ScuDo
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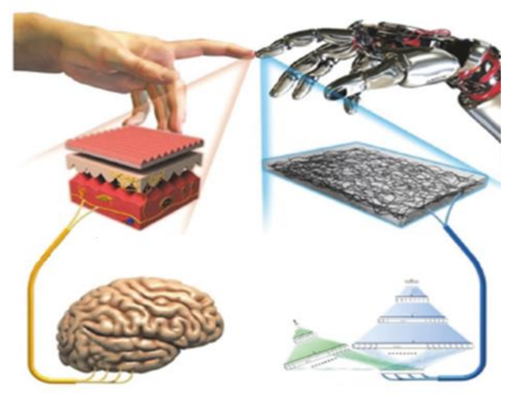
38th Cycle

Flexible smart sensors development for human signals biomonitoring

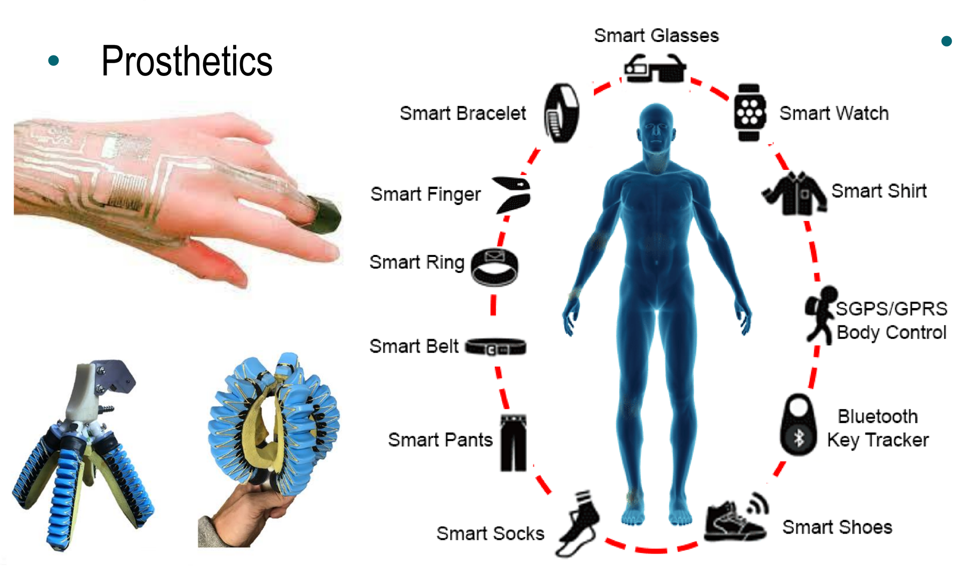
Giorgio Mogli
Supervisor: Stassi Stefano, Candido Pirri

Research context and motivation

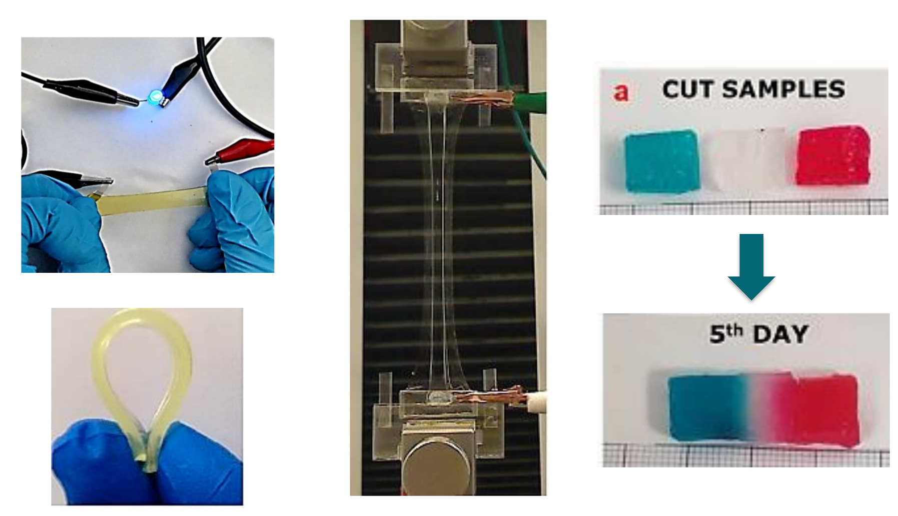
- The exponential expansion of technology has enhanced the need to interface the soft human world with the robotic one.
- **Tactile or smart sensors**, namely devices that can mimic the human tactile system sensing external stimuli, could serve as a bridge between the living soft tissues and the rigid electronic components.
- **Hydrogels** are optimal candidate to produce flexible sensors due to the tunability of their mechanical and electrical properties.



