FLEXIBLE E-SKIN SENSORS, ENERGY HARVESTING AND MICROFLUIDIC DEVICES

i3N|CENIMAT, Materials Science Department,
NOVA School of Science and Technology,
NOVA University of Lisbon and CEMOP/UNINOVA,
Campus de Caparica, 2829-516 Caparica, Portugal

Rui Igreja, rni@fct.unl.pt

ALLSENSORS 2022
June 26, 2022 to June 30, 2022
Porto, Portugal

Presenter Short Resume:

Researcher areas and interests:

- Impedance Spectroscopy
- Planar electrodes
- Instrumentation
- Sensors
- Biosensors
- e-skin devices
- Digital microfluidic systems

Prof. Rui Igreja
rni@fct.unl.pt
Researcher ID J-3670-2013
Scopus ID 6602536589

Participated in a total of 18 scientific research projects, national and European, 4 as local coordinator.
Professor @ DCM-FCT/UNL
Coordinator of BSc in Micro end Nanotechnology
Researcher @ CENIMAT|i3N and /CEMOP
Former sub-director of CENIMAT|i3N

NOVA SCHOOL OF SCIENCE & TECHNOLOGY DEPARTMENT OF MATERIALS SCIENCE CENIMAT CENTRO DE INVESTIGAÇÃO DE MATERIAIS i3N INSTITUTO DE NANOESTRUTURAS, NANOMODELAÇÃO E NANOFABRICAÇÃO cemop uninova

Outline

- **CENIMAT|I3N and UNINOVA-CEMOP**

- **e-skin devices**
  - Piezoresistive pressure sensors (health, robotics)
  - Piezoresistive using Temperature Shrinking Polymer Molds
  - Piezoresistive temperature/pressure sensing
  - Flexible Piezo/Tribo devices

- **Fiber based devices**
  - Energy harvesting devices
  - TFT for smart textiles

- **Digital μFluidics**

Outline

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Where are we?

FCT-NOVA campus, ~15min south Lisbon, Portugal

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CENIMAT|I3N and UNINOVA-CEMOP

CENIMAT

- Center for materials research, directly linked to the Materials Science Department @ FCT-NOVA
- Evaluated as *Excellent* by panel of international experts in Materials Science and Engineering since 1996.
- Since 2006 integrates the Associated Laboratory i3N - Institute for Nanostructures, Nanomodelling and Nanofabrication
- 3 research groups:
  - **Materials for Electronics, Optoelectronics and Nanotechnologies (MEON)**
  - Soft and biofunctional materials group (SBMG)
  - Structural Materials (SM)

Prof. Elvira Fortunato
Ex-Director of CENIMAT|i3N
Since 30th March 2022: Minister for Science, Technology and Higher Education

UNINOVA

- Private non-profit research institute acting in the fields of robotics, electronics, micro/nanoelectronics, optoelectronics, telecommunications, artificial intelligence, environment and vacuum/production technologies.

- Organized in centers of excellence (>150 scientists and technologists)
  - **Centre of Excellence in Microelectronics, Optoelectronics and Processes (CEMOP)**
  - Centre of Technology and Systems (CTS)

Prof. Rodrigo Martins
Director of UNINOVA-CEMOP

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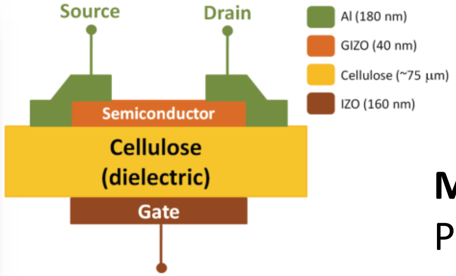
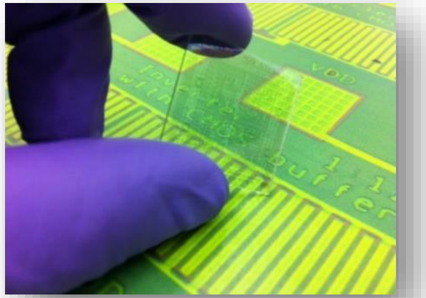
MEON-i3N|CENIMAT Research lines

Paper Electronics: Tunning paper properties towards different applications

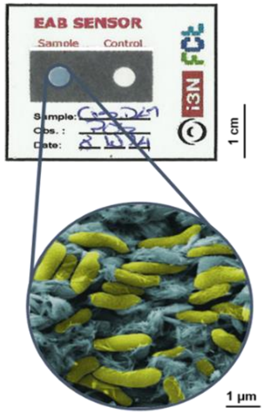


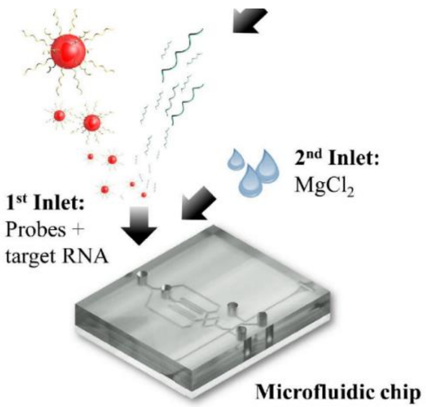
Chromogenic materials: Electrochromic displays; Thermochromic materials; pH sensors; Printed displays on paper

Micro and Nanoelectronics Processing: Physical and chemical processing, nanoscale and maskless patterning

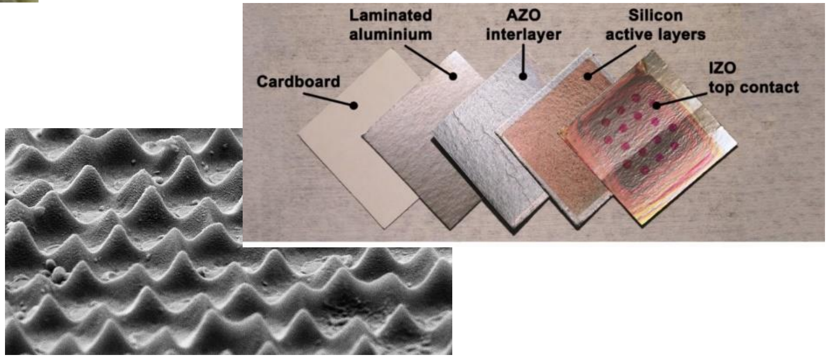


Sensors/Biosensors/Microfluidics: e-skin sensors; DNA sensors; Glucose sensors; PDMS based sensors, paper and digital Microfluidics, Electroactive bacteria detection, SERS





Energy Materials: Solar cells on paper; Thin film nanostructured silicon; Perovskites; BIPV; Thermoelectric devices; Supercapacitors; Photonics; Batteries



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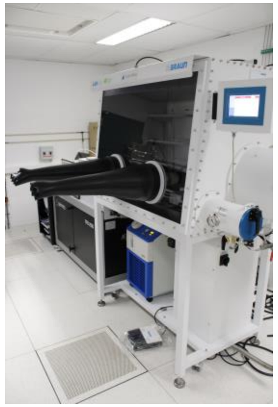
PROCESSING

Clean Room

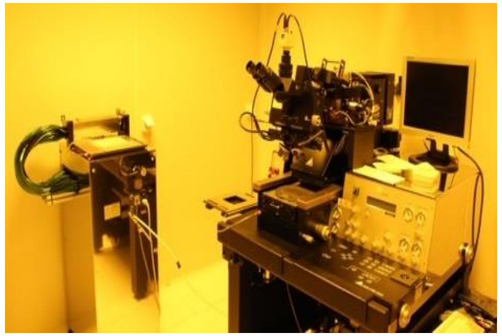


ALD

PECVD

Sputtering

Evaporator



Chemical synthesis

Microwave reactors

Spinner

High-T furnace

Further info @ https://www.cenimat.fct.unl.pt/lab-facilities

Laser Cutting and Engraving

CO_2 laser

CO_2 and fiber laser

Paper Lab

Inkjet printer

Screen printer

Flexo Printer

Wax printers

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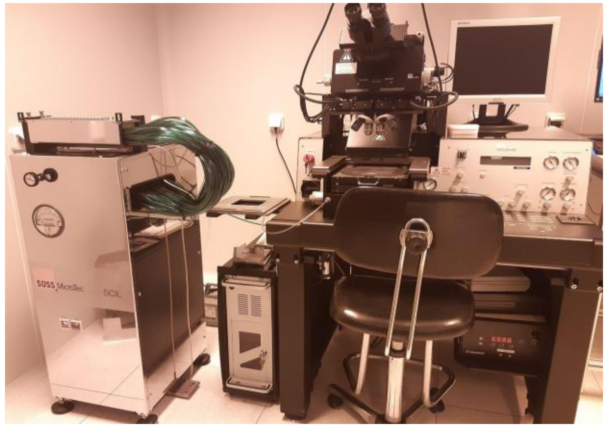
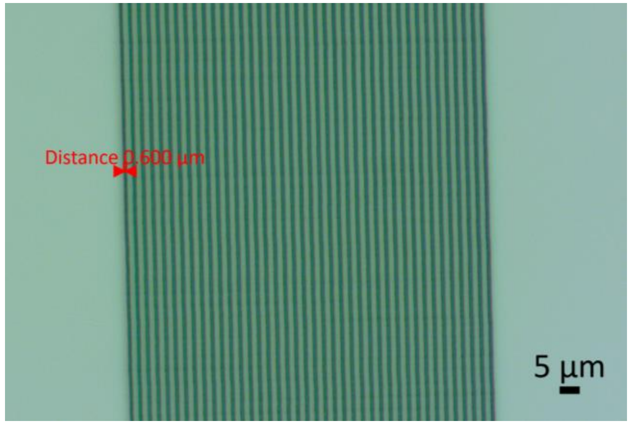
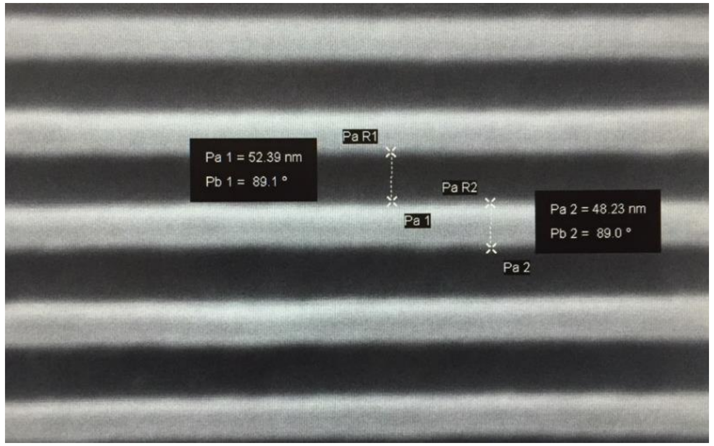
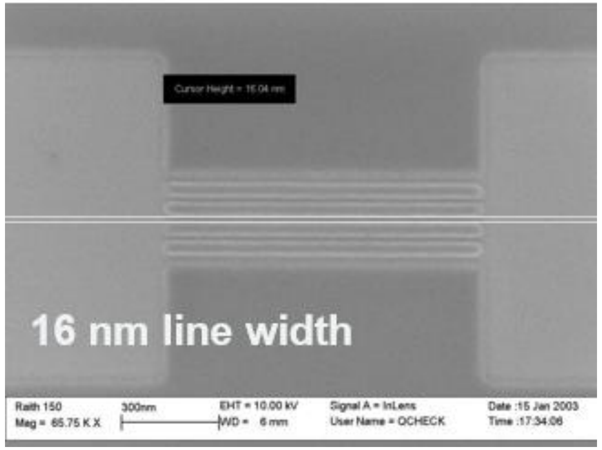
Lithographic processes for sub-micron scale devices

Linewidth	Direct laser writer (DLW)	Nanoimprint lithography (NIL)	Electron-beam lithography (EBL)
	600 nm	50 nm	10 nm









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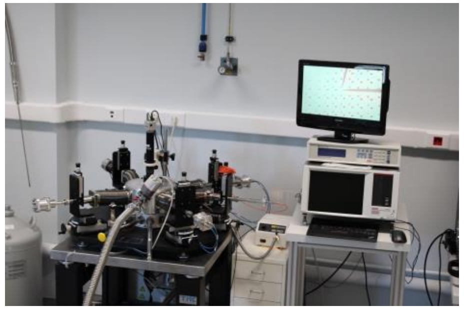
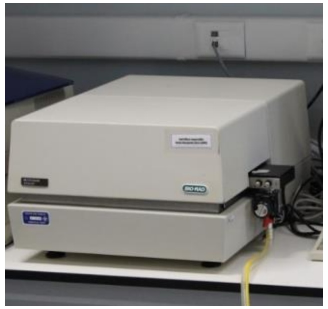
CHARACTERIZATION

Further info @ https://www.cenimat.fct.unl.pt/lab-facilities

Electrical and electrochemical


Cryogenic probe station


Hall-effect

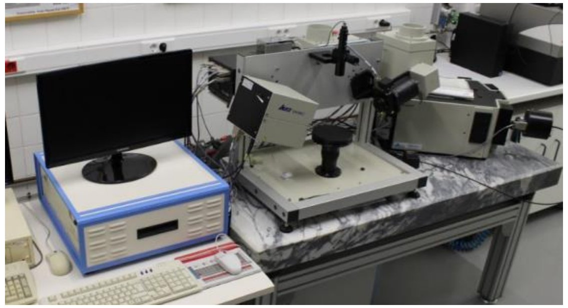

Potentiostats

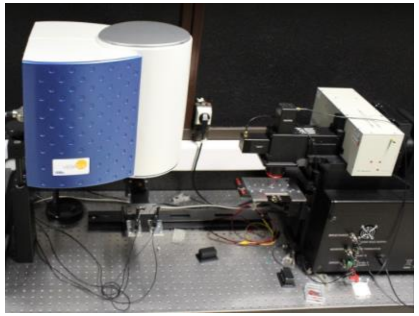

CV, IV, pulsed IV analyzers

Spectroscopy


XRD


FTIR


Spectroscopic ellipsometer


Spectral Response


Micro-Raman


XPS


UV-Vis-NIR

Microscopy

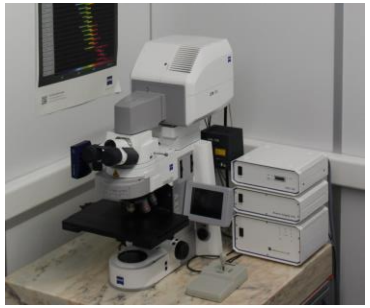

STEM (2021)


Cold-FE SEM


SEM-FIB-EBL


Tabletop SEM


AFM


Confocal

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  - TFT for smart textiles

- **Digital μFluidics**

e-skin devices

Skin: detection of pressure, touch, vibration, tickle, heat, cold, pain.

Sensors 20, 4407, (2020)

E-skin devices key features:

- self-healing
- Stretchability
- low thickness and conformability
- Flexibility
- self-powered
- biodegradability and recyclability
- biocompatibility

e-skin devices

Sensors 20, 4407, (2020)

E-skin devices applications:

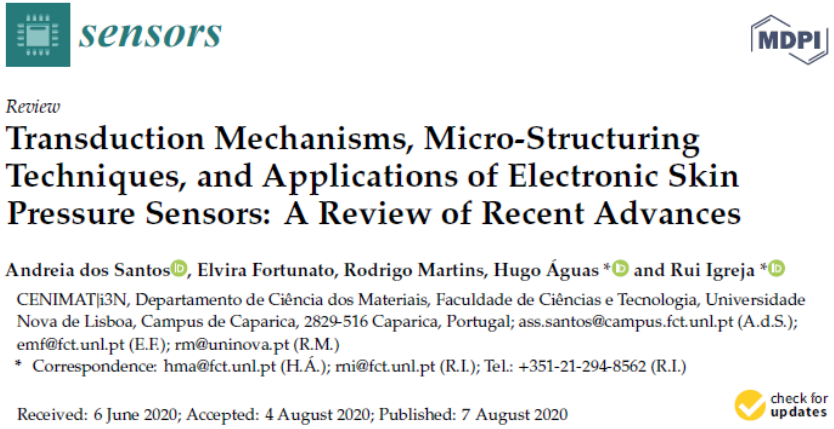
- health monitoring
- functional prosthesis
- robotics
- Human-machine interfaces
- Power harvesting

e-skin devices

Sensors 20, 4407, (2020)

E-skin devices transducer mechanisms:

- Capacitance
  - ✓ Simple design and analysis;
  - ✗ Limited miniaturization; Prone to hysteresis and high response times; More complex readout electronic.
- Piezoelectricity
  - ✓ Self-powered; Fast response time; High sensitivity
  - ✗ Unable to detect static pressure; Prone to noise from vibrations or high frequency stimuli; Drift in sensor's response over time; Temperature interference.
- Piezoresistivity
  - ✓ Simple structure; Simple readout mechanism
  - ✗ Power supply required; Requires micro-structuration for performance improvement;
- Triboelectricity
  - ✓ Simple design and analysis;
  - ✗ Unable to detect static pressure; Output affected by frequency of stimulus.


sensors MDPI

Review

Transduction Mechanisms, Micro-Structuring Techniques, and Applications of Electronic Skin Pressure Sensors: A Review of Recent Advances

Andreia dos Santos, Elvira Fortunato, Rodrigo Martins, Hugo Águas * and Rui Igreja *

CENIMAT|i3N, Departamento de Ciência dos Materiais, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal; ass.santos@campus.fct.unl.pt (A.d.S.); emf@fct.unl.pt (E.F.); rm@uninova.pt (R.M.)
* Correspondence: hma@fct.unl.pt (H.Á.); rni@fct.unl.pt (R.I.); Tel.: +351-21-294-8562 (R.I.)

Received: 6 June 2020; Accepted: 4 August 2020; Published: 7 August 2020

check for updates

e-skin devices: main goals @ cenimat

- **Develop of multifunctional e-skin sensors**
  - Pressure Sensing
  - Temperature Sensing
  - Energy Harvesting (self-power)

- **Implementation of a Novel Micro-structuring Strategy for Pressure Sensors**
  - Low cost and high tailoring
  - Study of several parameters that affect the micro-structuring outcome

- **Proof-of-concept – Tuning the E-skin Sensors for Different Applications**
  - pressure wave detection at the wrist
  - General health monitoring
  - Functional prosthesis and robotics

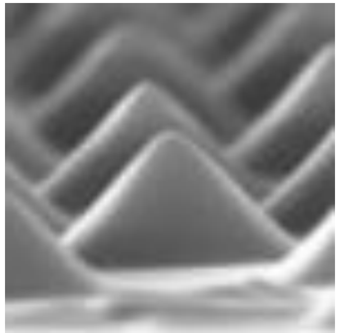
- **Development Multifunctional Sensors**
  - Temperature and Pressure out of the same functional material/device

- **Development of Energy Harvesters**
  - Novel micro-structured composites

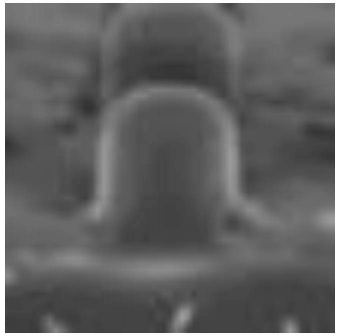
Piezoresistive e-skin pressure sensors

Photolitography

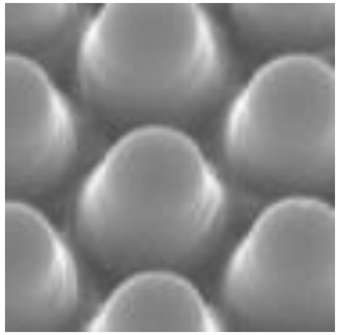
Pyramides



Pillars



Domes

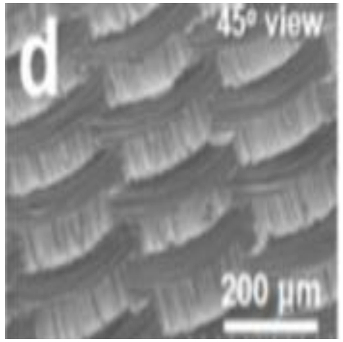


Fibres

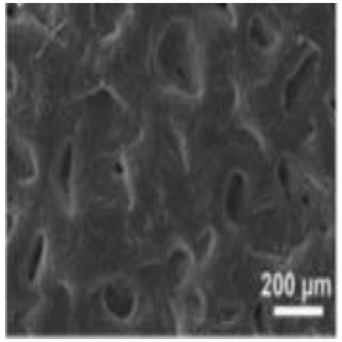
J. Park; et al. BioNanoScience 2014, 4
C. Pang; et al. Nature Materials 2012, 11
J. Park; et al. ACS Nano 2014, 8, 5

