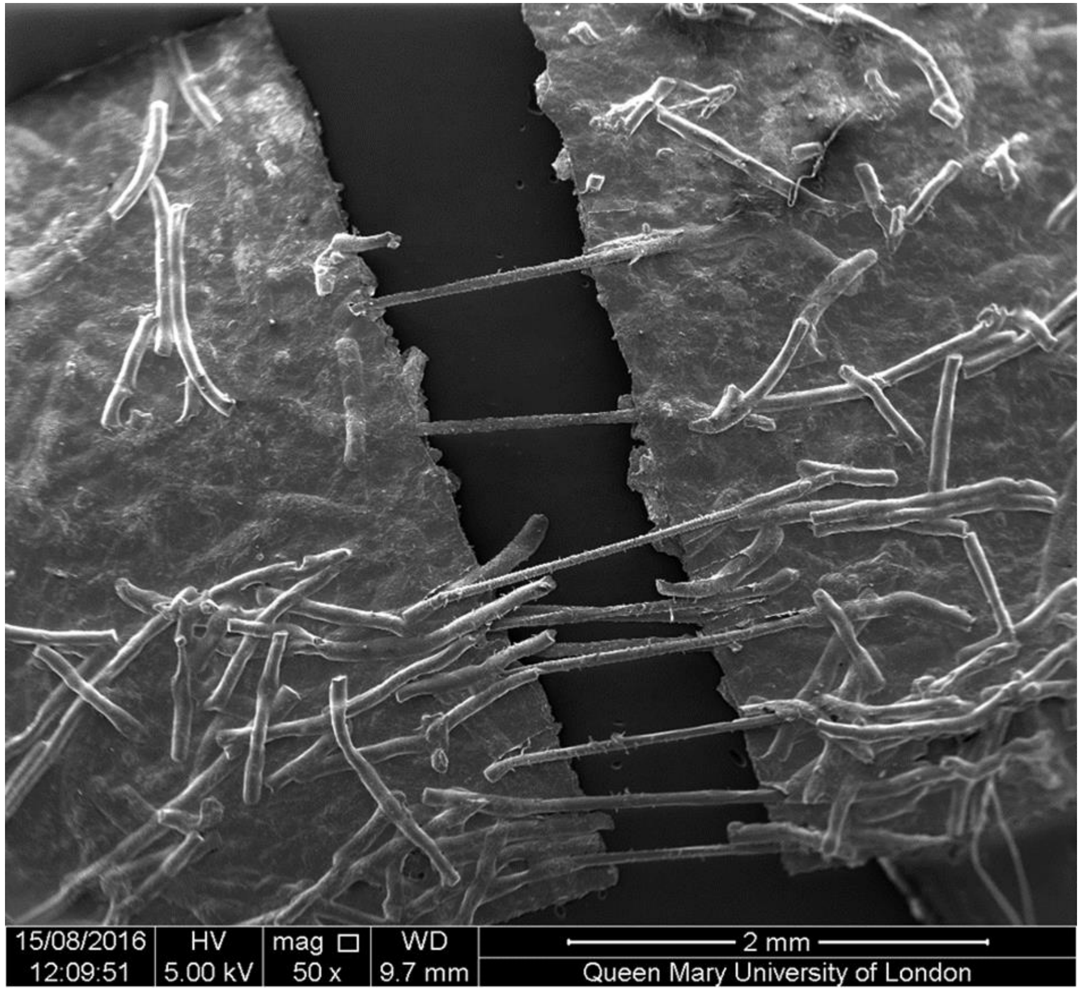


CYCLIC TEST - 50% SPANDEX AFTER CRACKING SHOWS HIGHEST SENSITIVITY