Applications:
- Soft robotics
- Wearables
- E-skin
- HMI
- Prosthetics



Tactile sensors main features:
- Flexibility
- Stretchability
- Self-healing
- Sensitivity
- Durability
- Multimodal sensing
- Conductivity
- Biocompatibility

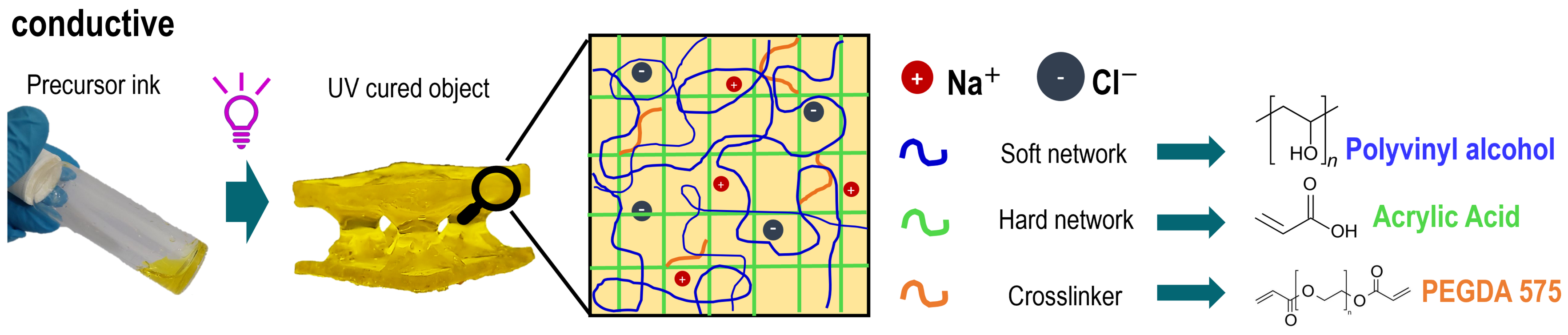


Addressed research questions/problems

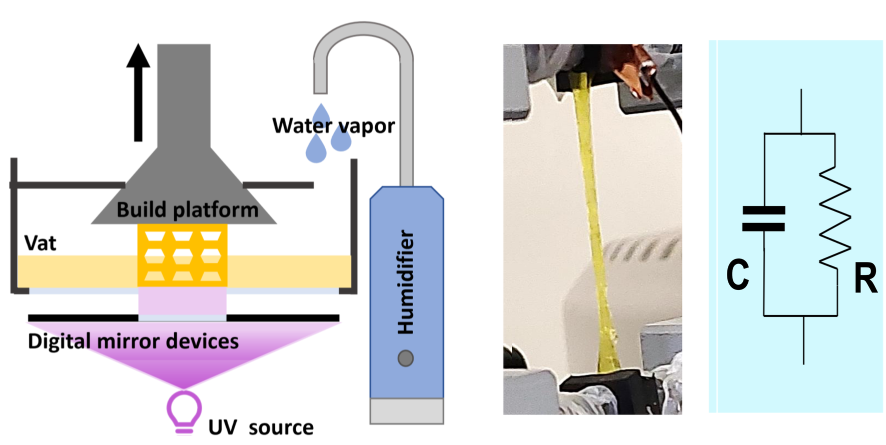
- **Developing** a tactile sensor that includes the greatest number of the previously mentioned features exploiting **3D manufacturing**
  - → Complex geometries, quick manufacturing, low materials waste.
- Producing sensors with **complex geometries** that could improve their sensitivity
- **Characterizing** the tactile sensor both **mechanically** and **electrically**
- **Human bio-signals** monitoring
- **Power supply**