Natural molds

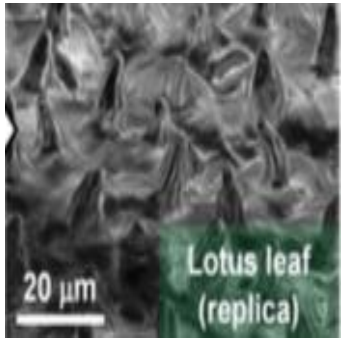
Sylk



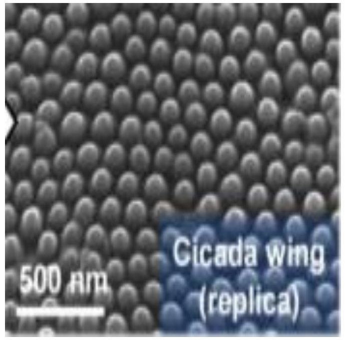
Sandpaper



Leafs

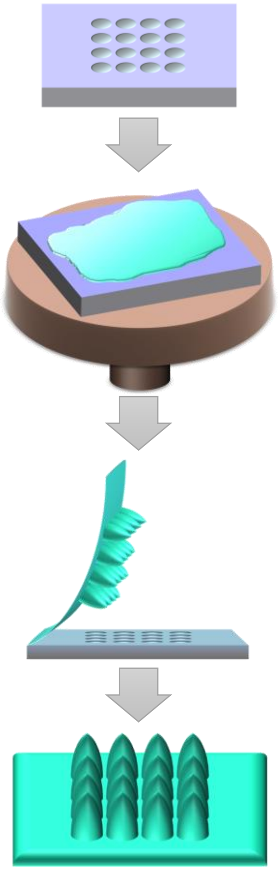


Insect wings



X. Wang; et al. Adv. Mater. 2014, 26, 1336
Q.-J. Sun et al. ACS Appl. Mater 2018, 10, 4086
M.-L. Seol; et al. Small 2014, 10, 3887
M.-L. Seol; et al. Small 2014, 10, 3887

Our work (laser engraved molds)

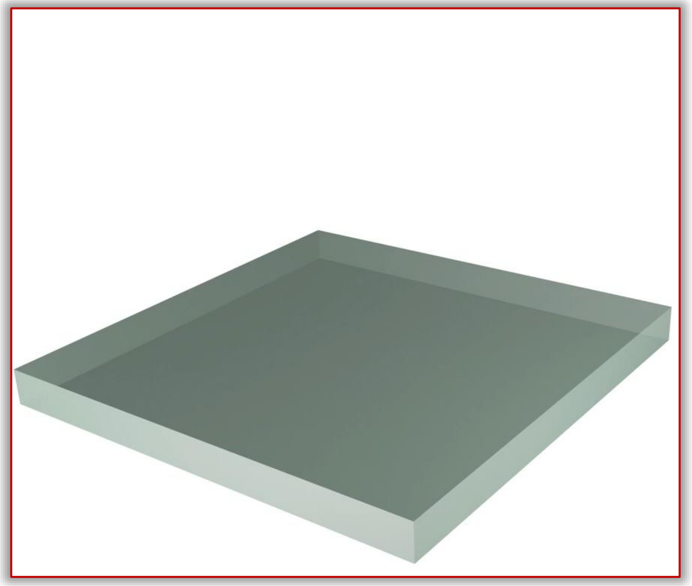


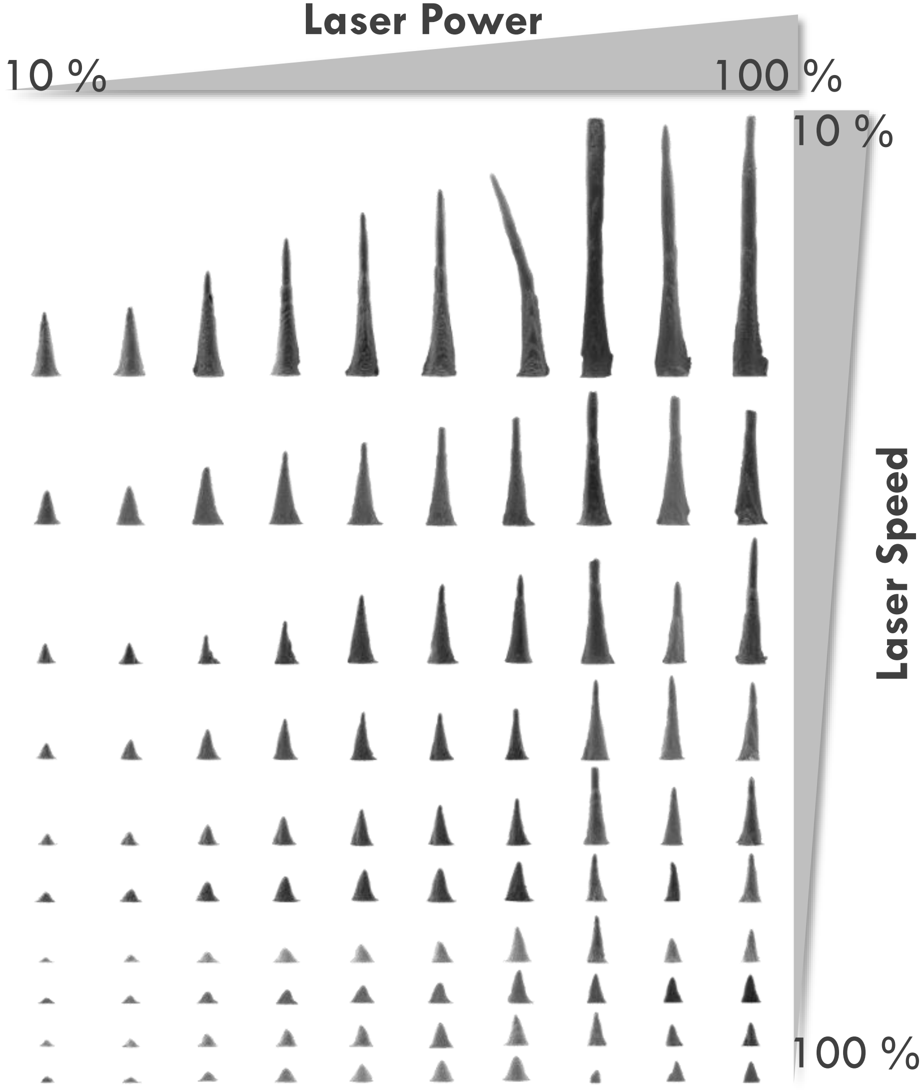
Acrylic
h-PDMS
Shrinking polymer

Adv. Electron. Mater. 4 (9), 1870041, (2018)

Piezoresistive e-skin pressure sensors

CO_2 Laser engraving technique





Parameters that impact the micro-structuring:

- Shape, size, spacing, and line thickness of figures being engraved
- Material (substrate) being engraved
- Distance between laser beam and substrate
- Laser power
- Laser speed
- Laser mode (vectorial/rast)

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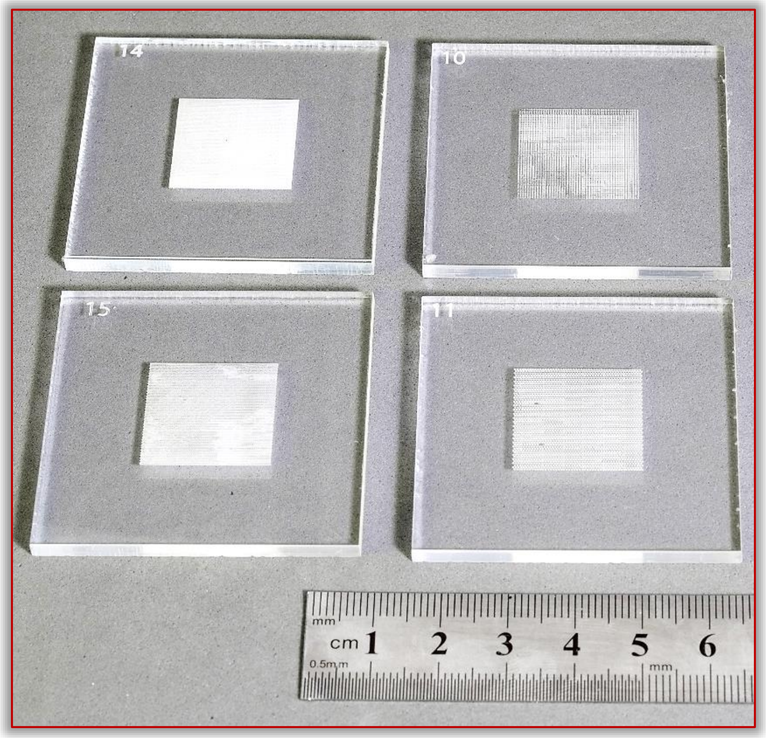
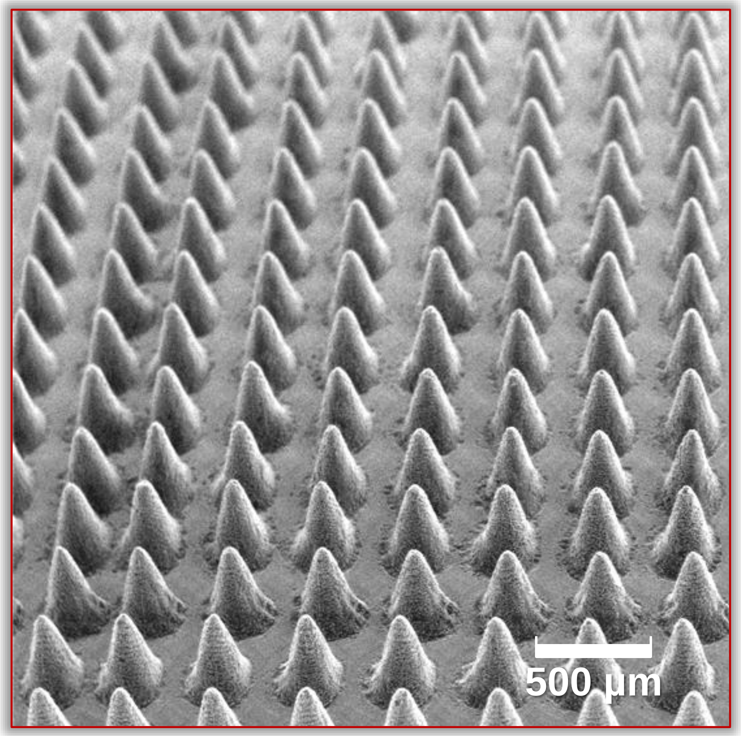
Piezoresistive e-skin pressure sensors

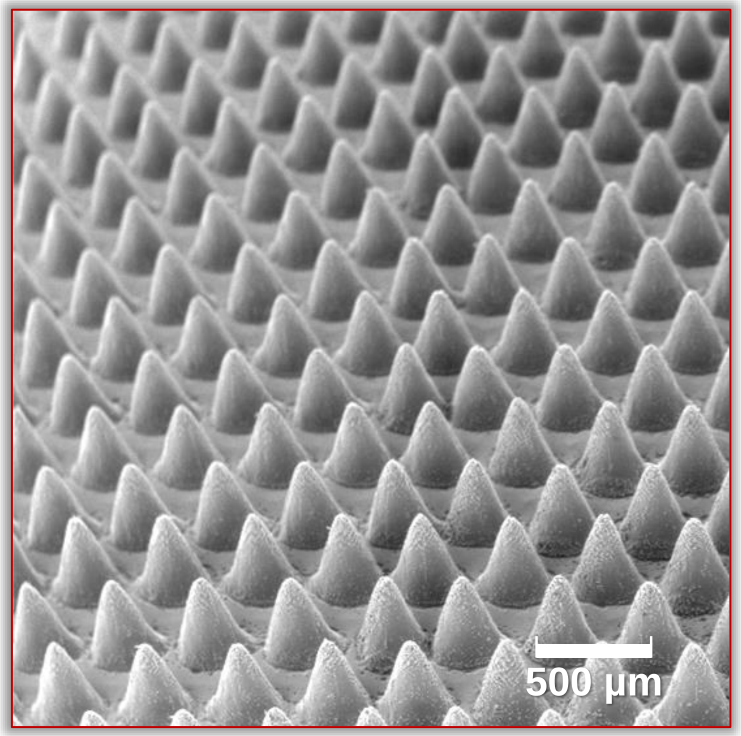
Acrylic Molds



PDMS Membrane (aligned pyramids)

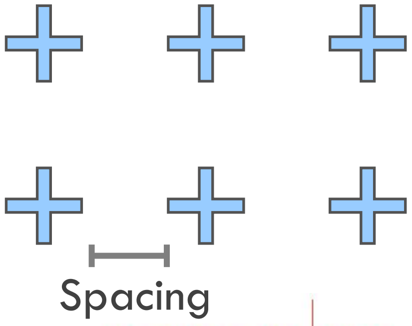


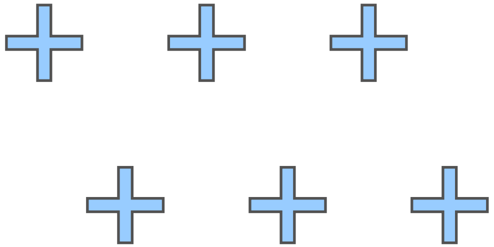
PDMS Membrane (misaligned pyramids)



Engraved Patterns:

Spacing = 150 µm to 300 µm





Adv. Electron. Mater. 4 (9), 1870041, (2018)

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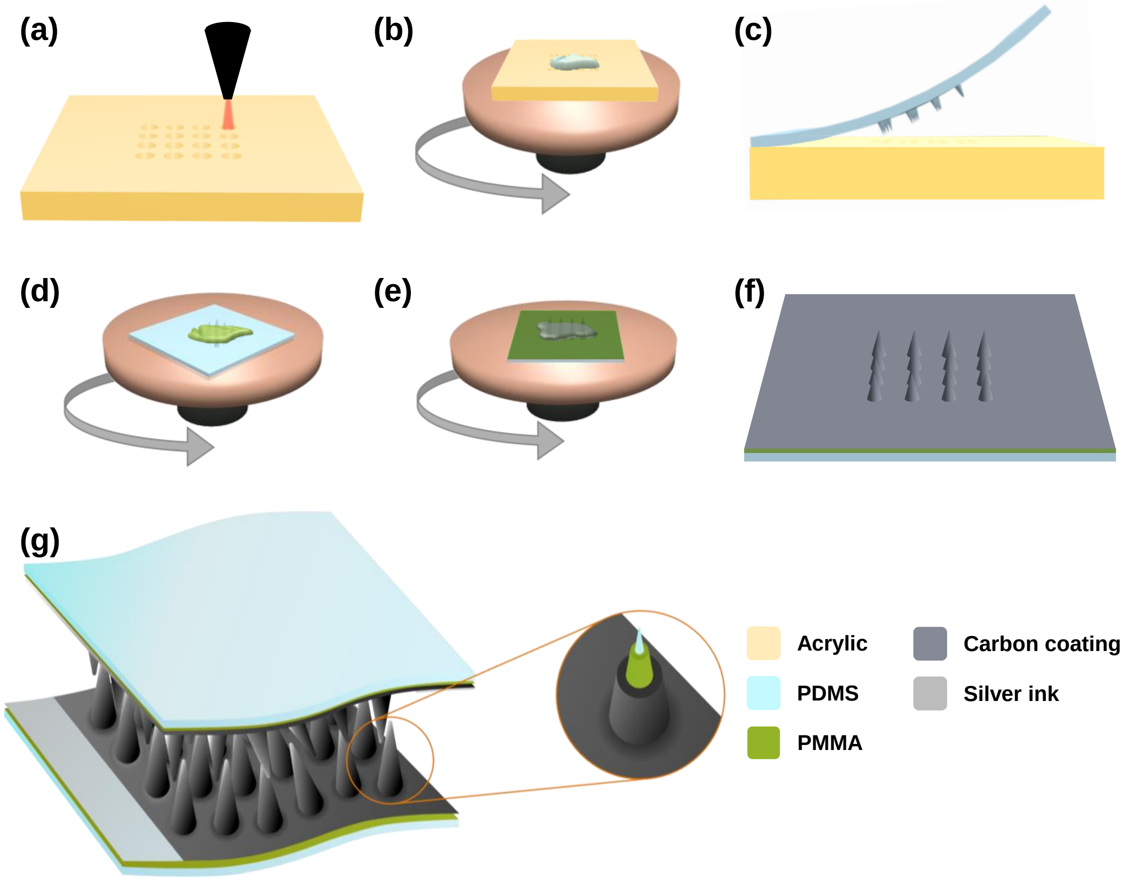
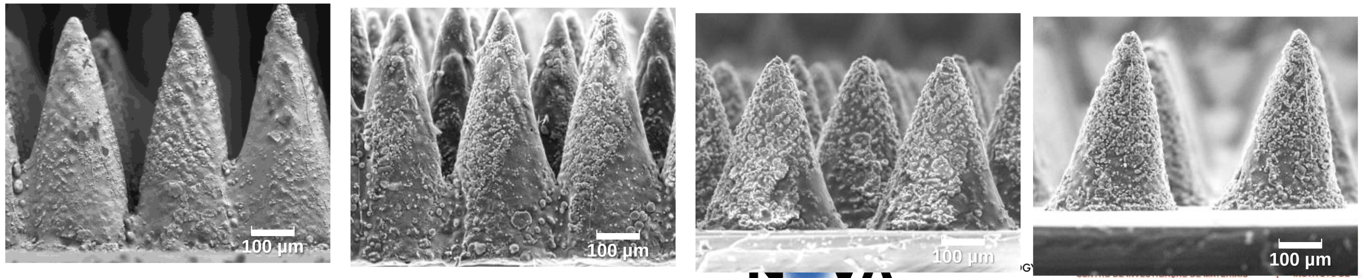
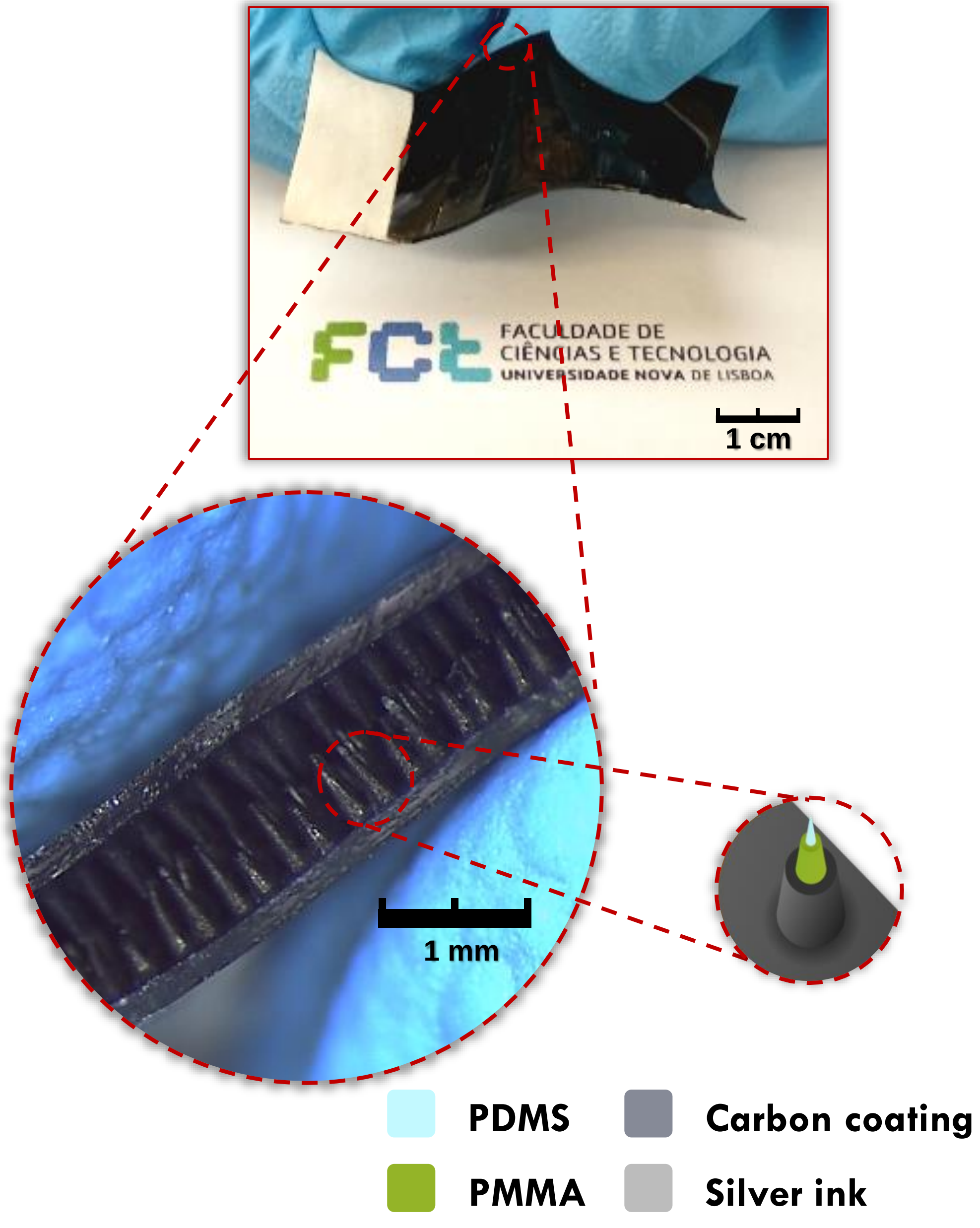
Piezoresistive e-skin pressure sensors