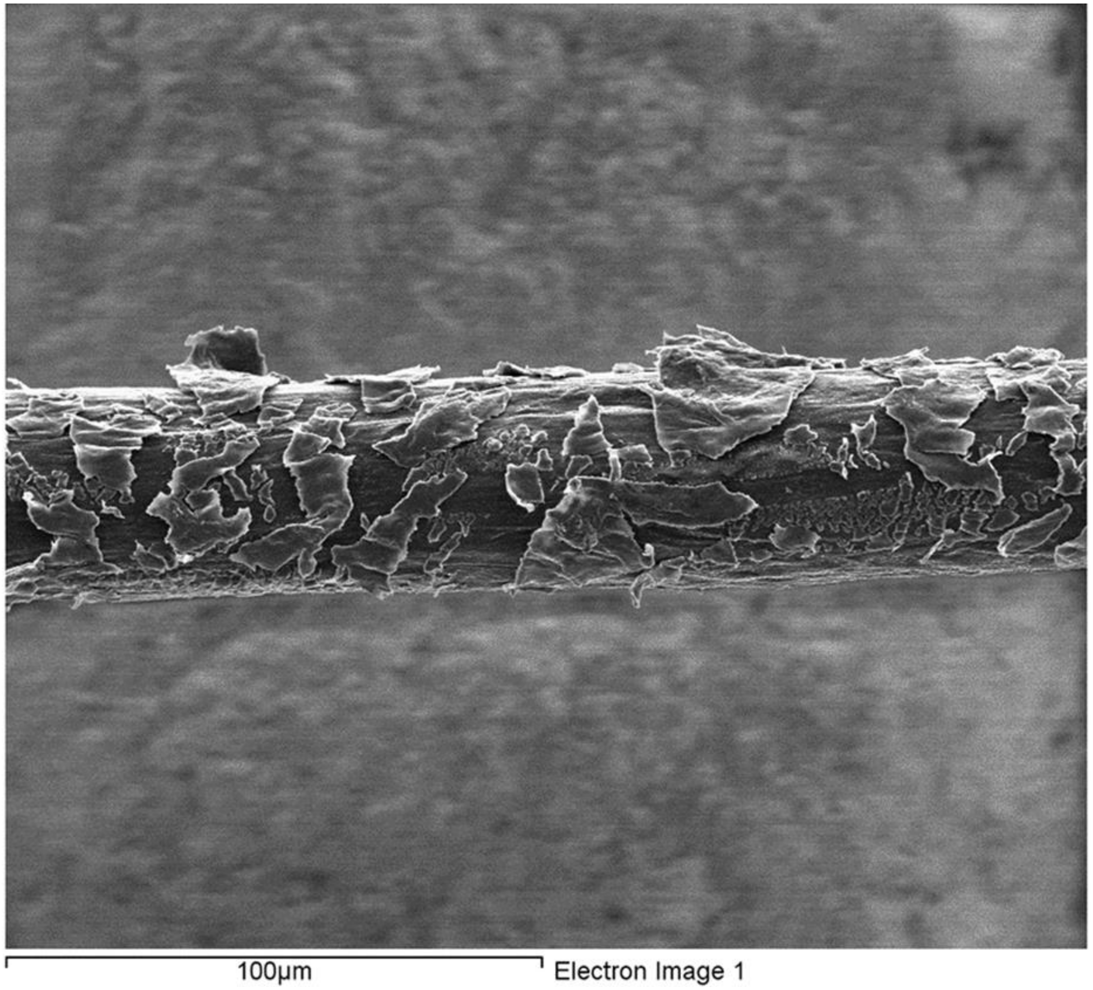




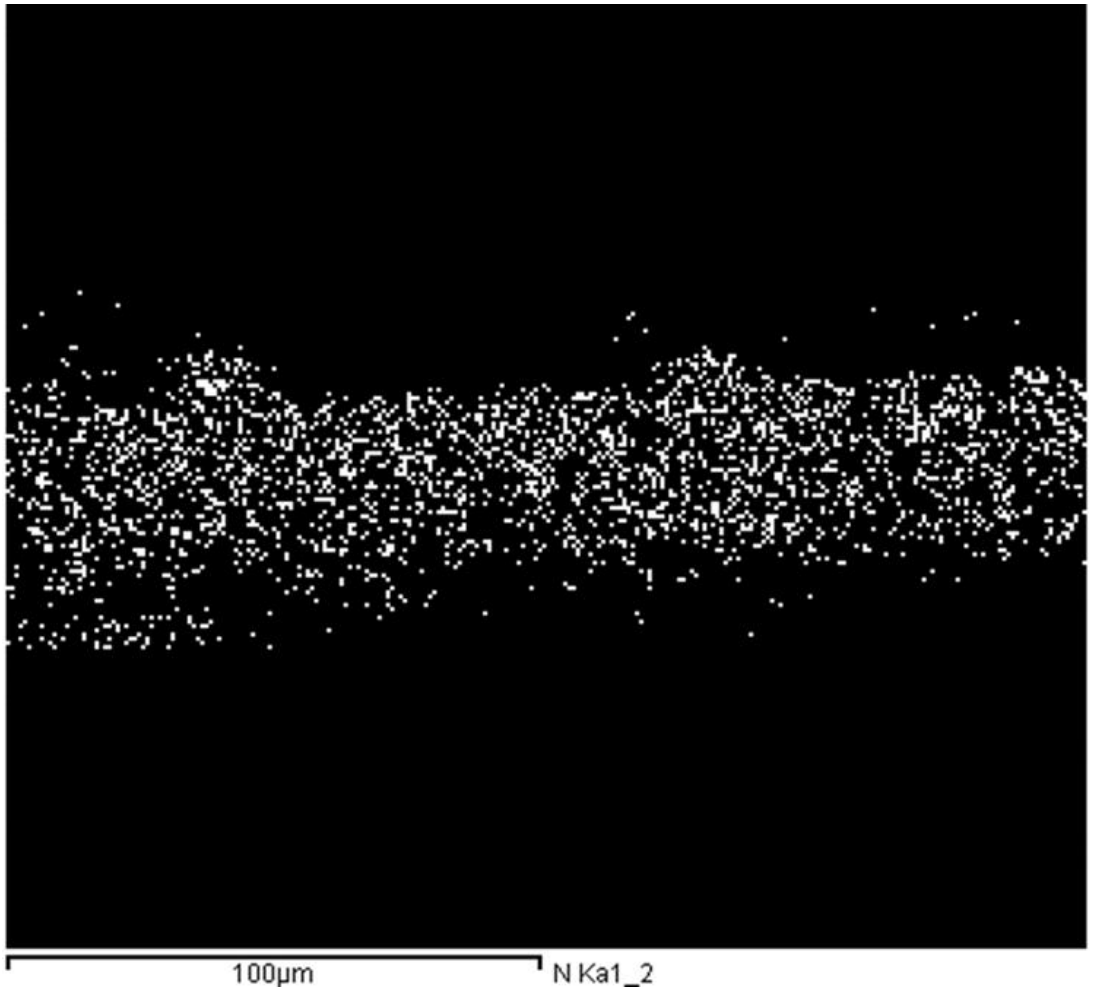
SEM of a cracked film



SEM



EDX – NITROGEN (FROM SPANDEX)