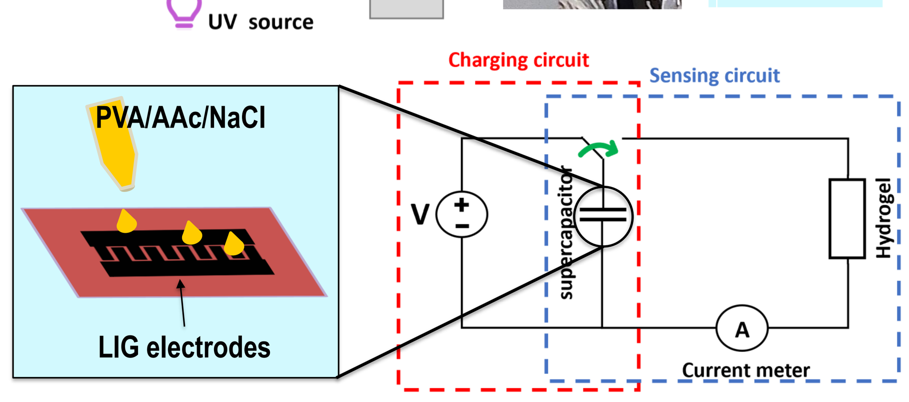
Adopted methodologies

- **Dissolving NaCl** in the precursor solution of a UV curable hydrogel (**PVA/AAc/PEGDA**)[1] to make it **ionically conductive**



- **DLP (Digital Light processing)** 3D printing of the ink through the support of a **humidifier** → water evaporation during printing reduced
- LCR meter (1000 Hz, 50 mV) for electrical test, modelling its impedance as a **resistor parallel to a capacitor**
  - → **piezoresistance / piezocapacitance modes**
- **Tensile** and **compression** analyses coupled with electrical measures
- Coupling with an interdigited **LIG supercapacitor**[2] that owns the same PVA/AAc/NaCl hydrogel as electrolyte, analyzed → **self powered integrated system**





[1] M. Caprioli, I. Roppolo, A. Chiappone, L. Larush, C. F. Pirri, S. Magdassi, Nat Commun 2021, 12, 2462. https://doi.org/10.1038/s41467-021-22802-z
[2] P. Zaccagnini, A. Lamberti, Appl Phys Lett 2022, 120, 100501. https://doi.org/10.1063/5.0078707

Publications

- Published works: 1 journals,
- Submitted works: 2 journals
- Mogli, G., Chiappone, A., Sacco, A., Pirri, C. F., & Stassi, S. (2023). Ultrasensitive Piezoresistive and Piezocapacitive Cellulose-Based Ionic Hydrogels for Wearable Multifunctional Sensing. ACS Applied Electronic Materials, 5(1), 205–215. https://doi.org/10.1021/acsaelm.2c01279