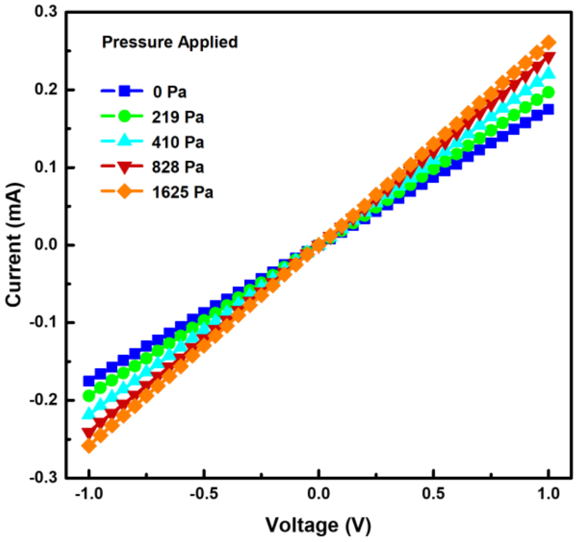


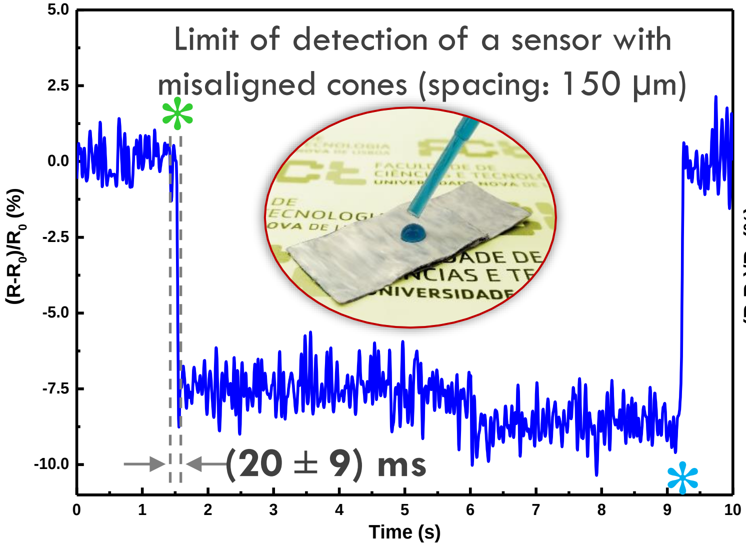




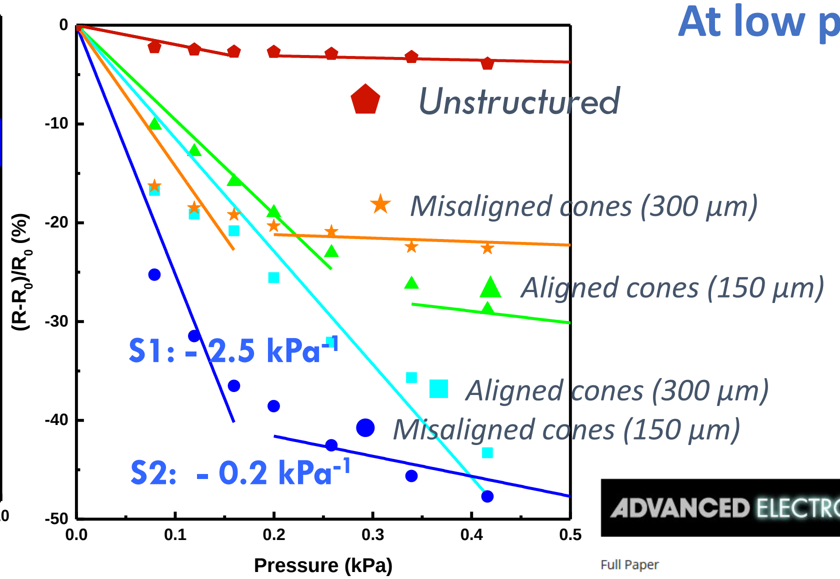
Adv. Electron. Mater. 4 (9), 1870041, (2018)

Piezoresistive e-skin pressure sensors





Sensitivity



Very High Sensitivity
At low pressure regime

ADVANCED ELECTRONIC MATERIALS

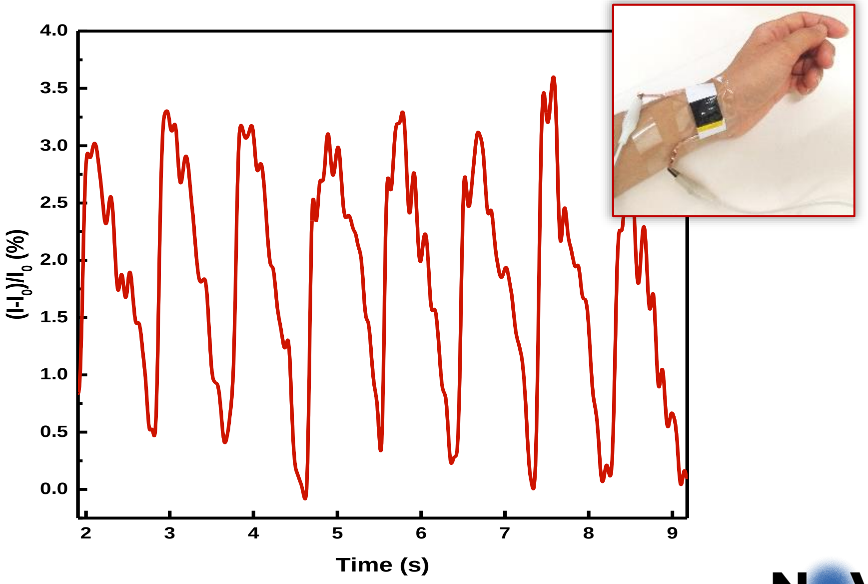
Full Paper

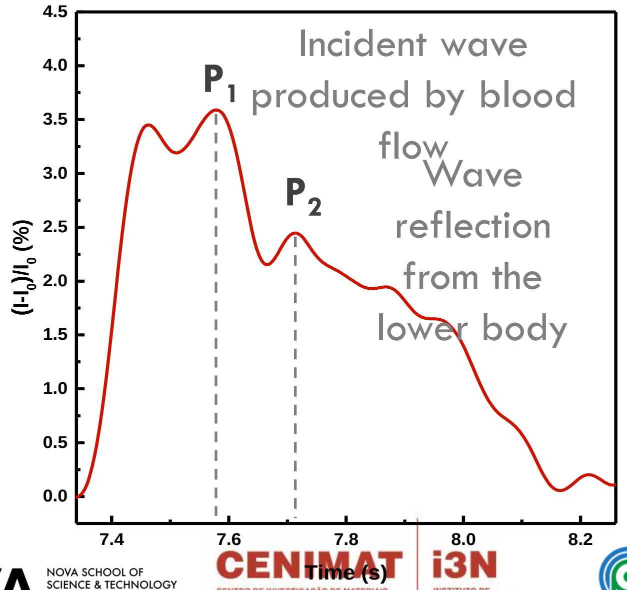
Piezoresistive E-Skin Sensors Produced with Laser Engraved Molds

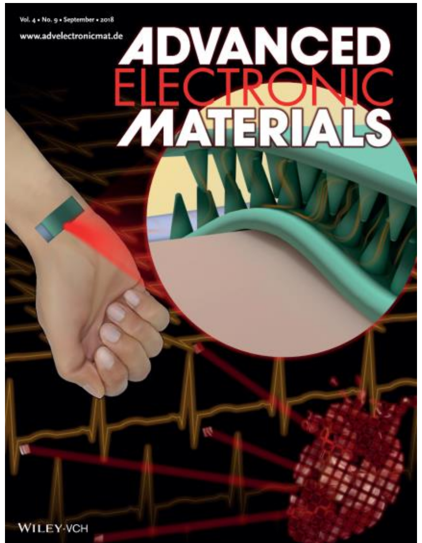
Andreia dos Santos, Nuno Pinela, Pedro Alves, Rodrigo Santos, Elvira Fortunato, Rodrigo Martins, Hugo Águas, Rui Igreja

First published: 12 June 2018 | https://doi.org/10.1002/aelm.201800182

Blood wave pressure on wrist







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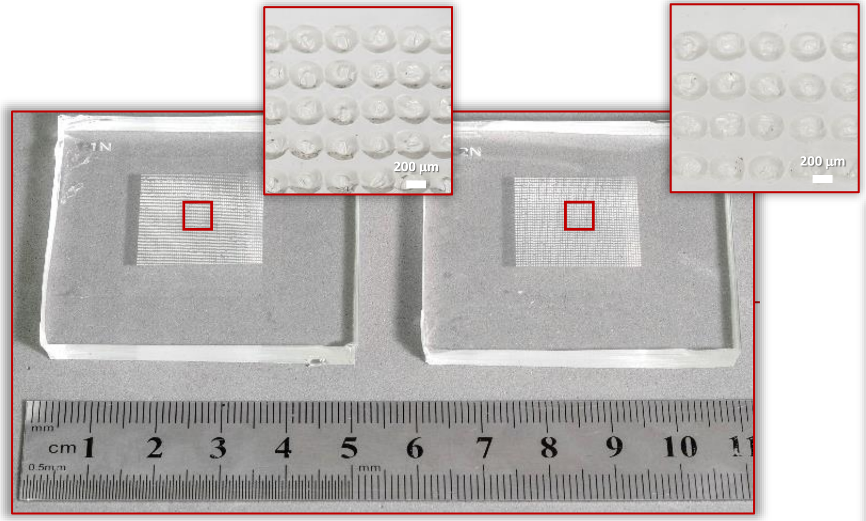
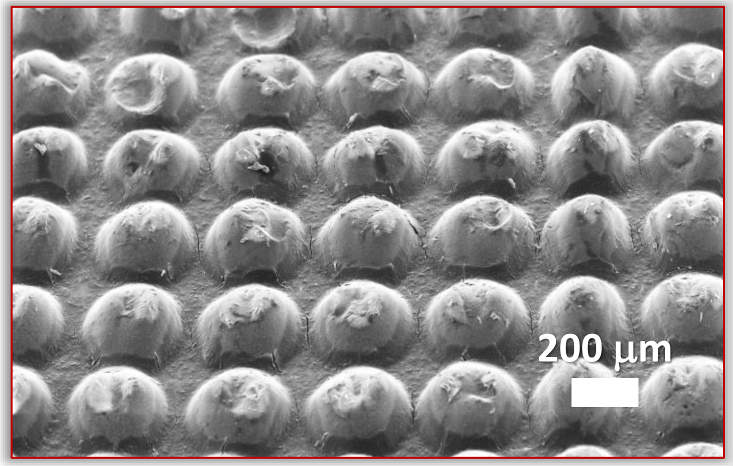
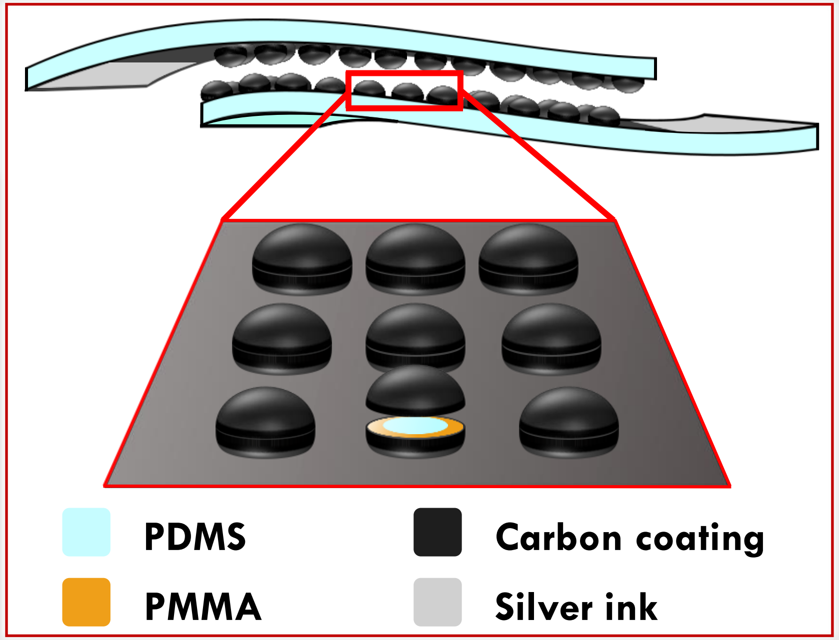
Piezoresistive e-skin pressure sensors

hard-PDMS Molds

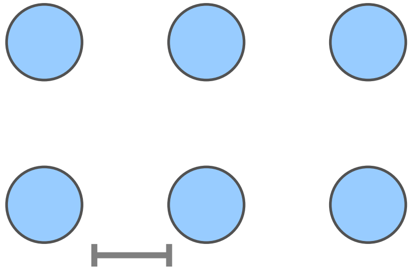






Engraved Patterns:

Spacing = 150 µm to 200 µm



- To produce an e-skin to target robotics/functional prosthesis applications
- Constant sensitivity between < 10 kPa and 100 kPa
- Semi-spheres are less compressible: can withstand higher pressures before saturating

Sensors 19 899, (2019)

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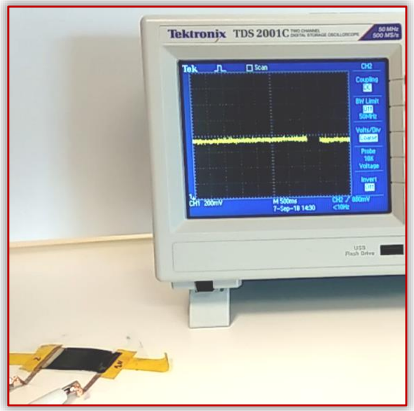
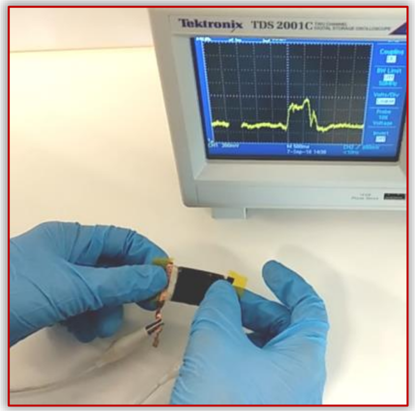
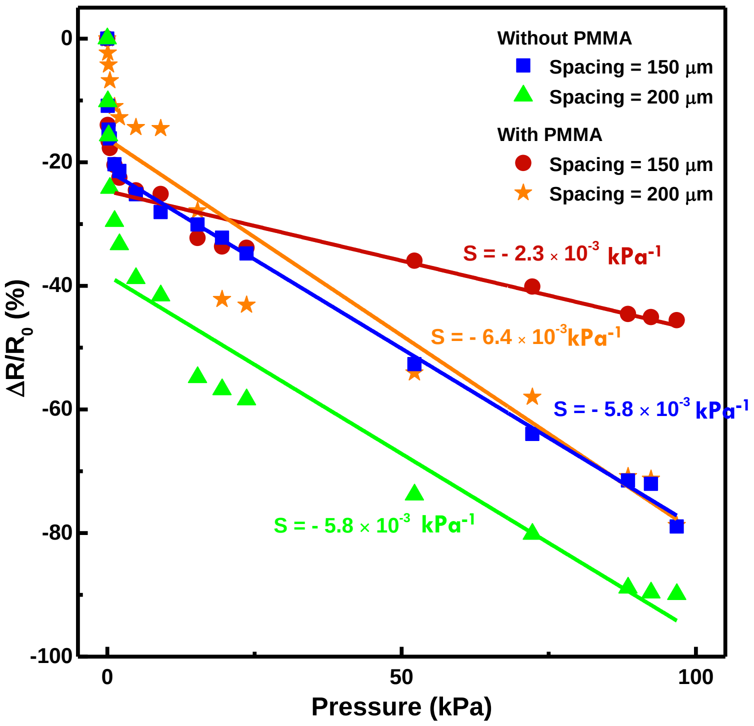
Piezoresistive e-skin pressure sensors





Sensors 19 899, (2019)

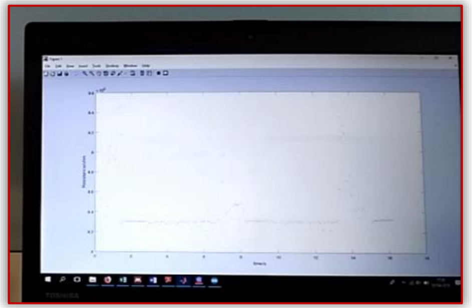
Sensitivity

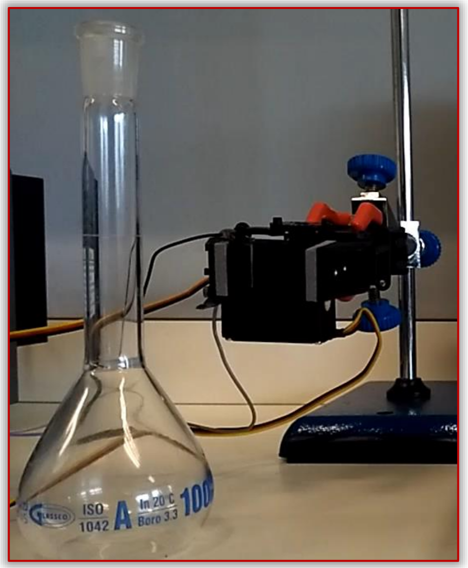


Constant sensitivity: 1.2 kPa to 100 kPa

S = -6.4x10^{-3} kPa^{-1}

Pressure detection for robtics and prosthesis





Stable performance over 27 500th

Proceedings 2018, 2(13), 1039; https://doi.org/10.3390/proceedings2131039 Open Access Proceedings

E-Skin Pressure Sensors Made by Laser Engraved PDMS Molds†

Andreia dos Santos, Nuno Pinela, Pedro Alves, Rodrigo Santos, Elvira Fortunato, Rodrigo Martins, Hugo Águas and Rui Igreja *

CENIMAT|i3N, Departamento de Ciência dos Materiais, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal

† Presented at the Eurosensors 2018 Conference, Graz, Austria, 9–12 September 2018.

* Author to whom correspondence should be addressed.

Published: 12 November 2018

(This article belongs to the Proceedings of Eurosensors 2018)

Sensors 2019, 19(4), 899; doi: 10.3390/s19040899 Open Access

Article

E-Skin Bimodal Sensors for Robotics and Prosthesis Using PDMS Molds Engraved by Laser †

Andreia dos Santos, Nuno Pinela, Pedro Alves, Rodrigo Santos, Ricardo Farinha, Elvira Fortunato, Rodrigo Martins, Hugo Águas and Rui Igreja *

CENIMAT|i3N, Departamento de Ciência dos Materiais, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal

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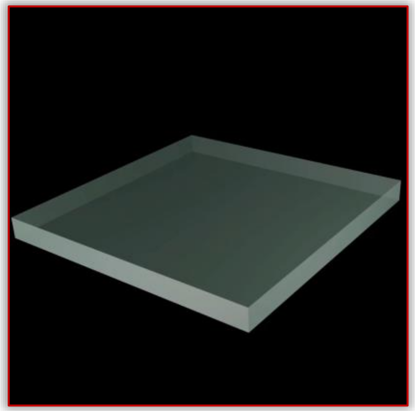
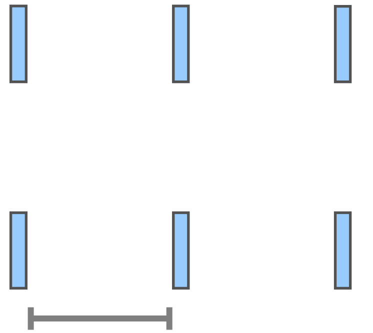
Piezoresistive e-skin pressure sensors

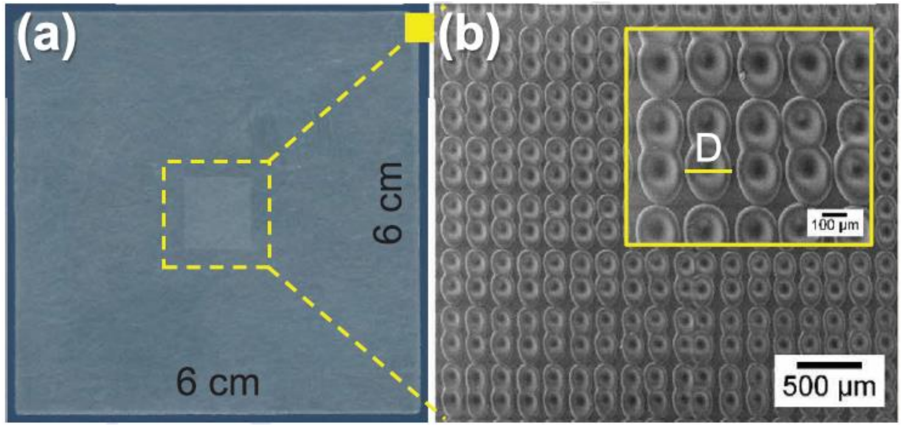
Goals: Thinner and high conformable sensor layers; high microstructure features resolution; high sensitivity al low-pressure regimes and fast recovery times.