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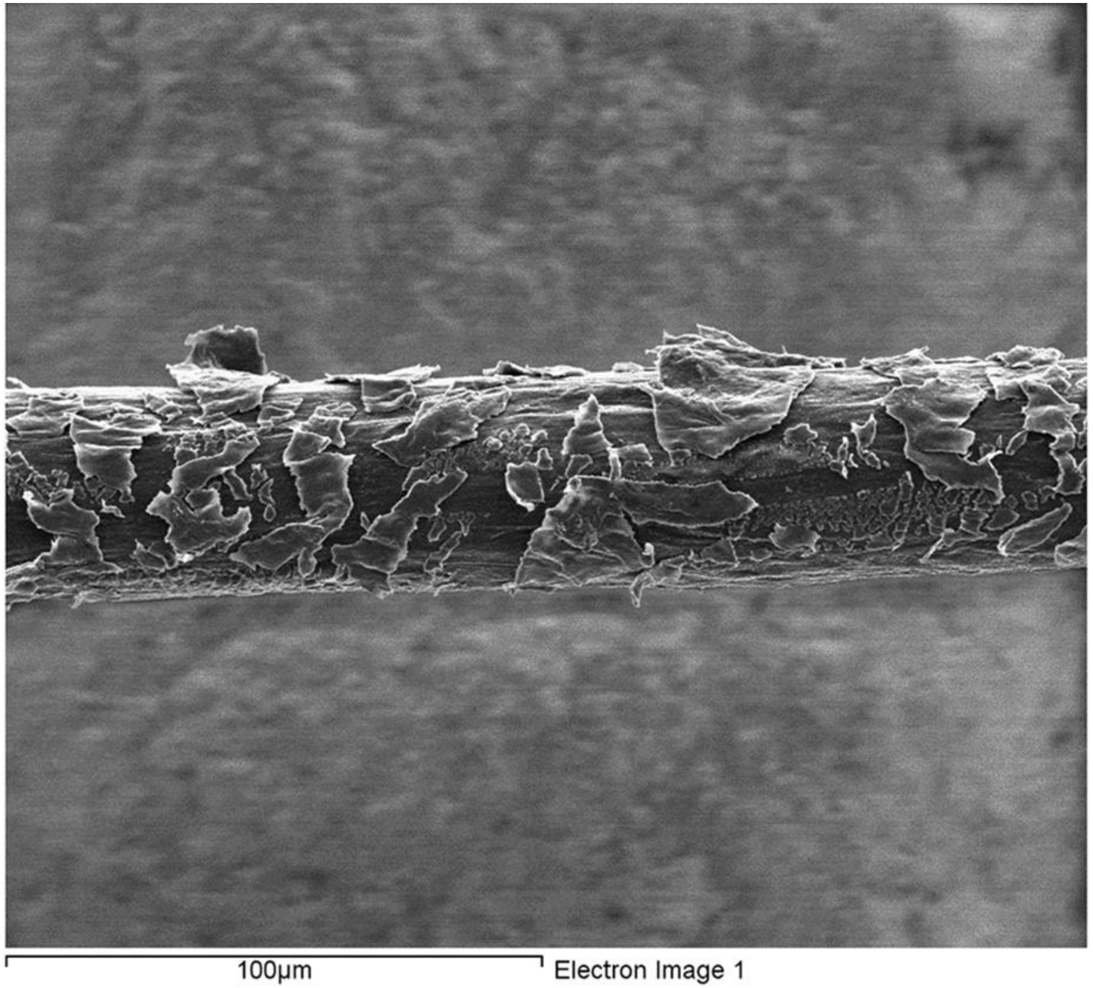
SEM



EDX – SULPHUR (FROM PEDOT:PSS)