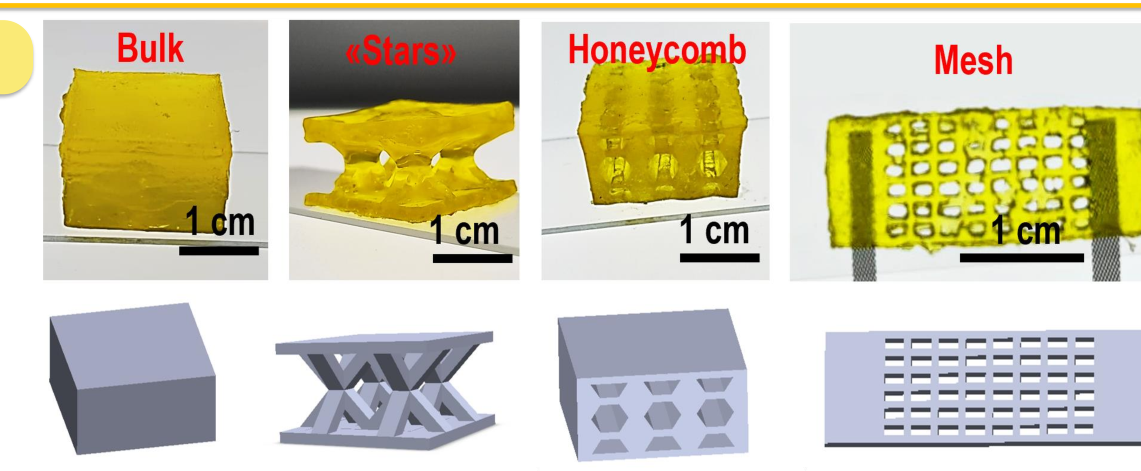
Novel contributions

3D printability

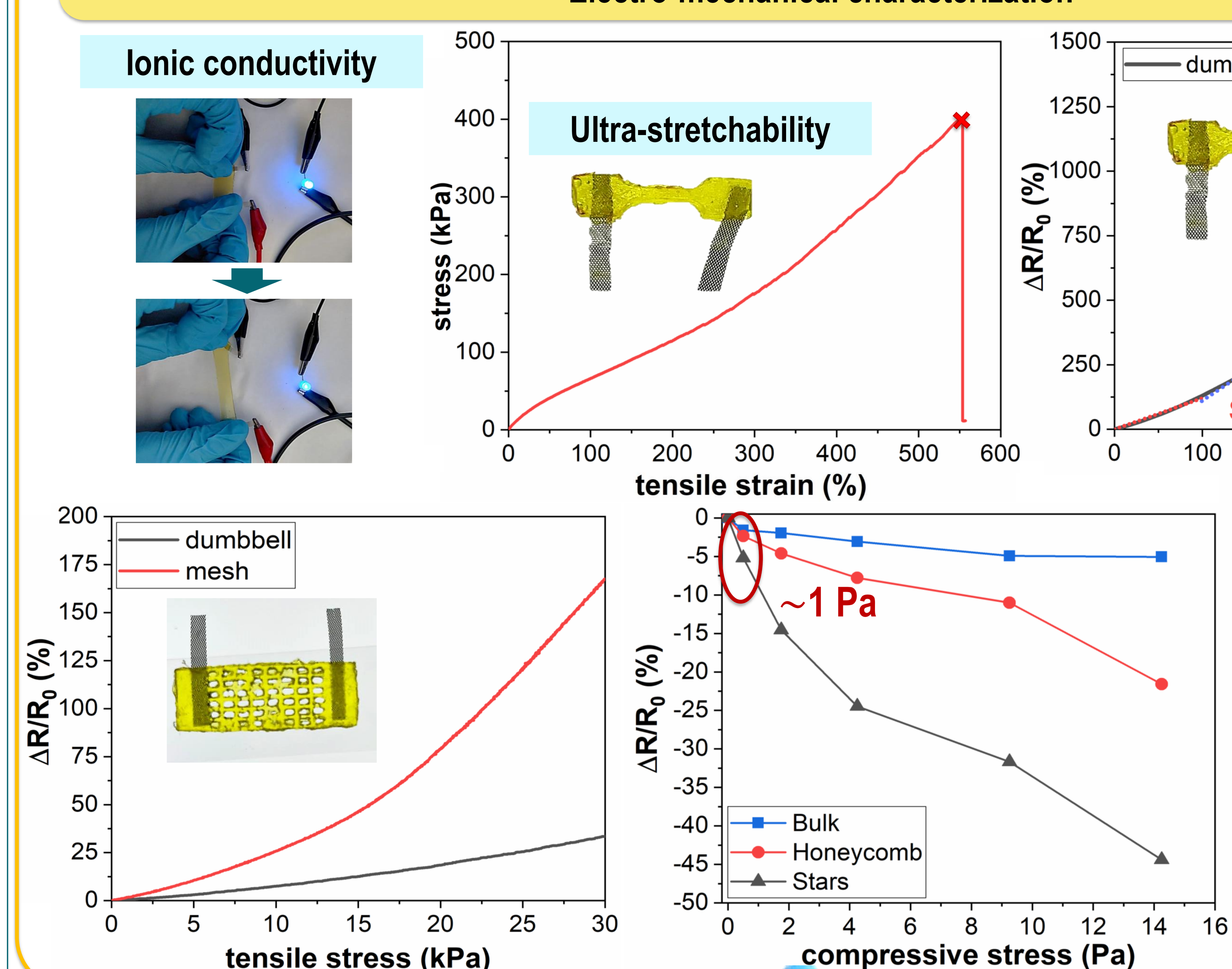
Concentration of **1 M NaCl** ensures the best trade-off between **conductivity** and **viscosity** of the precursor solution