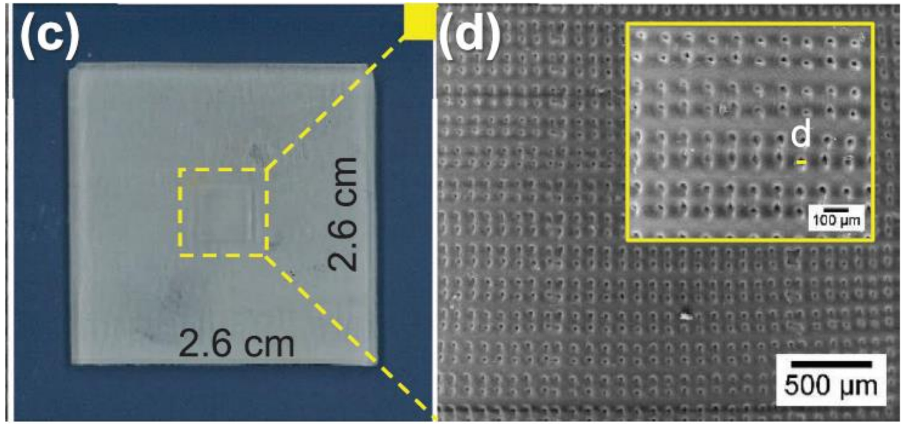
ENGRAVED PATTERN:



Before Shrinking



After Shrinking

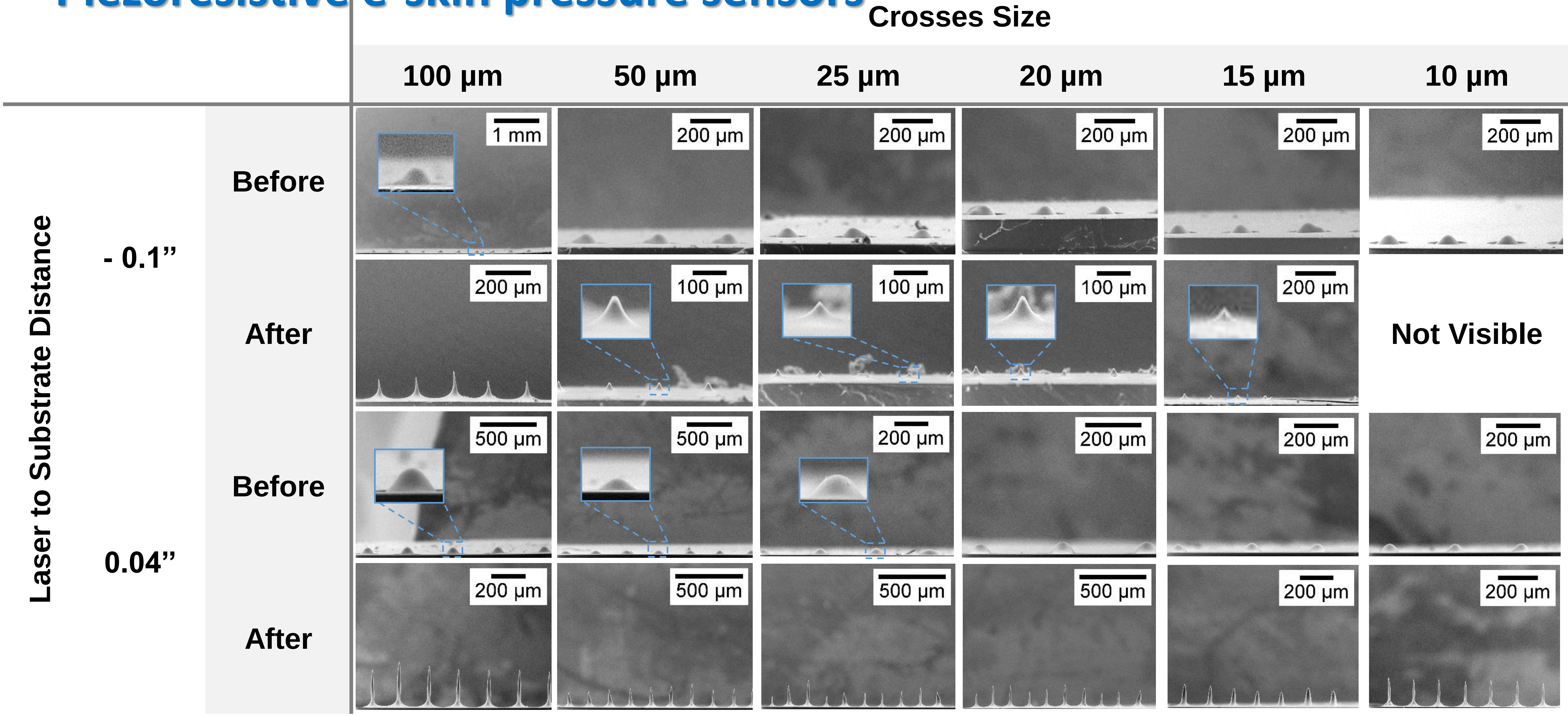


- **Shrinking polymer films (SPF)**
- **Ag NWs as conductive layer**

- It shrinks with temperature (160 °C)
- If shrunken after engraving, the cavities get smaller: possibility to achieve smaller structures
- Shrunken SPF can withstand temperature during Ag NWs spray coating

Adv. Mater. Interfaces 8 (21), 2100877, (2021)

Piezoresistive e-skin pressure sensors



Adv. Mater. Interfaces 8 (21), 2100877, (2021)

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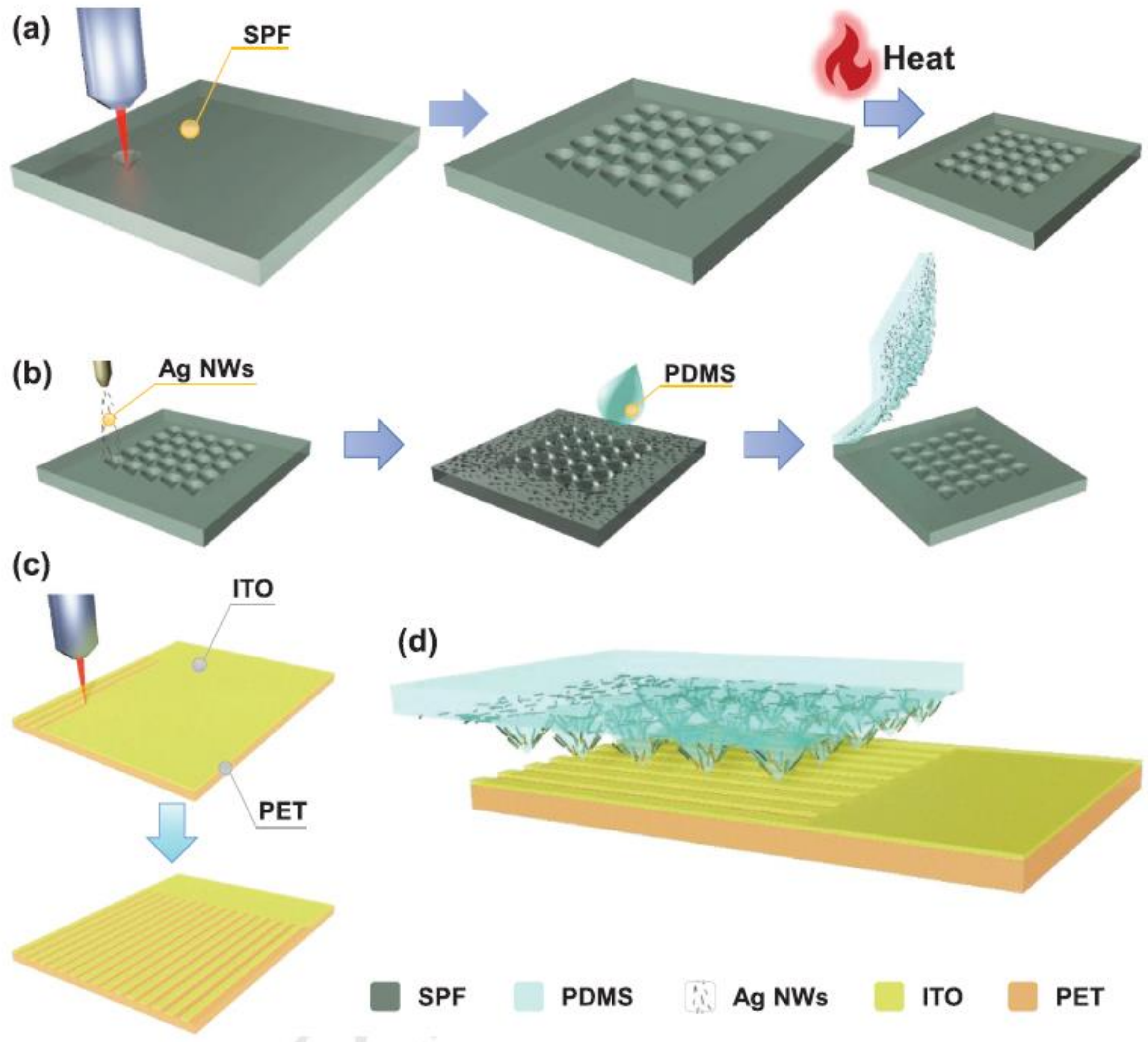
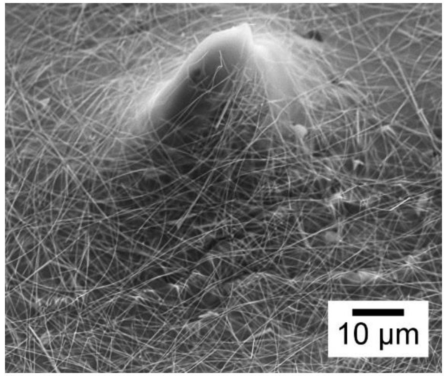
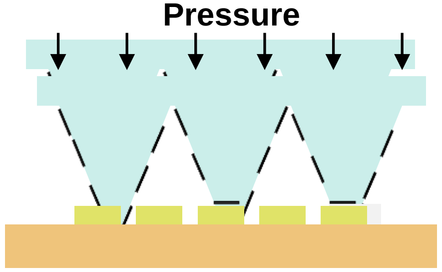
Piezoresistive e-skin pressure sensors



Homogeneous coverage of Ag NWs (except tip)



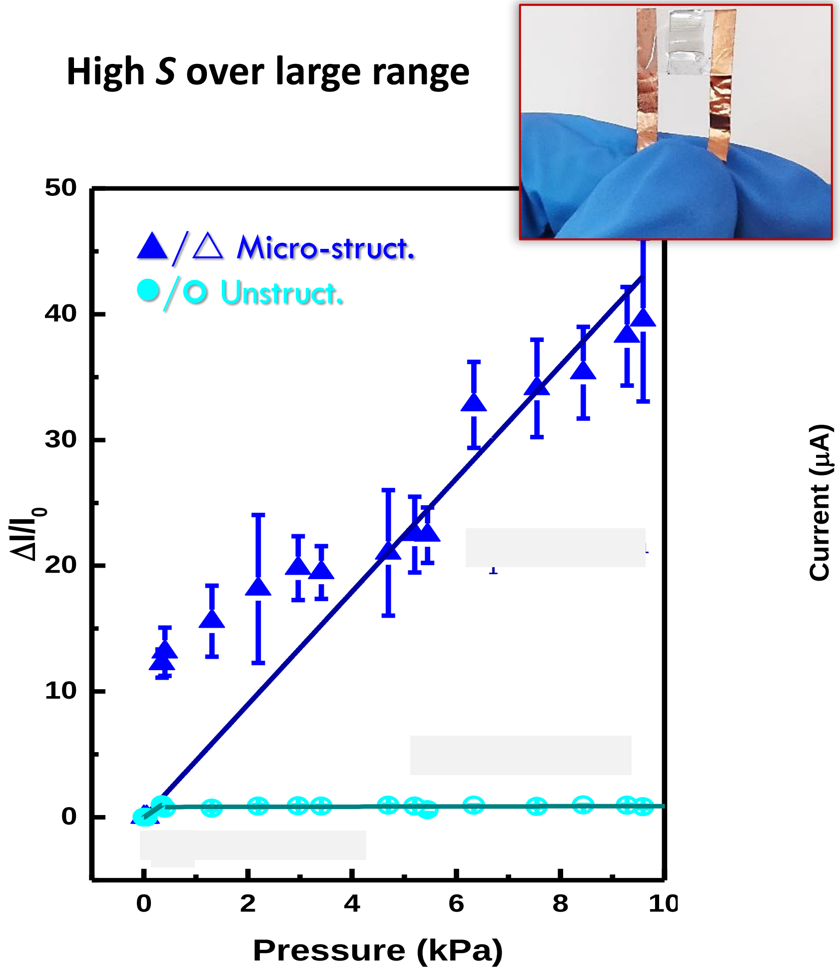


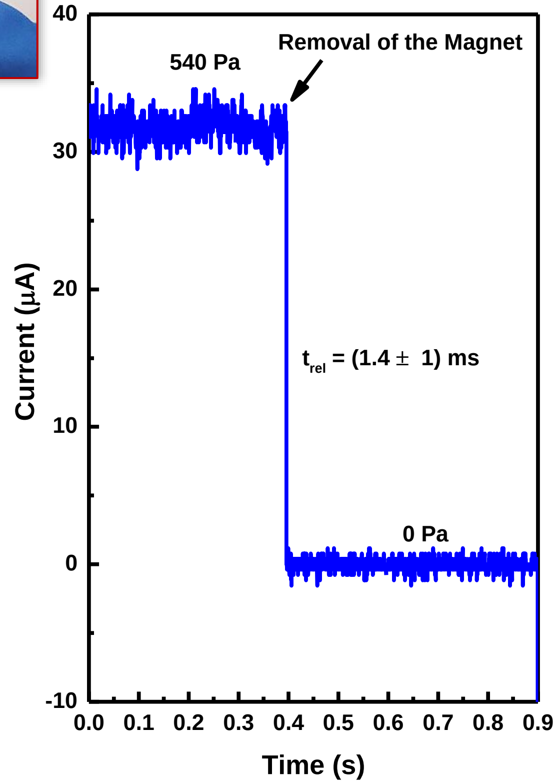
Pressure sensing mechanism

Adv. Mater. Interfaces 8 (21), 2100877, (2021)

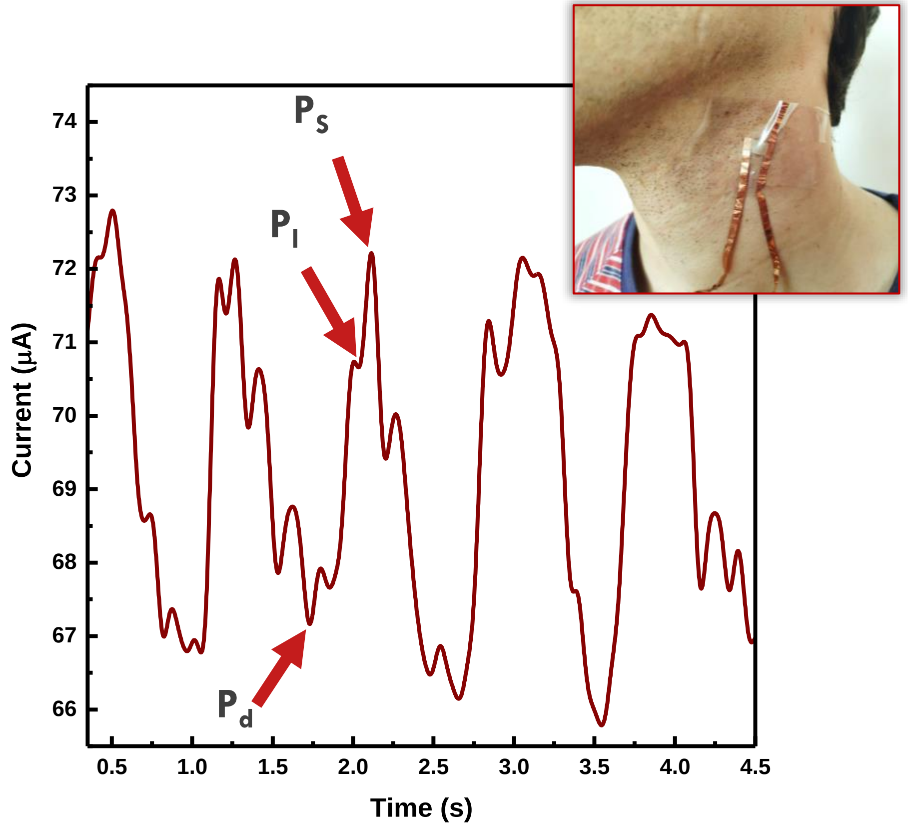
Piezoresistive e-skin pressure sensors

High *S* over large range





Detection of the BPW at the neck



sensitivity of −1.4 kPa^{-1} below 10 kPa, a 1.4 ms recovery time

Adv. Mater. Interfaces 8 (21), 2100877, (2021)

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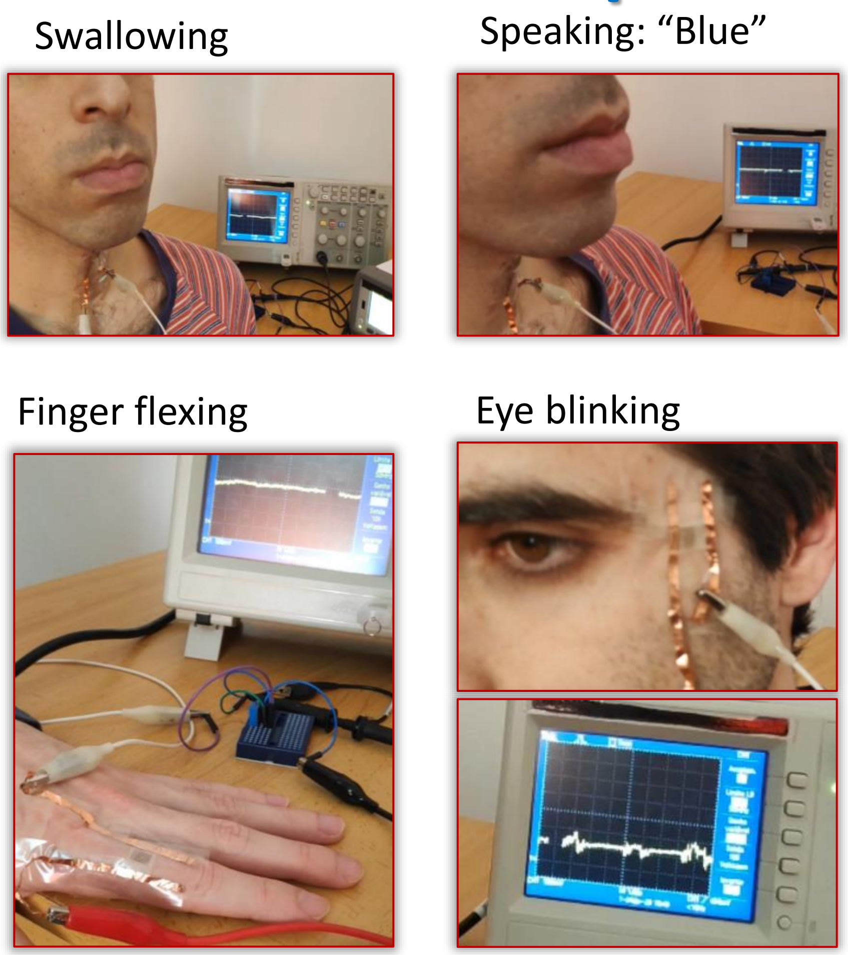
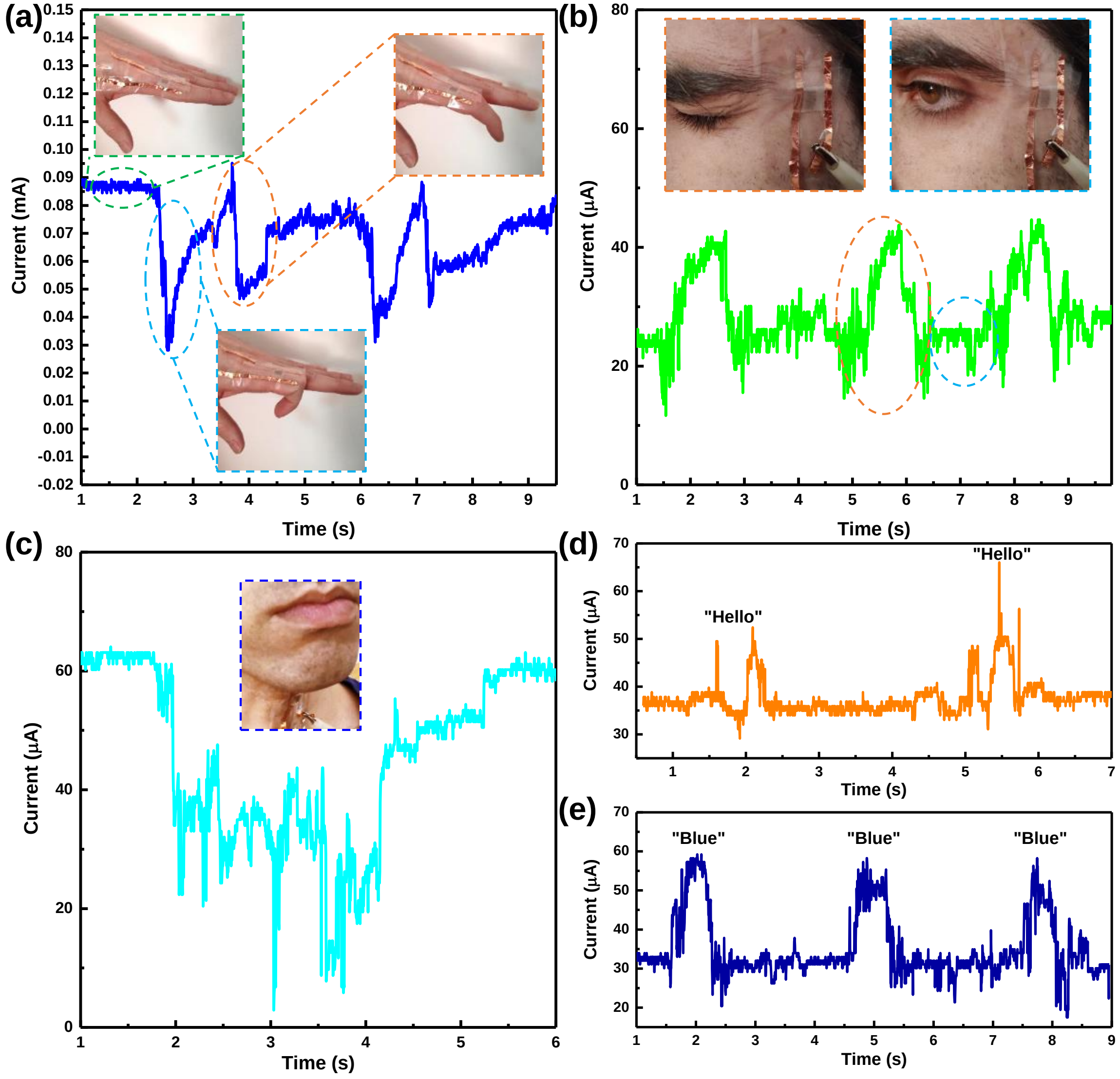
Piezoresistive e-skin pressure sensors