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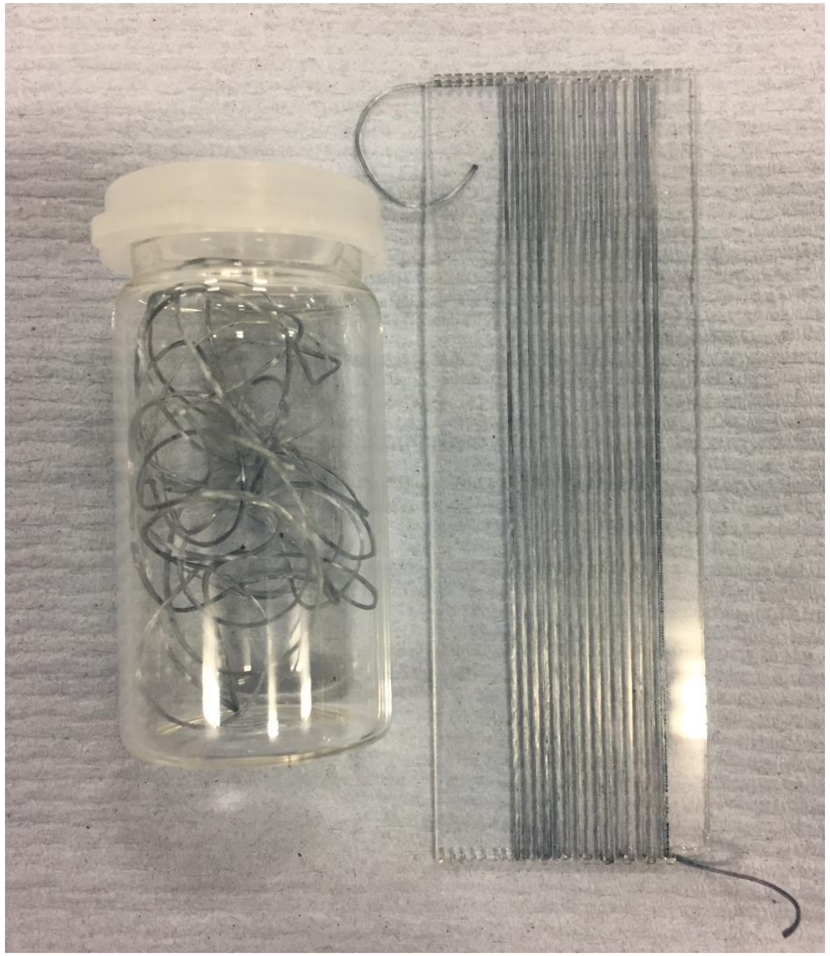
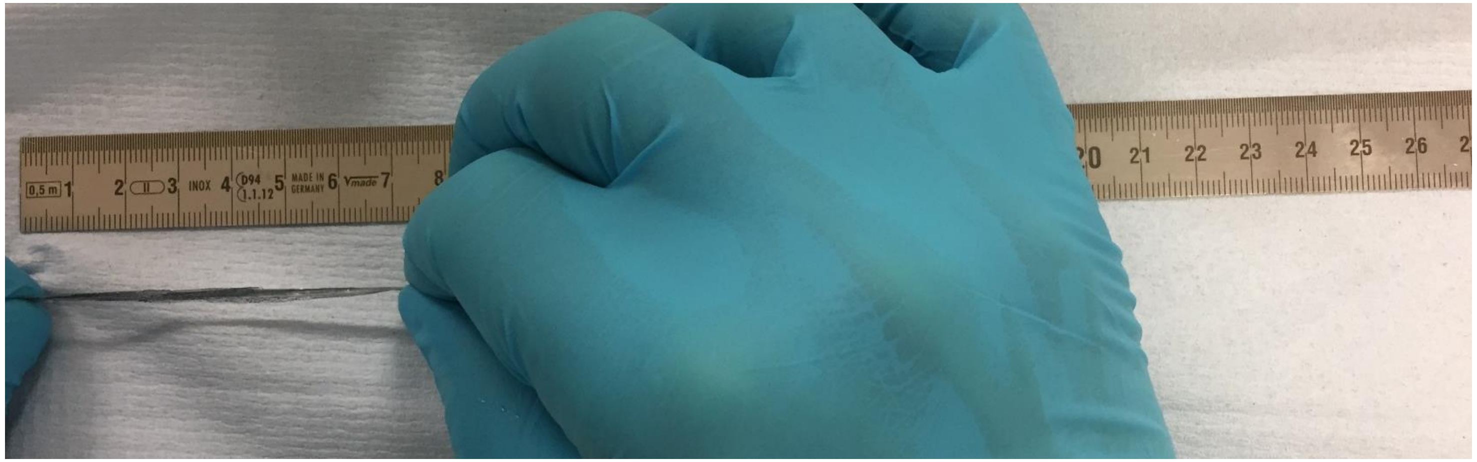