↓

3D printable through DLP technique



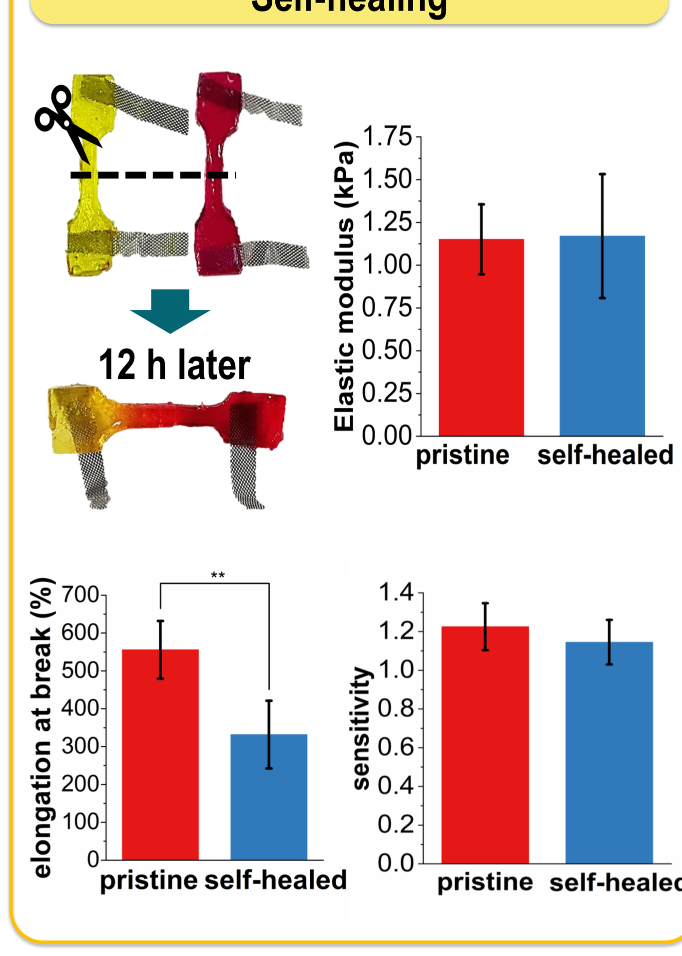
Electro-mechanical characterization

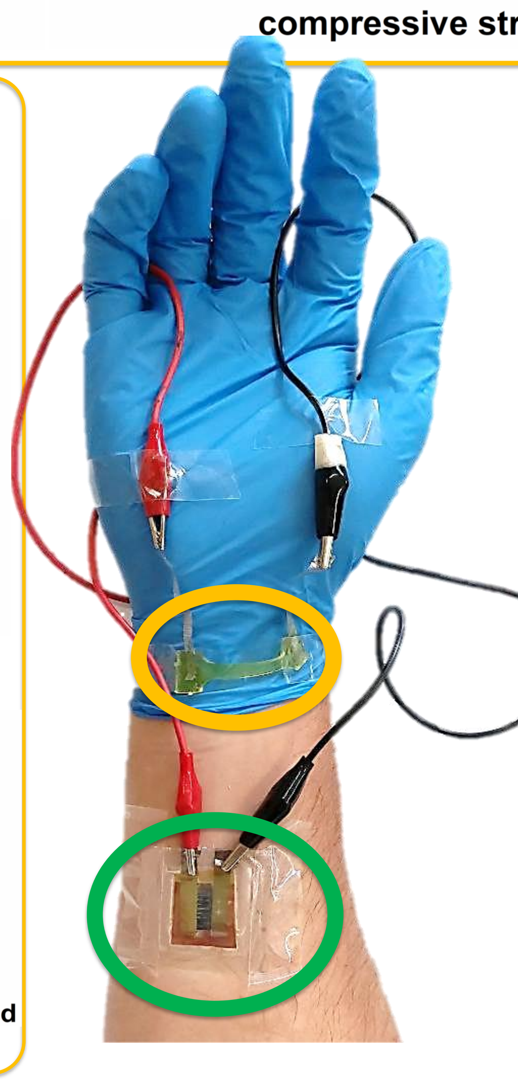


Complex geometries improve **stress** and **pressure sensing** abilities

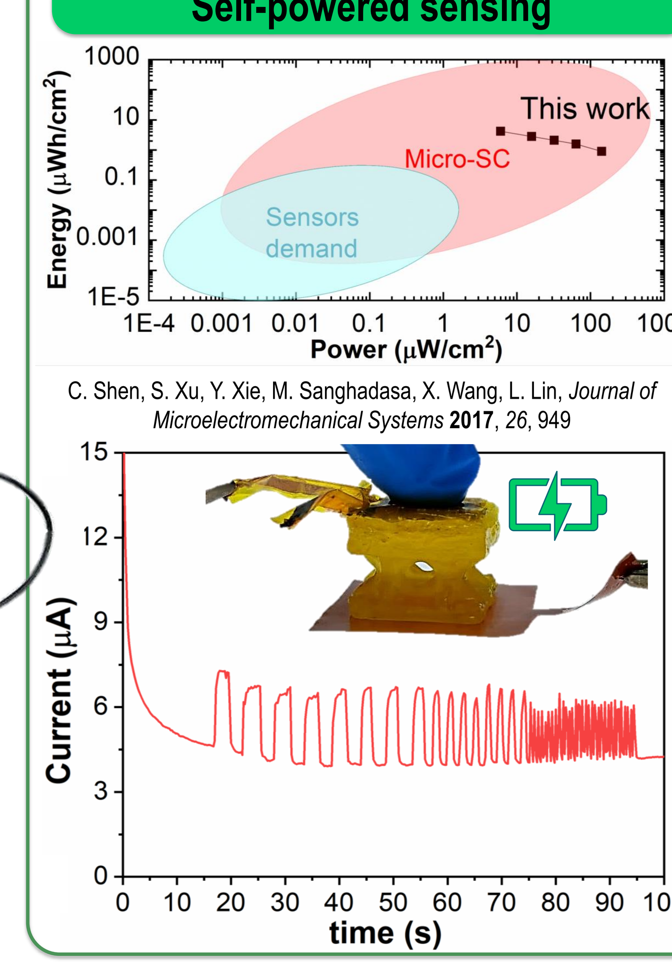
Low pressure detection limit

Self-healing



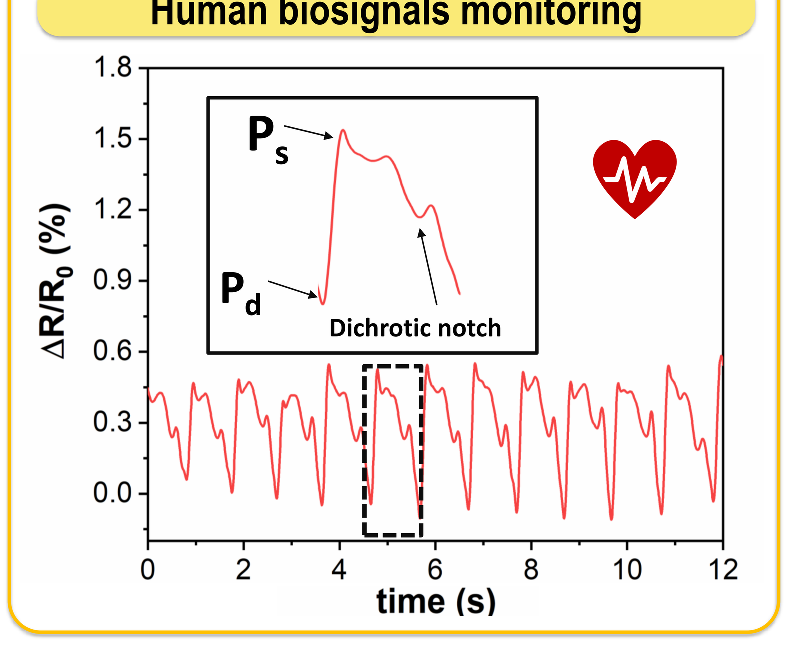