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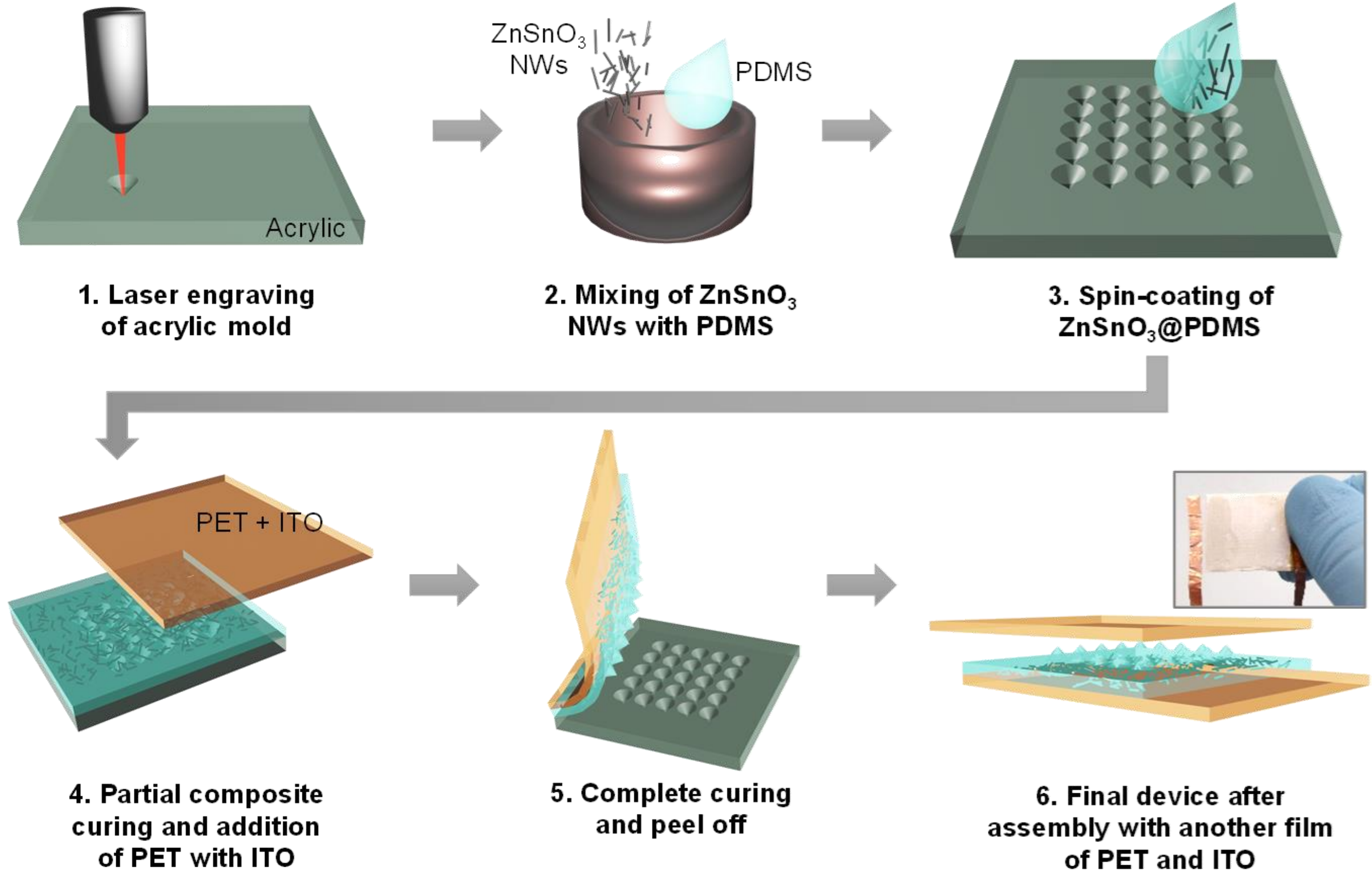
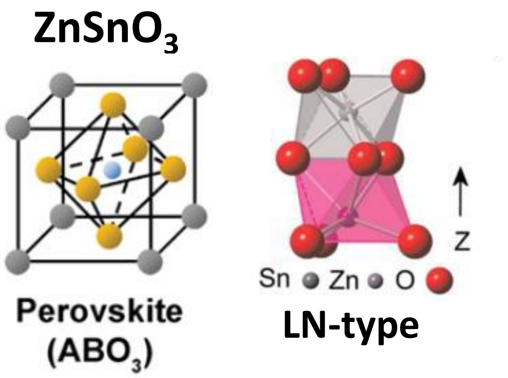
Energy harvesters using ZnO NRs and ZnSnO3 NWs

Hybrid $ZnSnO_3$ NWs @ microstructured PDMS nanogenerators

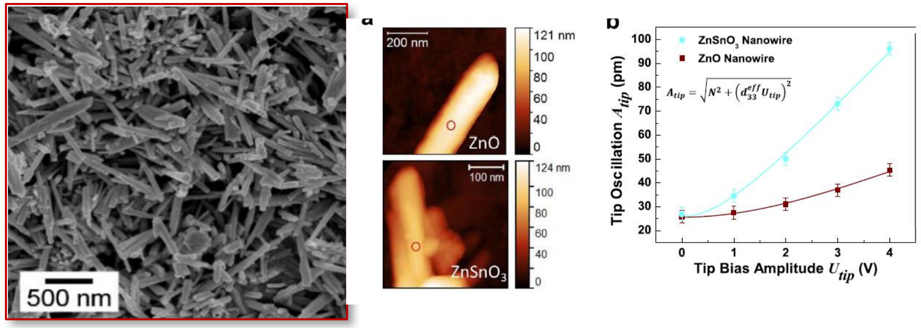


ACS Appl. Mater. Interfaces 12, 18421-18430 (2020)



$ZnSnO_3$ nanowires

One step hydrothermal process @ 200 °C established @ CENIMAT



ACS Applied NanoMat 1(8), 3986 (2018)
Nanomaterials, 9(7), 1002 (2019)

d_{33} (ZnO) = 9 ± 2 pm/V

d_{33} ($ZnSnO_3$) = 23 ± 4 pm/V

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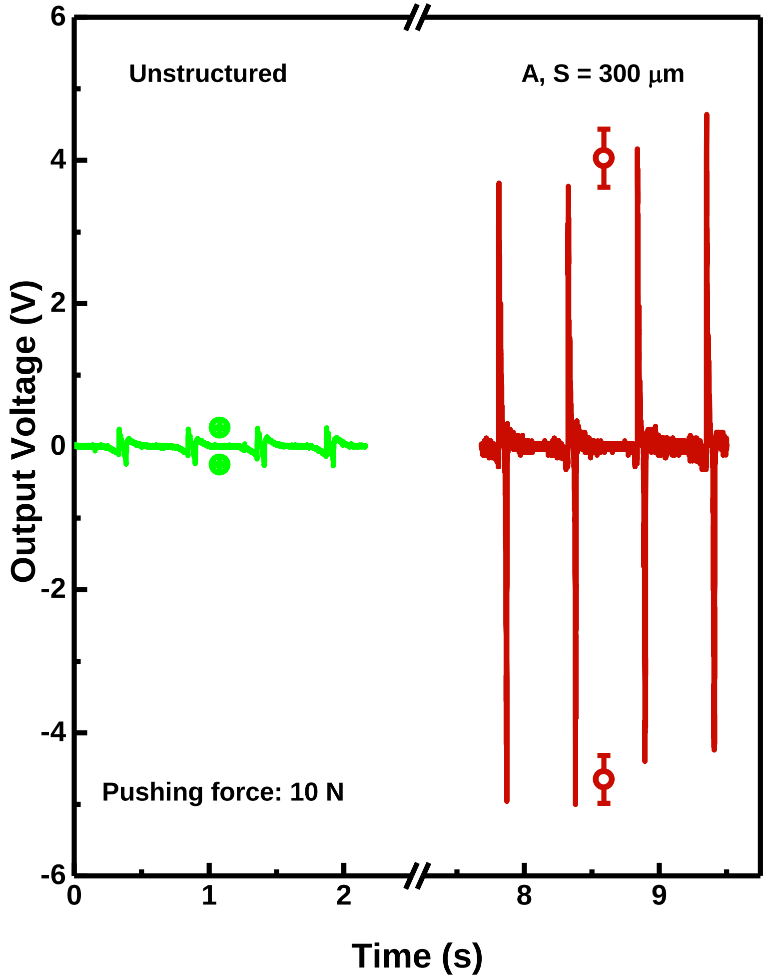
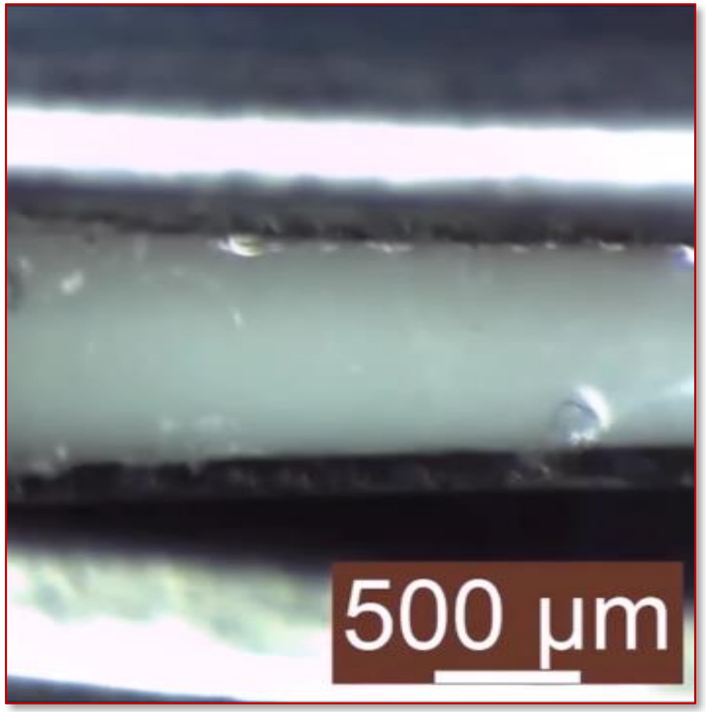
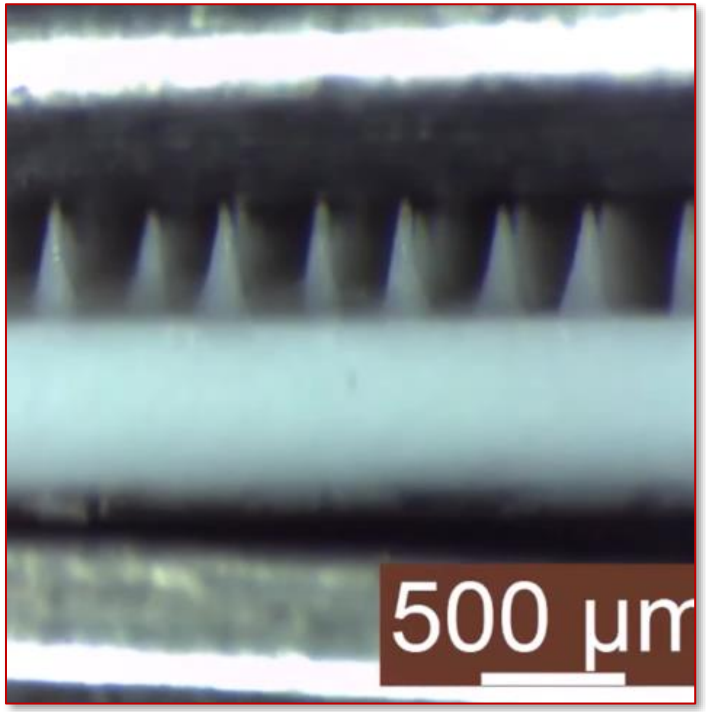
Energy harvesters using ZnO and ZnSnO3 NWs

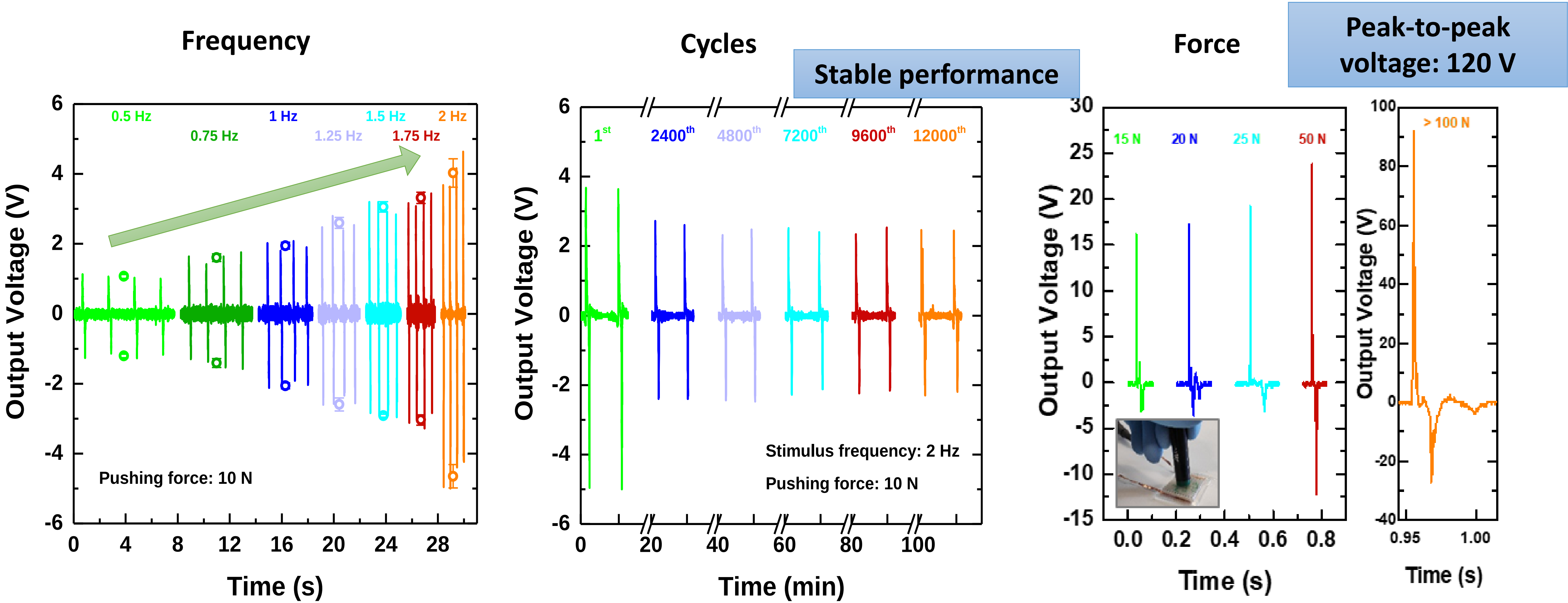






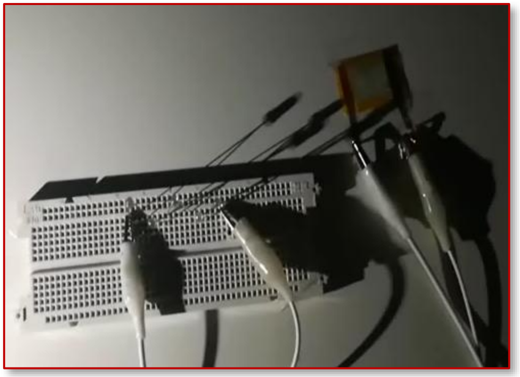
ACS Appl. Mater. Interfaces 12, 18421-18430 (2020)

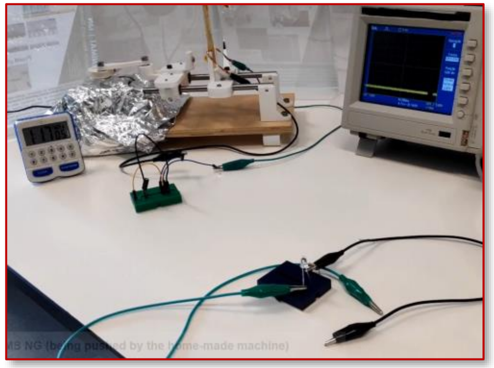
Energy harvesters using ZnO and $ZnSnO_3$ NWs

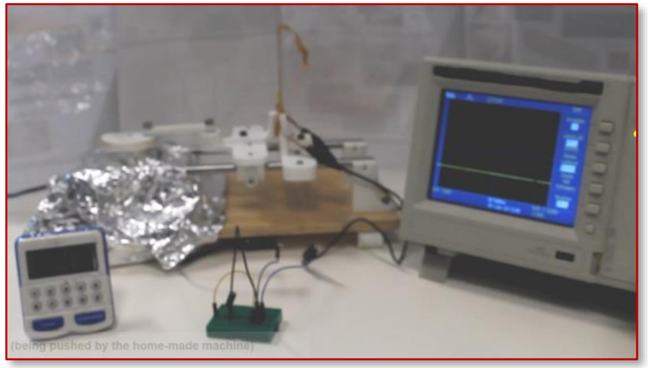


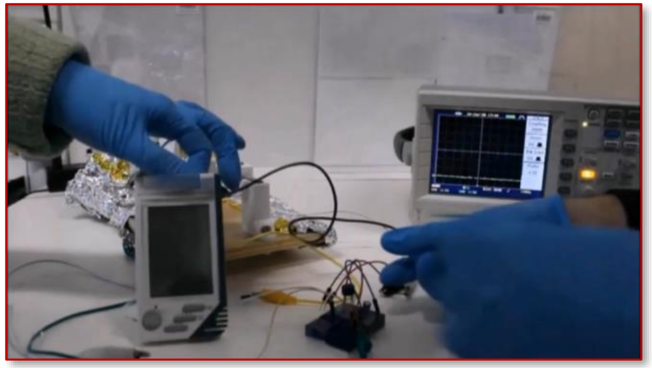
ACS Appl. Mater. Interfaces 12, 18421-18430 (2020)

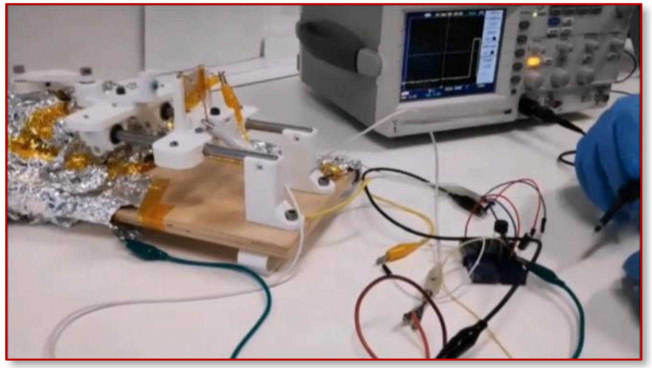
Energy harvesters using ZnO and ZnSnO3 NWs











… or charge a capacitor (15 min, 80 μJ) to power small electronic devices

Harvester able to directly power LEDs…

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Piezoelectricity Enhancement of Nanogenerators Based on PDMS and $ZnSnO_3$ Nanowires through Microstructuration

Ana Rovisco, Andreia dos Santos, Tobias Cramer, Jorge Martins, Rita Branquinho, Hugo Águas, Beatrice Fraboni, Elvira Fortunato, Rodrigo Martins, Rui Igreja*, and Pedro Barquinha*

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Publication Date: March 20, 2020
https://doi.org/10.1021/acsami.9b21636

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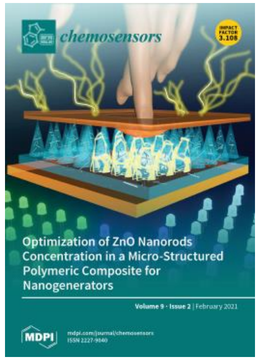
SUBJECTS: Composites, Piezoelectrics, Nanowires,



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Optimization of ZnO Nanorods Concentration in a Micro-Structured Polymeric Composite for Nanogenerators

by Andreia dos Santos †, Filipe Sabino †, Ana Rovisco *, Pedro Barquinha, Hugo Águas, Elvira Fortunato, Rodrigo Martins and Rui Igreja *

Institute for Nanostructures, Nanomodelling and Nanofabrication (i3N)/Centro de Investigação em Materiais (CENIMAT), Department of Materials Science, NOVA School of Science and Technology (FCT-NOVA) and Center of Excellence in Microelectronics Optoelectronics and Processes (CEMOP)/Instituto de Desenvolvimento de Novas Tecnologias (UNINOVA), NOVA University Lisbon, Campus de Caparica, 2829-516 Caparica, Portugal

* Authors to whom correspondence should be addressed.
† These authors contributed equally to this work.