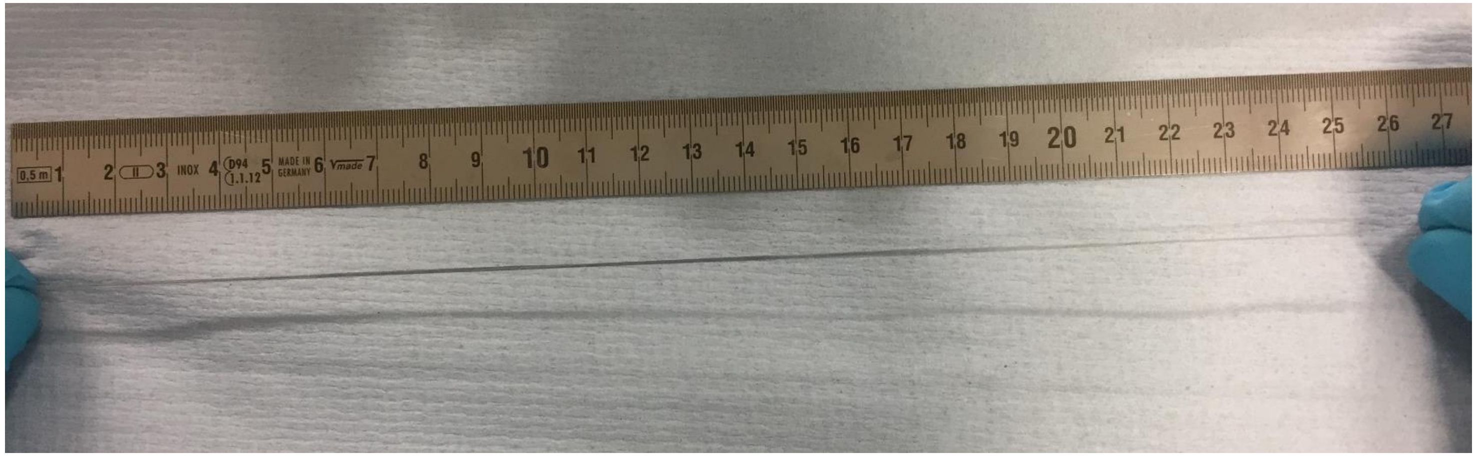
NEW DEVICE CONCEPT: SPANDEX FIBRE COATED WITH PEDOT:PSS