Self-powered sensing

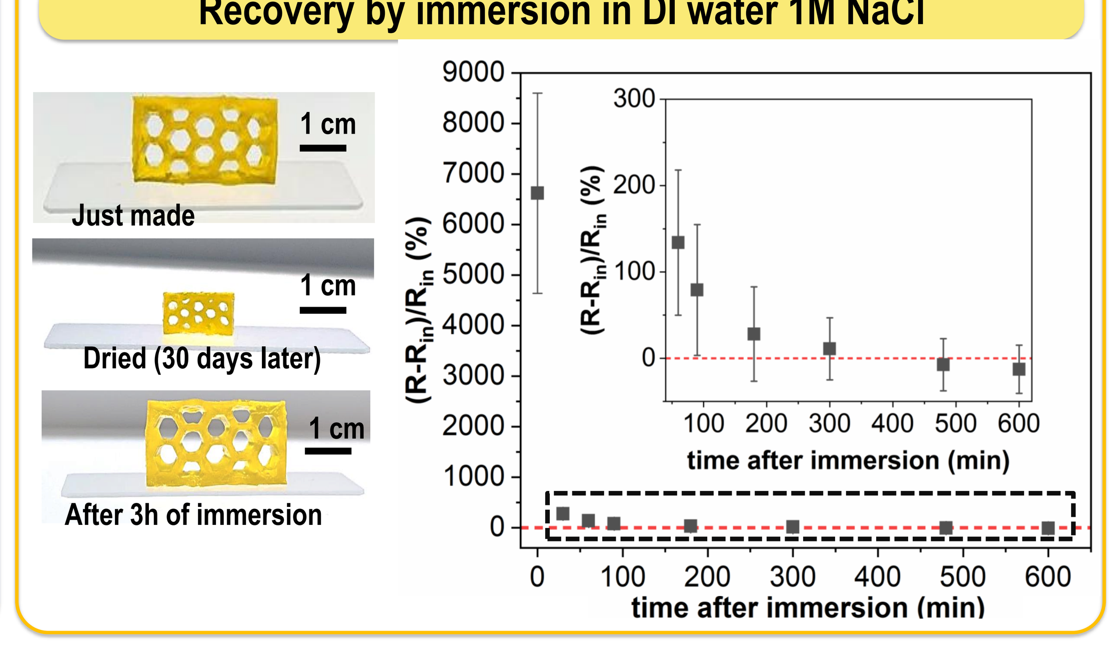


C. Shen, S. Xu, Y. Xie, M. Sanghadasa, X. Wang, L. Lin, *Journal of Microelectromechanical Systems* **2017**, *26*, 949

Human biosignals monitoring



Recovery by immersion in DI water 1M NaCl



Future work

- Improve **durability** of sensors using a **binary solvent** (glycerol/water)
- Testing **temperature sensitivity**
- Further test on the sensor-supercapacitor integrated system
- Substituting the present materials with more **environmentally-friendl**y and **biocompatible** ones (GelMa, Chitosan)
- **Skin compatibility** test
- **Piezoionic effect** investigation

Politecnico di Torino

PhD program in
Electrical, Electronics and Communications Engineering