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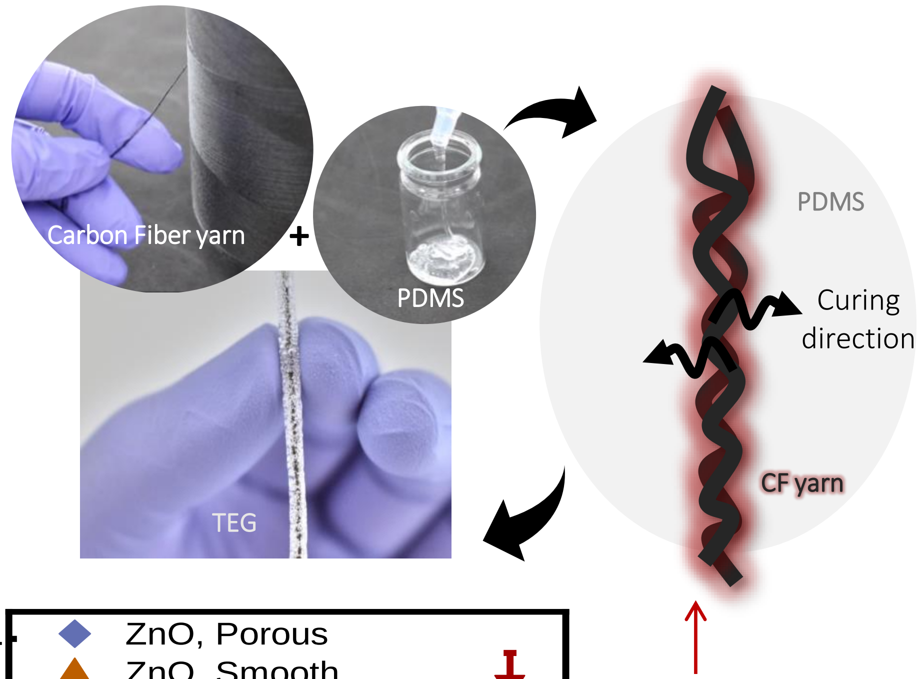
(This article belongs to the Special Issue Nanowire-Based Sensors)

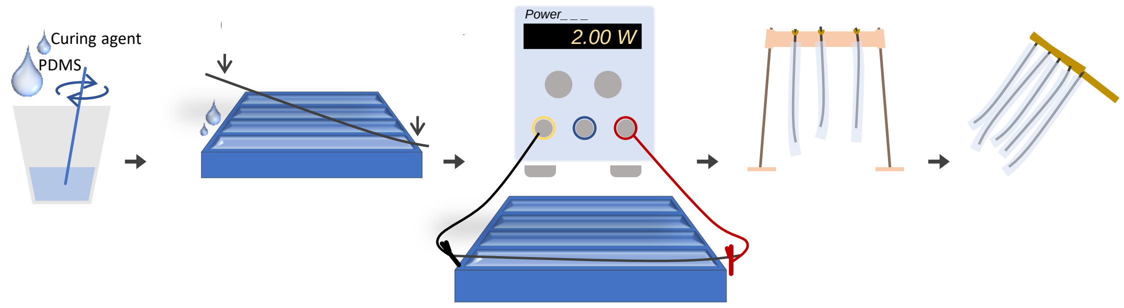
Outline

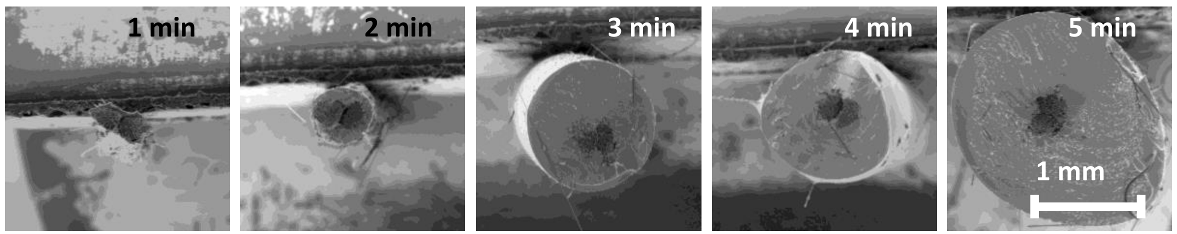
- **CENIMAT|I3N and UNINOVA-CEMOP**
- **e-skin devices**
  - Piezoresistive pressure sensors (health, robotics)
  - Piezoresistive using Temperature Shrinking Polymer Molds
  - Piezoresistive temperature/pressure sensing
  - Flexible Piezo/Tribo devices
- **Fiber based devices**
  - Energy harvesting devices
  - 1D-NEON projet; MIP2Sensors Projet
- **Digital μFluidics**

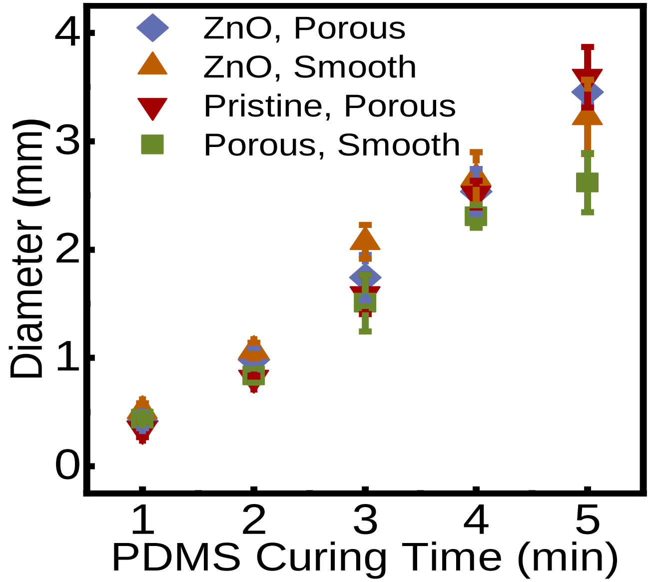
F- piezo energy harvesters

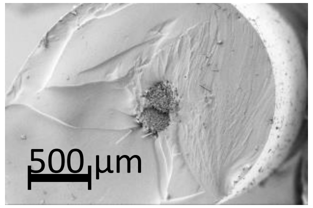
Porous PDMS conformable coating for high power output carbon fibers based triboelectric energy harvesters



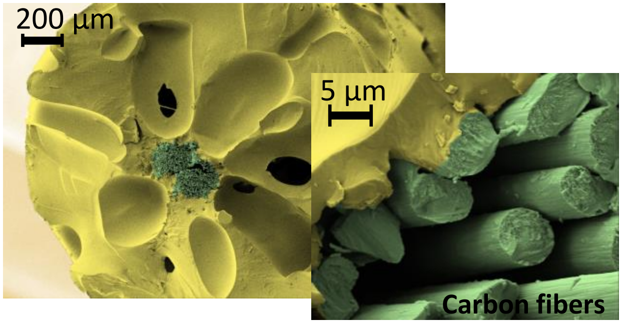




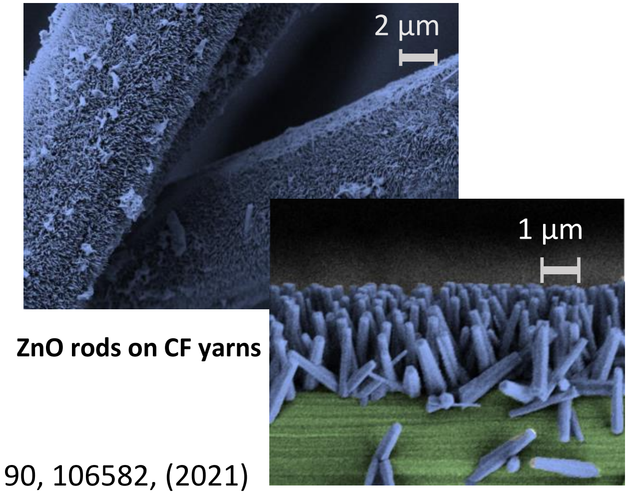




Smooth PDMS



Porous PDMS



ZnO rods on CF yarns

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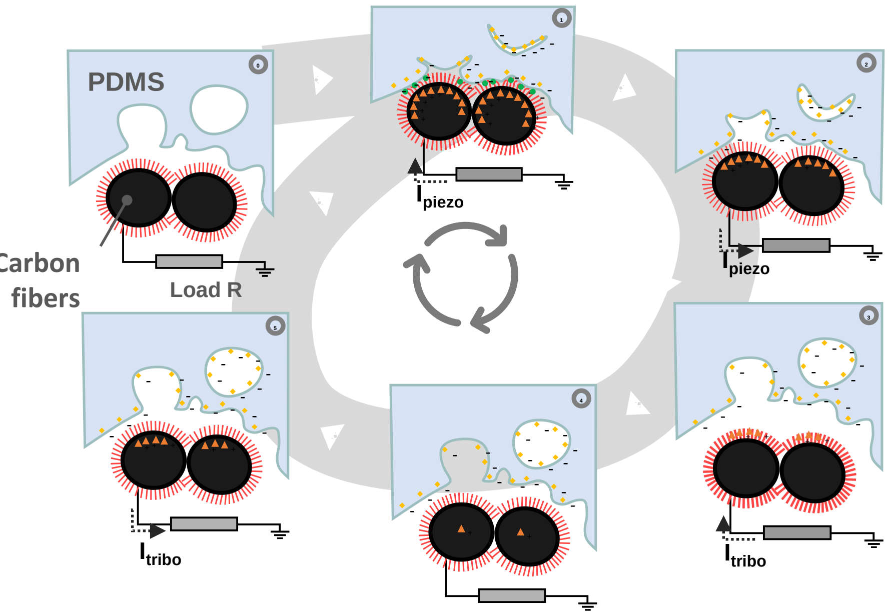
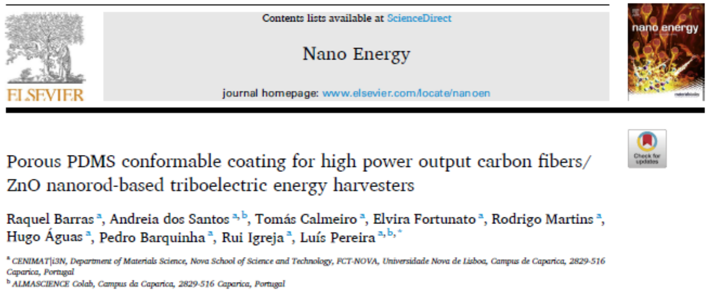
Nano Energy 90, 106582, (2021)

F- piezo energy harvesters

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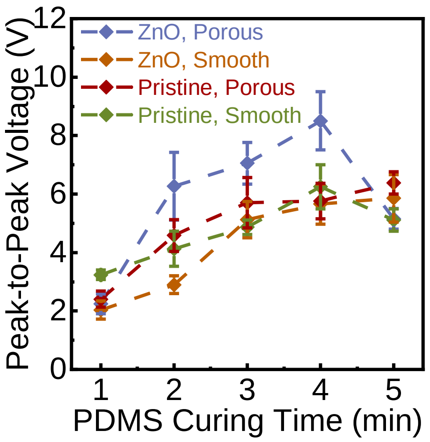
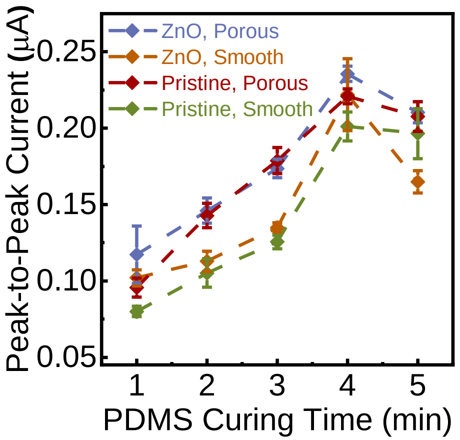
journal homepage: www.elsevier.com/locate/nanoen

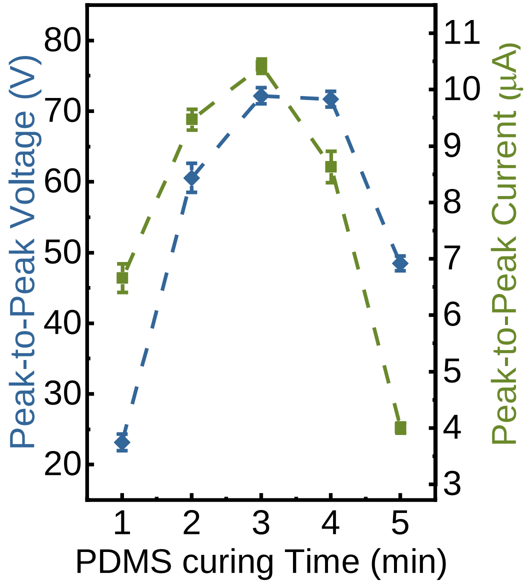
Porous PDMS conformable coating for high power output carbon fibers/ZnO nanorod-based triboelectric energy harvesters

Raquel Barras[a], Andreia dos Santos[a,b], Tomás Calmeiro[a], Elvira Fortunato[a], Rodrigo Martins[a], Hugo Águas[a], Pedro Barquinha[a], Rui Igreja[a], Luís Pereira[a,b,*]

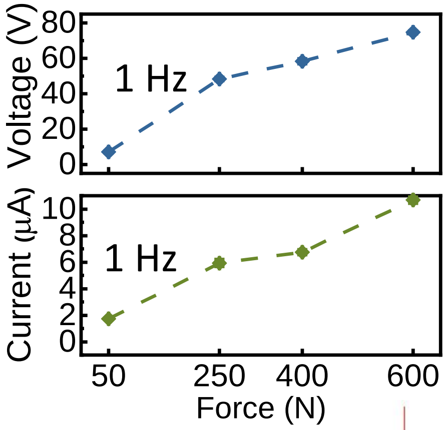
[a] CENIMAT|i3N, Department of Materials Science, Nova School of Science and Technology, FCT-NOVA, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal
[b] ALMASCIENCE Colab, Campus da Caparica, 2829-516 Caparica, Portugal

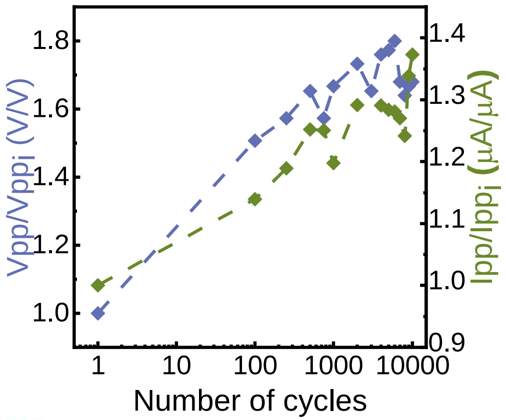


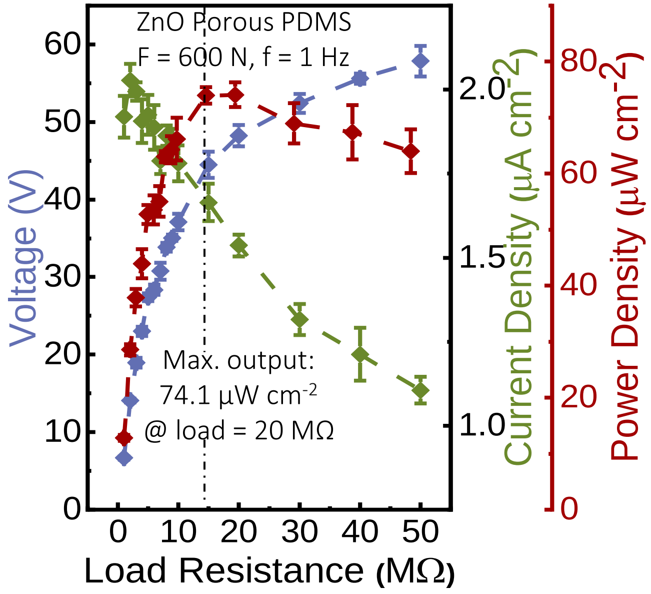


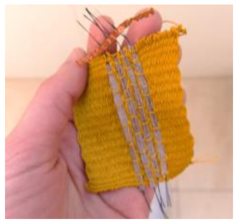


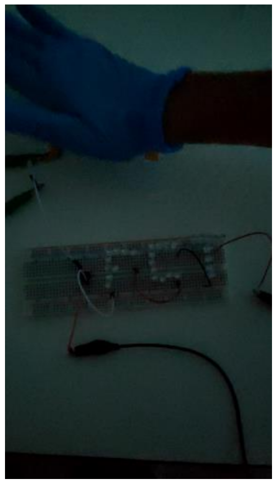
ZnO, Porous – 3 min curing











Nano Energy 90, 106582, (2021)

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F- piezo energy harvesters

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Full paper

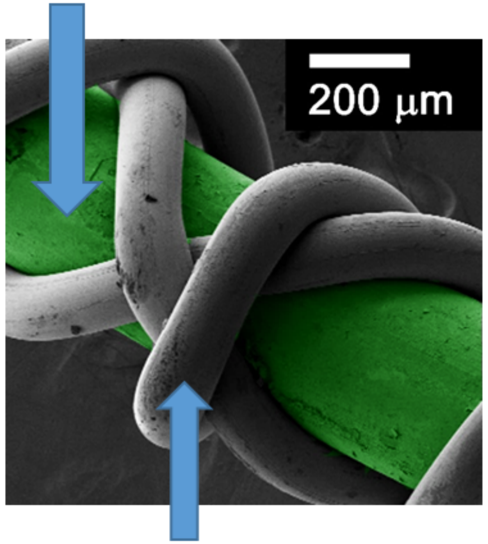
Human-motion interactive energy harvester based on polyaniline functionalized textile fibers following metal/polymer mechano-responsive charge transfer mechanism

Sumita Goswami, Andreia dos Santos, Suman Nandy*, Rui Igreja, Pedro Barquinha, Rodrigo Martins, Elvira Fortunato**

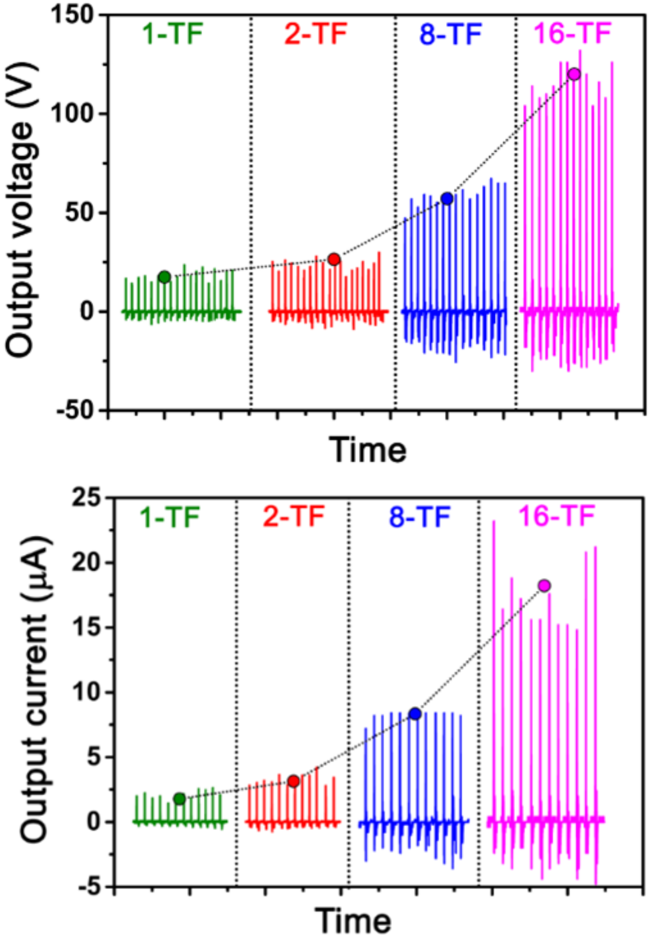
i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa and CEMOP/UNINOVA, Campus de Caparica, 2829-516, Caparica, Portugal