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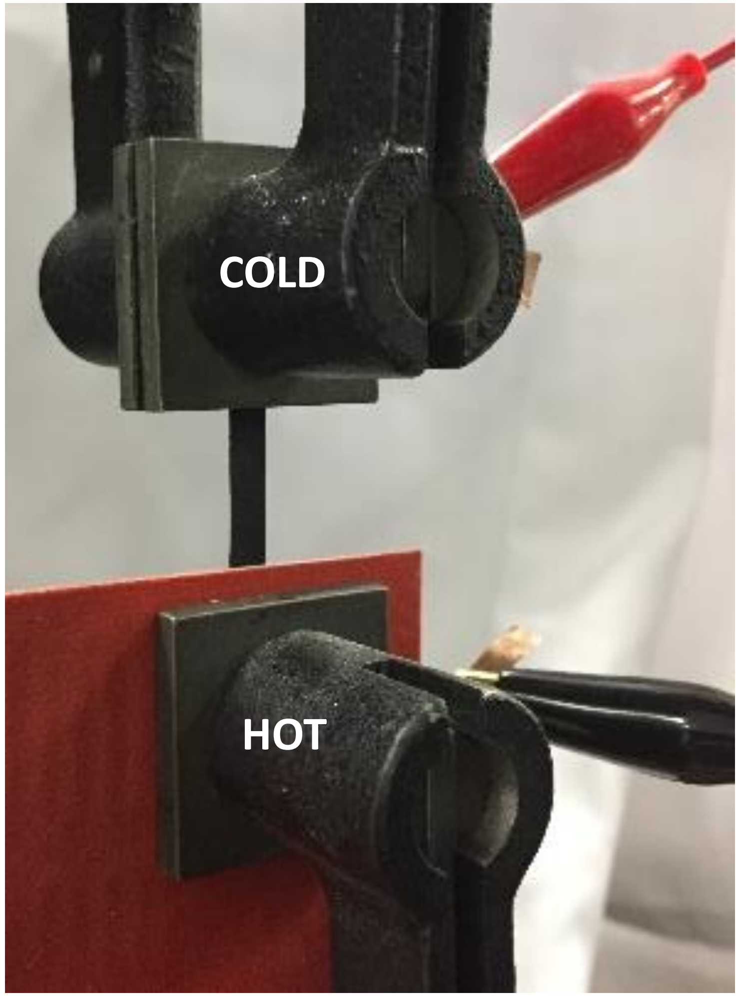
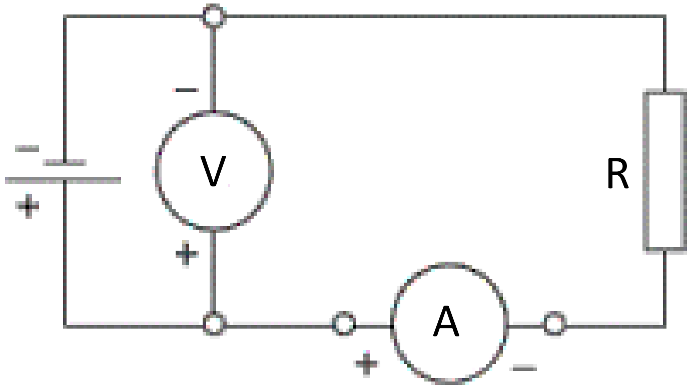
SELF-POWERED STRAIN SENSOR

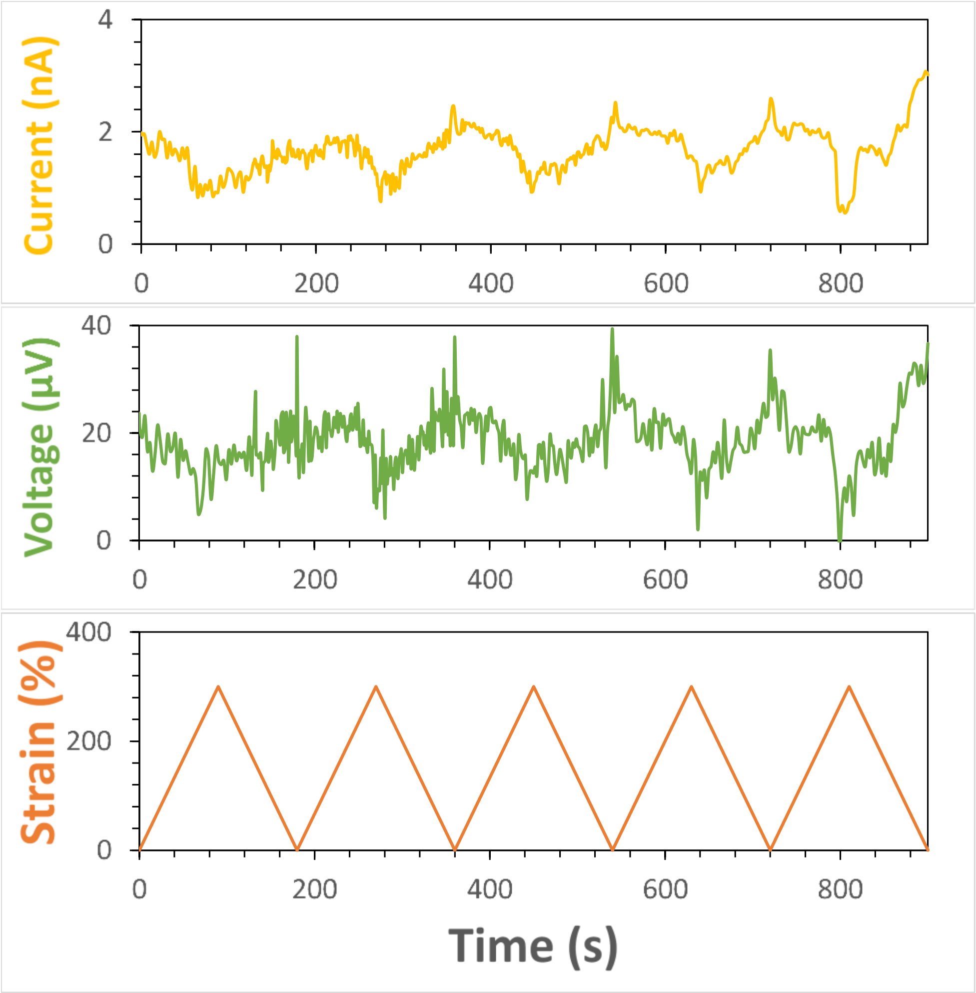
PROVE OF CONCEPT



ΔT ~ 10°C TEMPERATURE GRADIENT CREATES A VOLTAGE THAT POWERS THE DEVICE.



10 MΩ LOAD



Acknowledgments

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