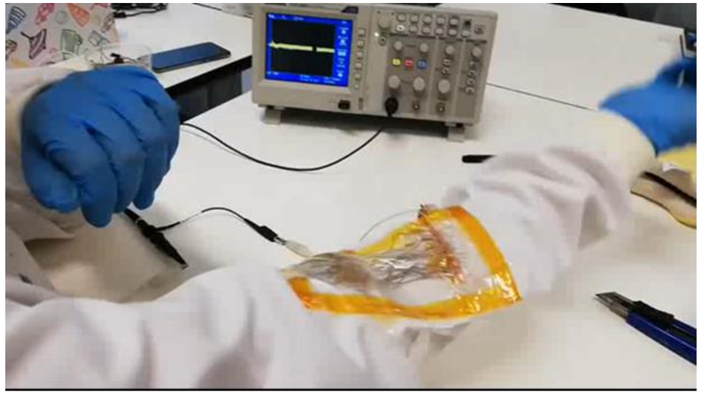
Doped polyaniline (d-PANi) functionalized textile fibre (TF) as energy harvester

Polyaniline functionalized layer

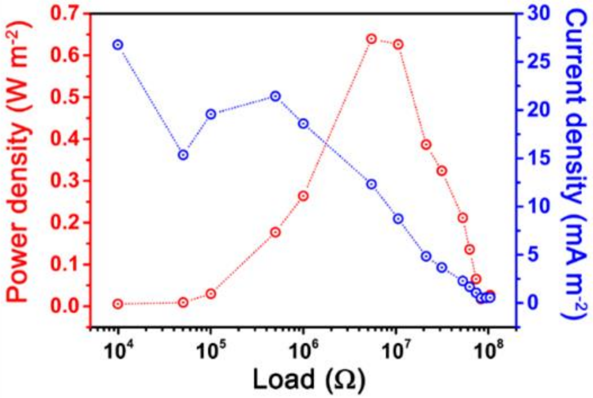


Conducting fibre (150 μm) knitted over functionalized fibre: Acts as stress-deliverer; charge-collector (SDCC) electrode





- Peak power-density ~0.6 W m^{-2}
- Output current-density ~22 mA m^{-2}
- Can power at least 10 white LEDs of 2.5 W



Nano Energy, 60, 794-801 (2019)

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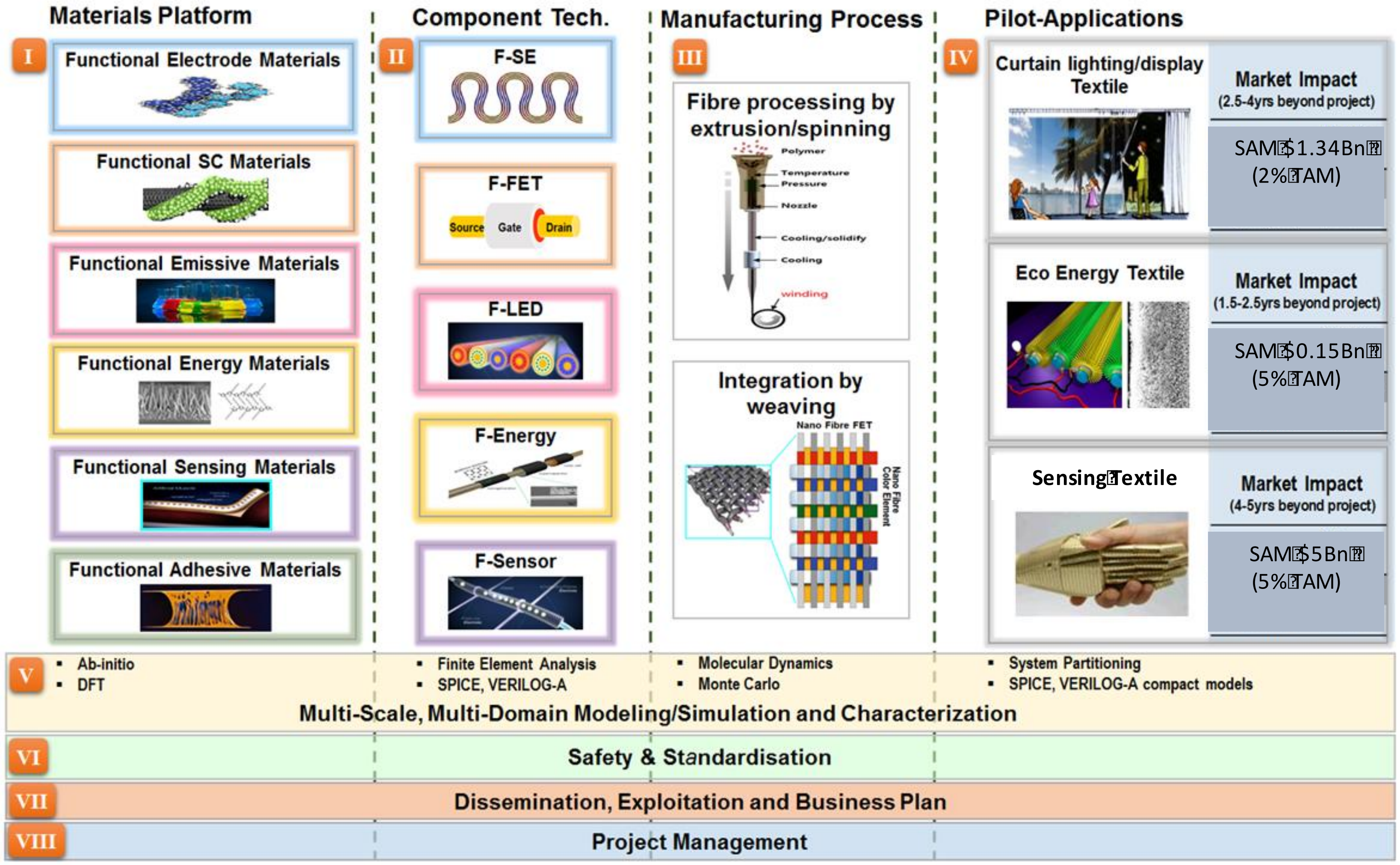
1D-NEON Project

- Coordinated by Professor Jong Min Kim, University of Cambridge, Department of Engineering
- Total project size €9.1M (€8M funding), start Apr. 2016 (48 months)
- Maturity Progression Plan TRL 4 to TRL 6



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ARTICLE

https://doi.org/10.1038/s41467-022-28459-6 OPEN

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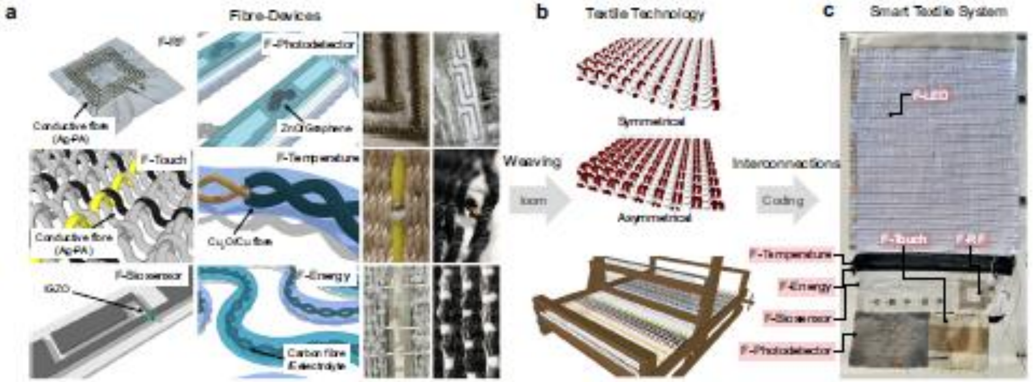
Smart textile lighting/display system with multifunctional fibre devices for large scale smart home and IoT applications

Hyung Woo Choi[1,20], Dong-Wook Shin[1,20], Jiajie Yang[1,20], Sanghyo Lee[1,20], Cátia Figueiredo[2], Stefano Sinopoli[3], Kay Ullrich[4], Petar Jovančić[5], Alessio Marrani[6], Roberto Momentè[7], João Gomes[8], Rita Branquinho[2], Umberto Emanuele[3], Hanleem Lee[1], Sang Yun Bang[1], Sung-Min Jung[1], Soo Deok Han[1], Shijie Zhan[1], William Harden-Chaters[1], Yo-Han Suh[1], Xiang-Bing Fan[1], Tae Hoon Lee[1], Mohamed Chowdhury[1], Youngjin Choi[1], Salvatore Nicotera[3], Andrea Torchia[3], Francesc Mañosa Moncunill[5], Virginia Garcia Candel[5], Nelson Durães[8], Kiseok Chang[9], Sunghee Cho[9], Chul-Hong Kim[9], Marcel Lucassen[10], Ahmed Nejim[11], David Jiménez[12], Martijn Springer[13], Young-Woo Lee[14,15], SeungNam Cha[14,16], Jung Inn Sohn[14,17], Rui Igreja[2], Kyungmin Song[18], Pedro Barquinha[2], Rodrigo Martins[2], Gehan A. J. Amaratunga[1], Luigi G. Occhipinti[1✉], Manish Chhowalla[19✉] & Jong Min Kim[1✉]



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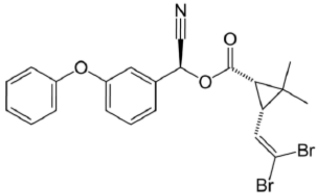
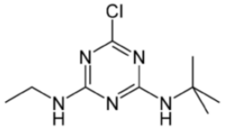
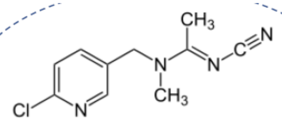
MIP2Sensors (NOVA/Uni Évora)



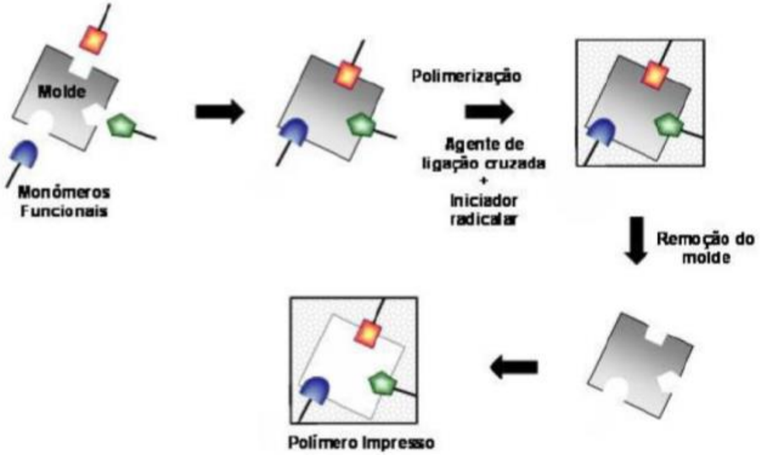
Deltametrina

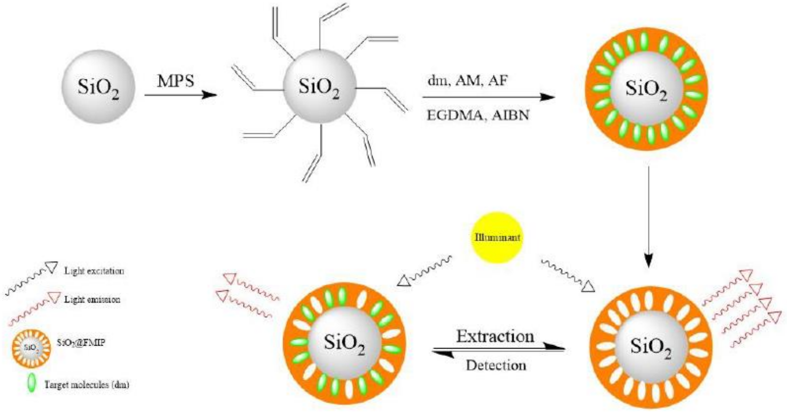


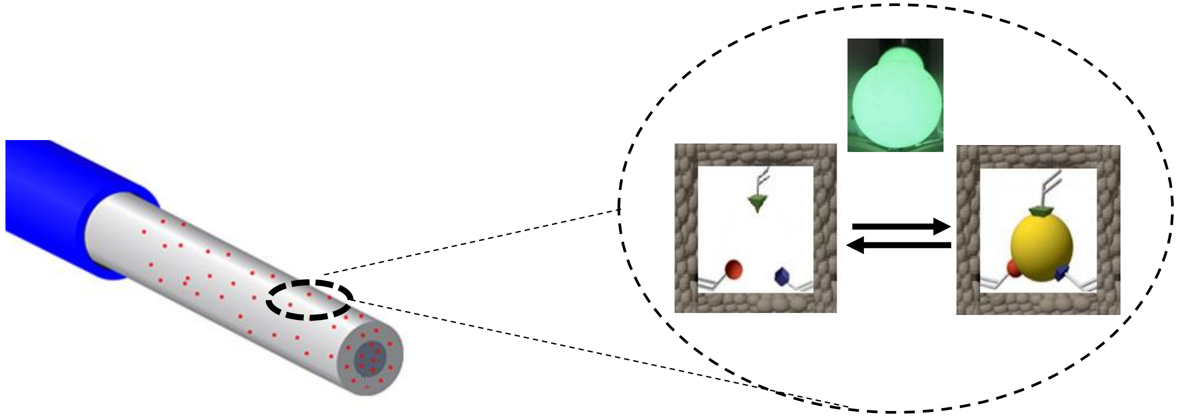
Terbutilazina



Acetamiprida







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Outline

- **CENIMAT|I3N and UNINOVA-CEMOP**
- **e-skin devices**
  - Piezoresistive pressure sensors (health, robotics)
  - Piezoresistive using Temperature Shrinkink Polymer Moulds
  - Piezoresistive temperature/pressure sensing
  - Flexible Piezo/Tribo devices
- **Fiber based devices**
  - Energy harvesting devices
  - TFT for smart textiles
- **Digital μFluidics**

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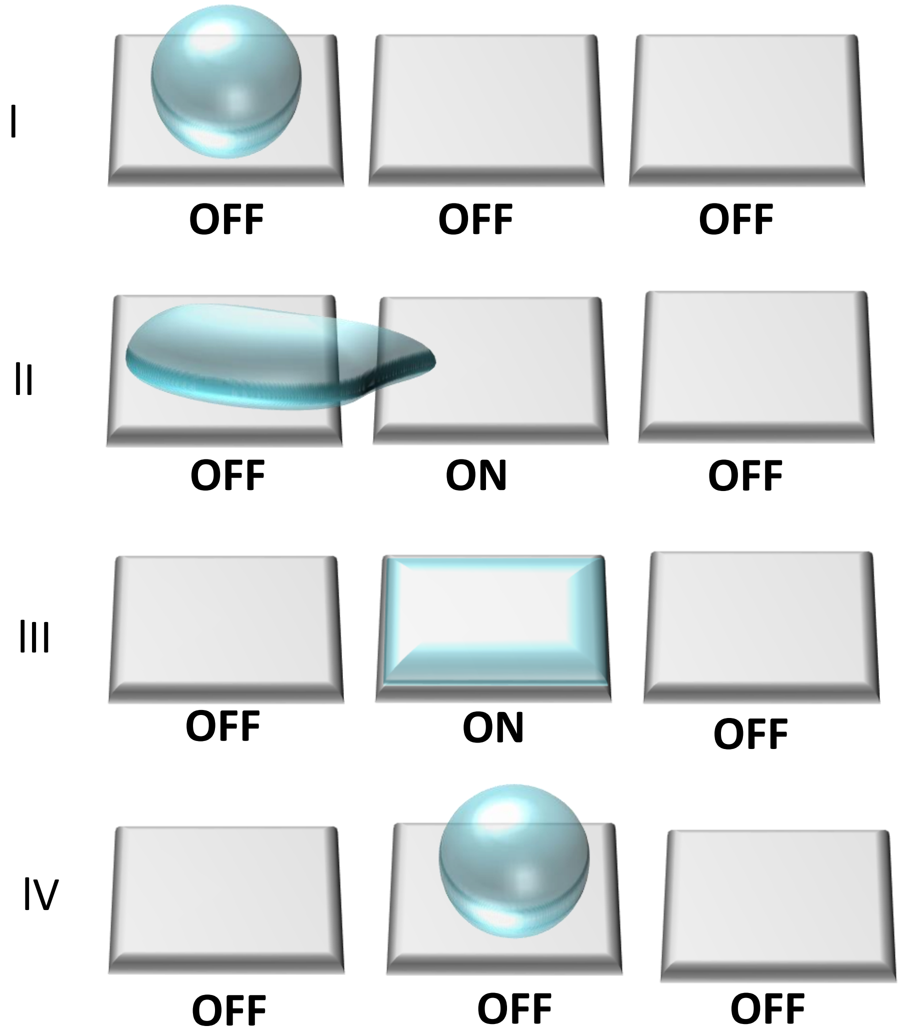
Digital microfluidic platform for biosensing

Voltage-based technology for automated processing of liquid Biological and Chemical reactions.



Any pathway is possible

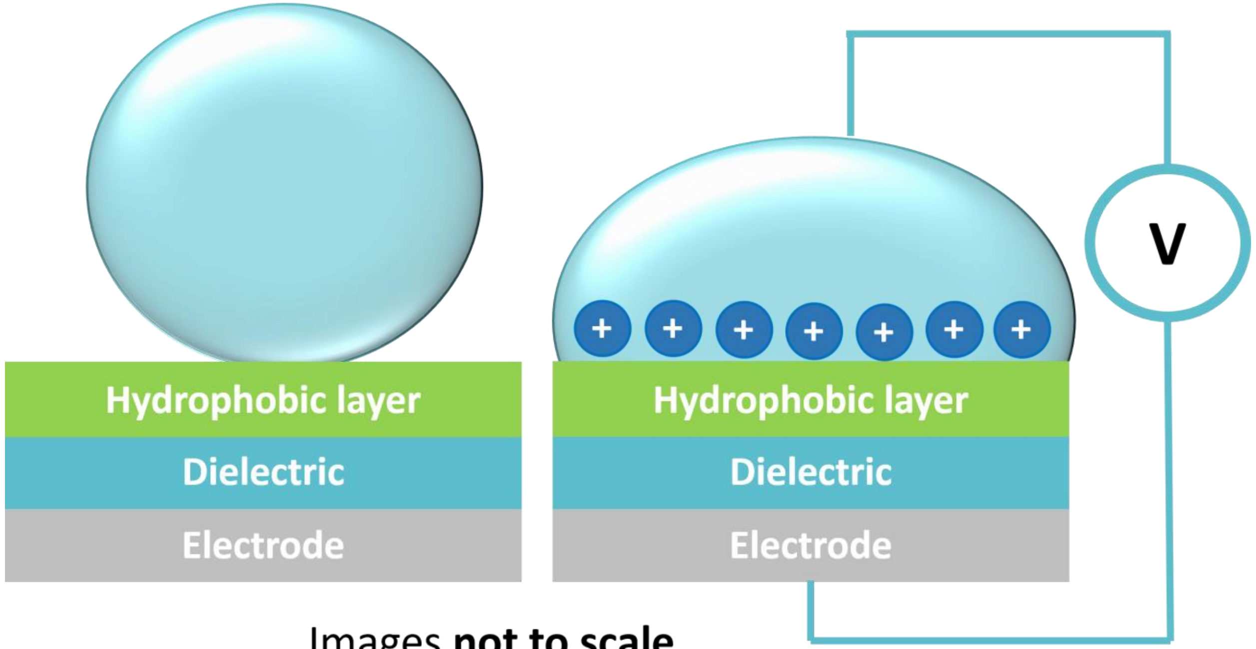
Any electrode sequence is possible

Any reaction/protocol order can be implemented

Digital microfluidic platform for biosensing

Electrowetting-on-dielectric (EWOD) phenomenon.

Change in contact anlge in response to an electric field

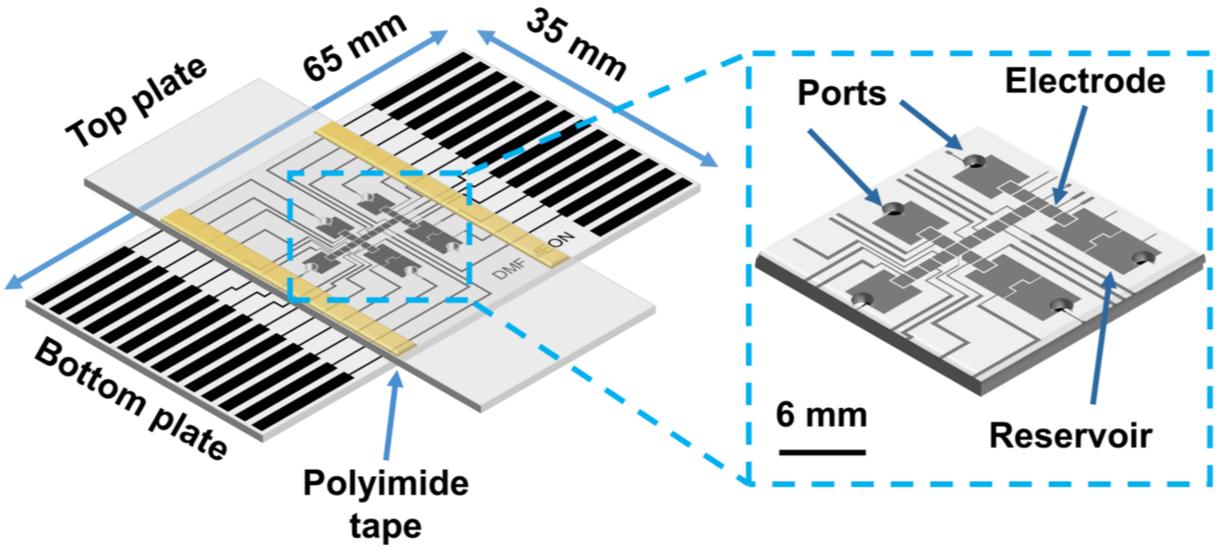


Images **not to scale**

- ✓ Portability
- ✓ Low volume reactions
- ✓ Microreactor control
- ✓ Multiplexing capability
- ✓ Easy integration
- ✓ Programmability

- ✓ Proteomics
- ✓ Immunoassays
- ✓ Chemical analysis
- ✓ DNA/RNA manipulation
- ✓ Cell manipulation
- ✓ Reaction monitoring
- ✓ (...) much more to explore

Digital microfluidic platform for biosensing



Biosensors 12(4), 201 (2022)

- ## DNA amplification for diagnostics

  Molecular diagnostics rely heavily on DNA amplification - **opportunity**

- ## DMF for DNA-based diagnostics

  Due to its unique combination of automation and low volume droplet handling, such devices are promising candidates for point-of-care testing (POCT) **- challenge**

- ## Multiplex assays

  Shifting the electrode architecture allows for several assay configurations, namely multiplex assays, where two or more experiments run simultaneously – **one step further**

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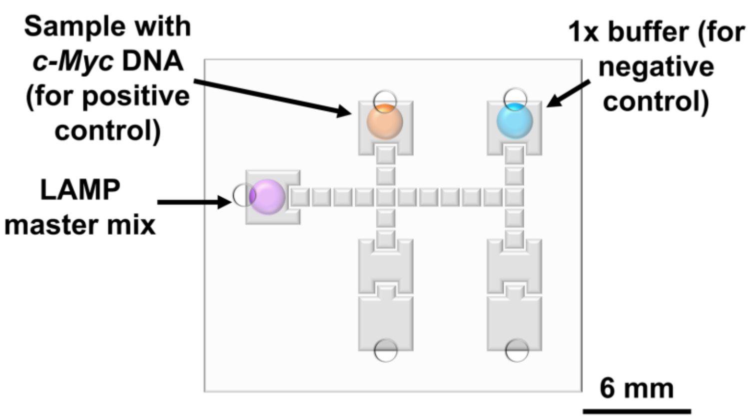
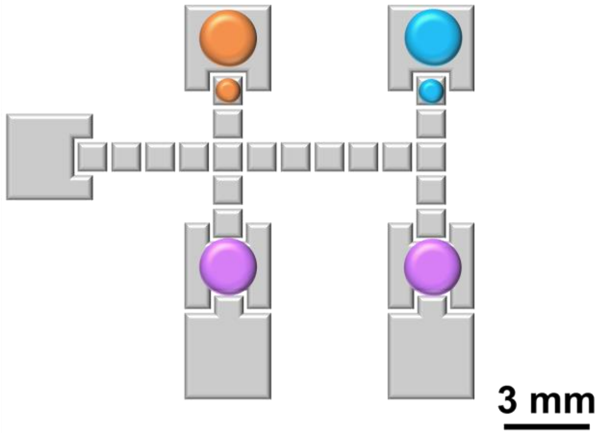
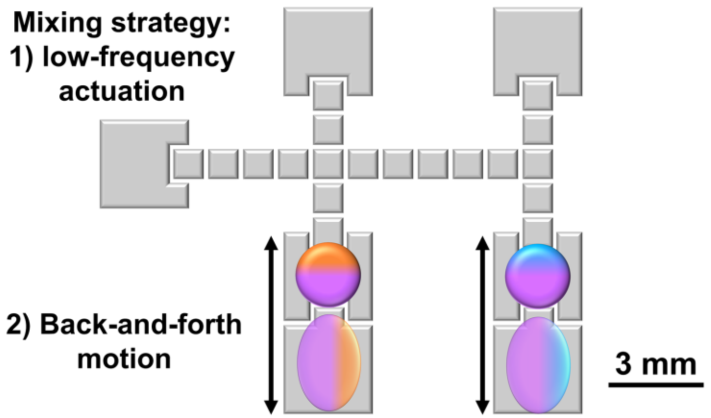
Digital microfluidic platform for biosensing

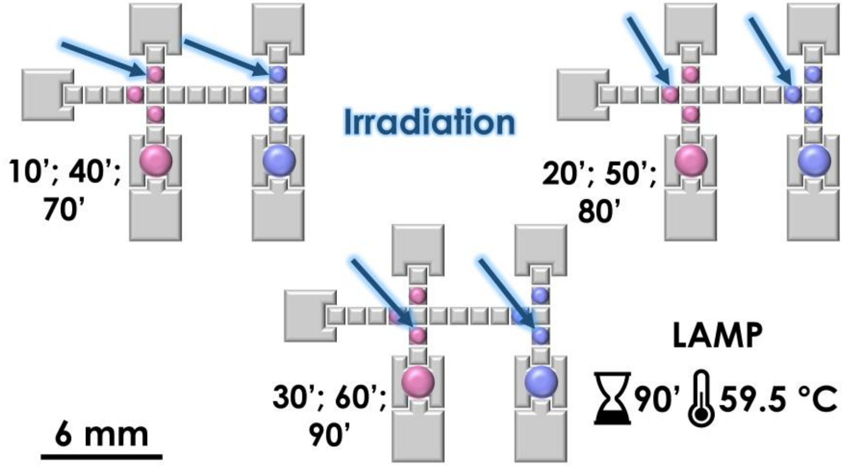
on-chip mixing







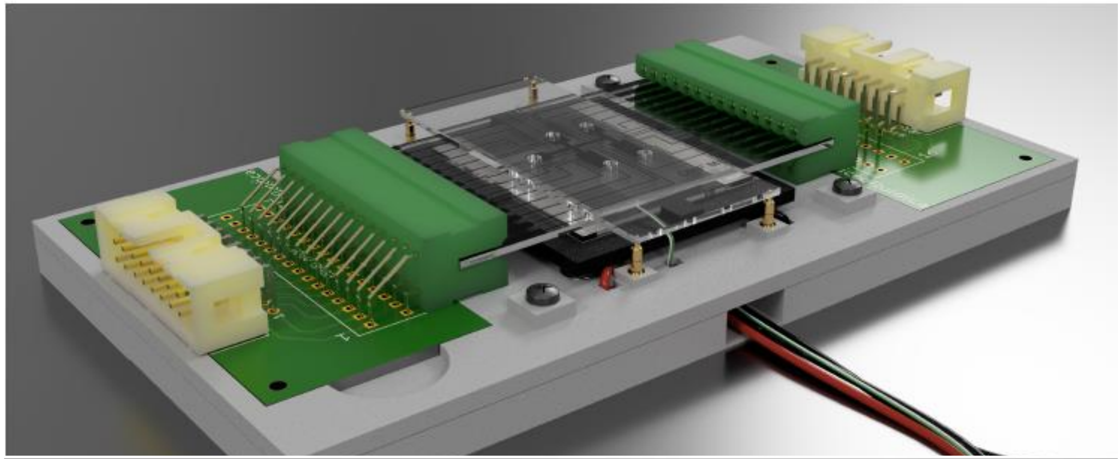
Against photobleaching: use 3 droplets and irradiate one droplet at a time

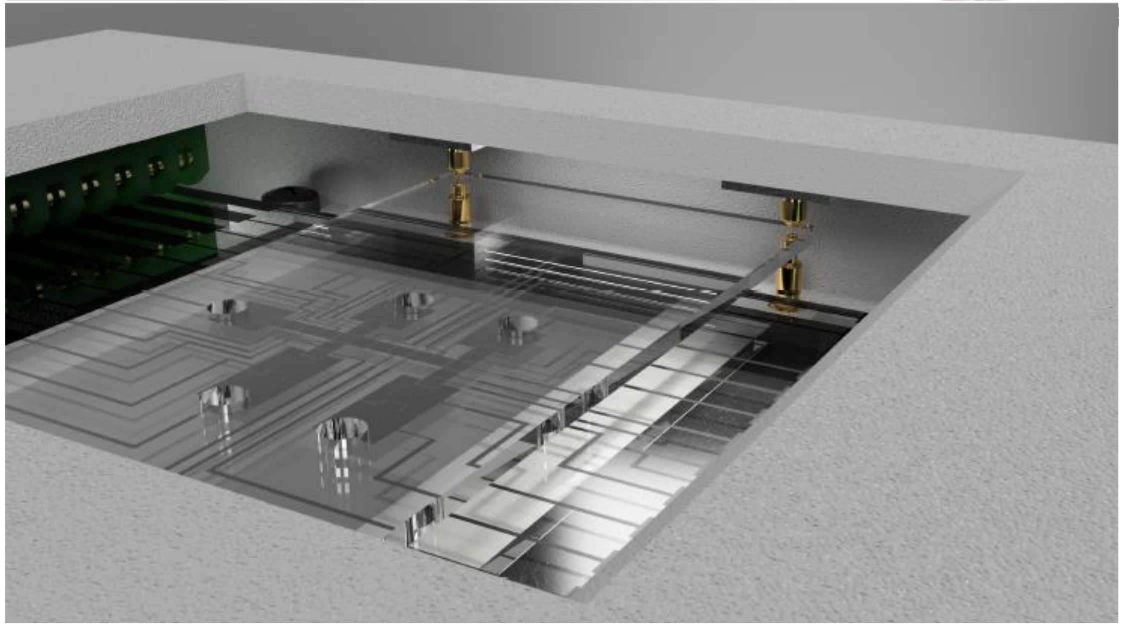


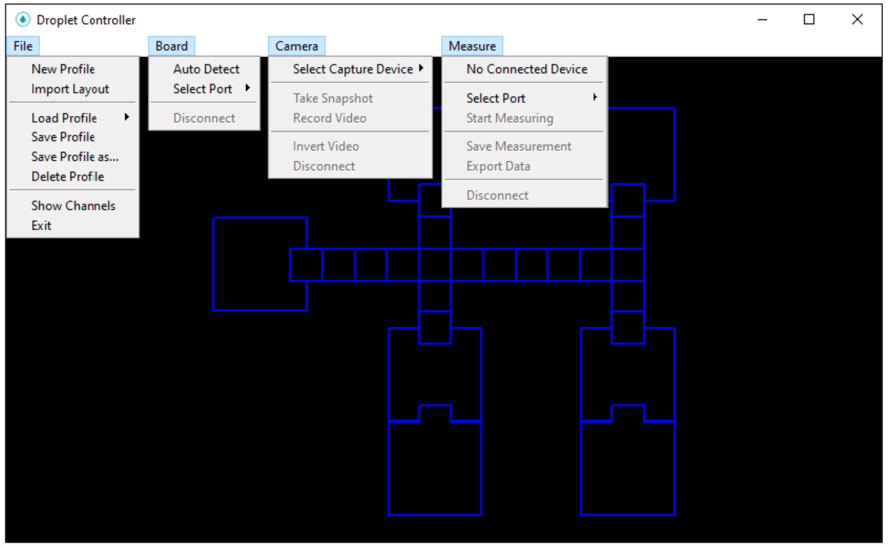
Remaining procedure identical to workflow 1

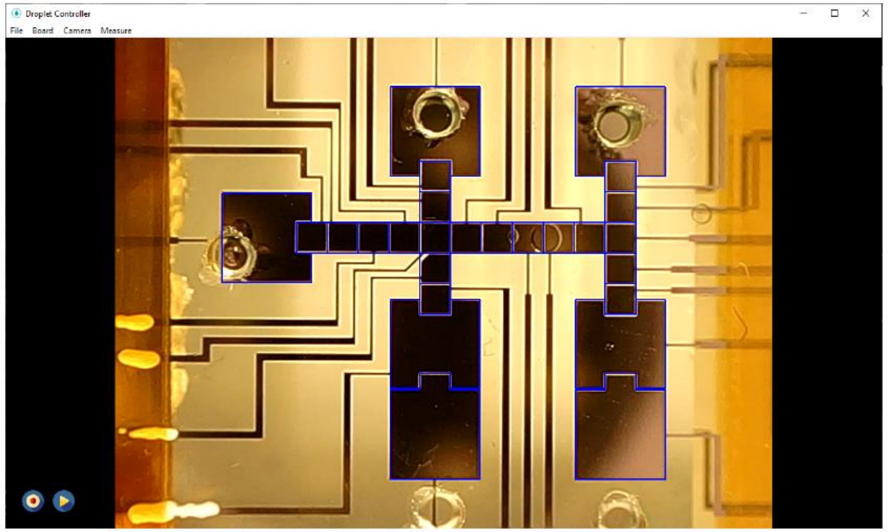
Digital microfluidic platform for biosensing

Digital microfluidic platform for biosensing









Biosensors 12(4), 201 (2022)
Sensors 17, 2616 (2017)
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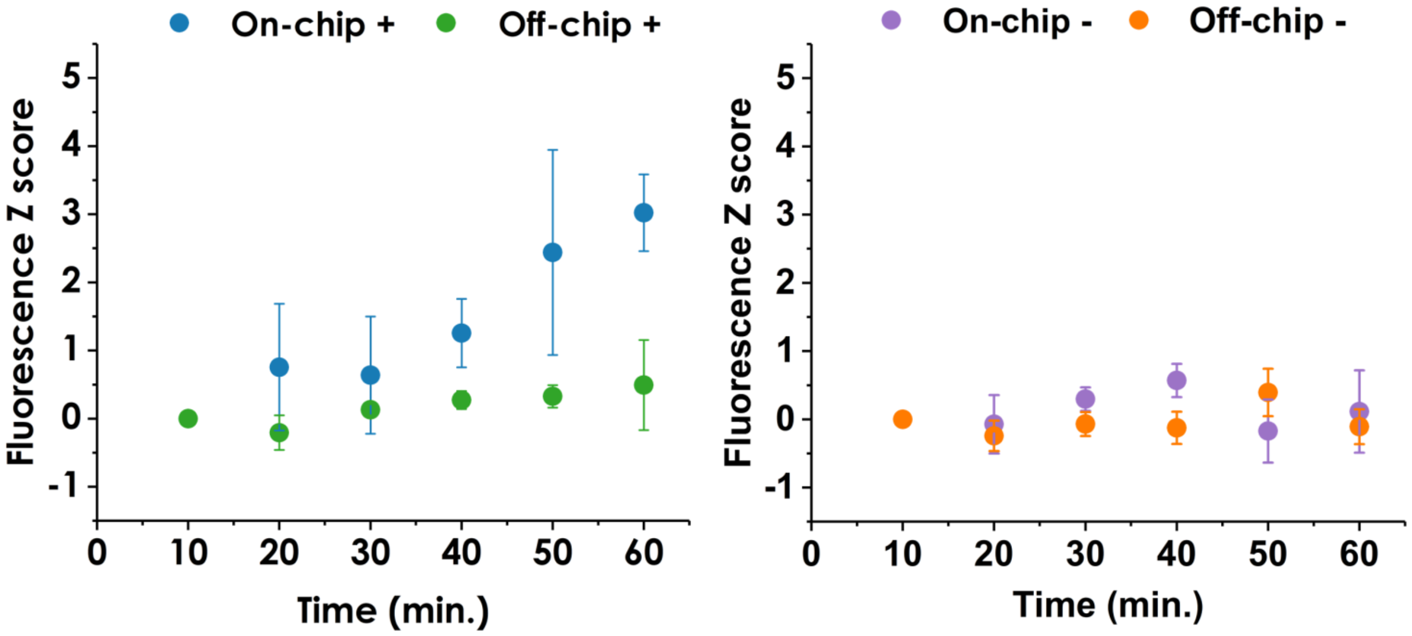
Digital microfluidic platform for biosensing



Biosensors 12(4), 201 (2022)

biosensors

MDPI

Article

Digital Microfluidics-Powered Real-Time Monitoring of Isothermal DNA Amplification of Cancer Biomarker

Beatriz Jorge Coelho [1,2], Bruno Veigas [3], Luís Bettencourt [1], Hugo Águas [1], Elvira Fortunato [1], Rodrigo Martins [1], Pedro V. Baptista [2,*] and Rui Igreja [1,*]

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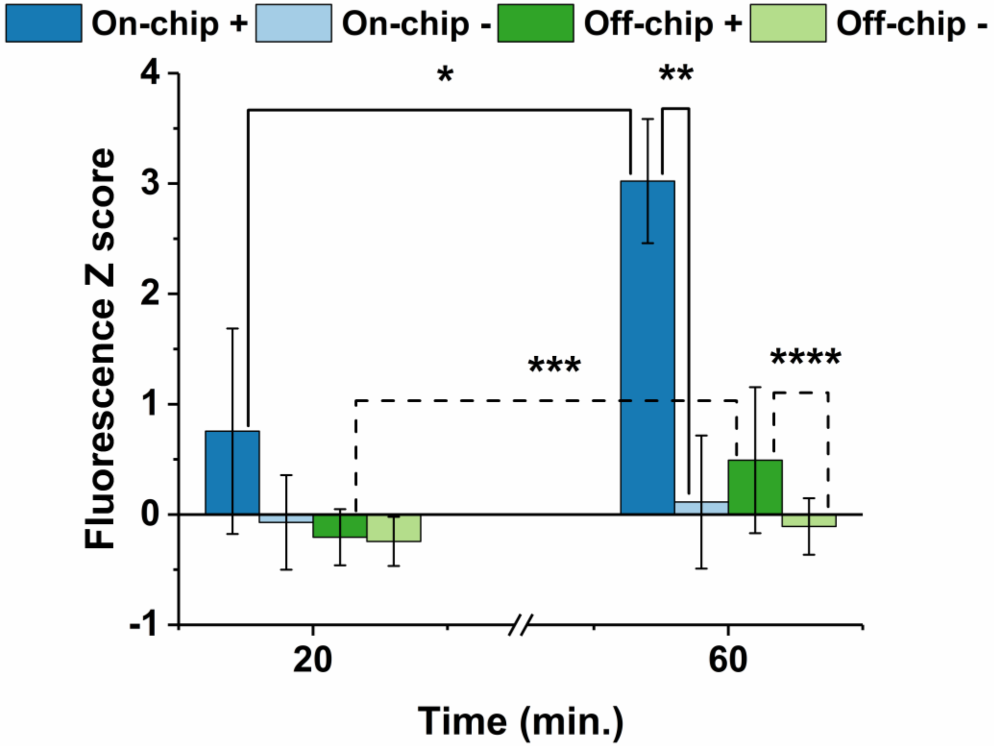
3 AlmaScience, Campus da Caparica, 2829-519 Caparica, Portugal; bruno.veigas@almascience.pt

* Correspondence: pmvb@fct.unl.pt (P.V.B.); rni@fct.unl.pt (R.I.)



Supporting publications from MEON group

Nature Communications 13, 814 (2022)

Biosensors 12(4), 201 (2022)

Advanced Materials Interfaces 8 (21), 2100877, (2021)

Nano Energy 90, 106582, (2021)

Nanopores, IntechOpen 1, (2021)

Chemosensors 9 (2), 27, 2, (2021)

ACS applied materials & interfaces 12 (16), 18421-18430, 17, (2020)

Sensors 20, 4407, (2020)

Nano Energy, 60, 794-801 (2019)

Sensors 19, 899, (2019)

Nanomaterials, 9(7), 1002 (2019)

Advanced Electronic Materials 4 (9), 1870041, (2018)

Scientific reports 8 (1), 1-10 (2018)

ACS Applied NanoMat 1(8), 3986 (2018)

Sensors 17, 2616 (2017)

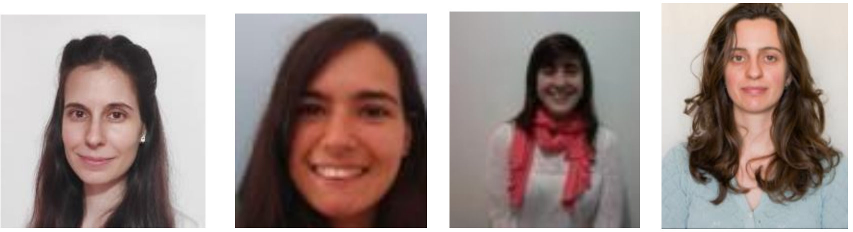
Sensors 17, 1495 (2017)

Rui Igreja, rni@fct.unl.pt

Acknowledgements

MEON group (as March 2022)

People more directly involved in the work presented



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Prof. Raquel Garcia (Unv. Évora)
Prof. Pedro Barquinha (i3N|CENIMAT) – Flexible electronics
Prof. Luis Pereira (i3N| CENIMAT) – Fiber based devices
Prof. Hugo Águas (i3N| CENIMAT) - Microfluidics

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Thank you for your kind attention!

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