

# Advancements in soft robotics and liquid state energy harvesting



Matteo Bevione<sup>1,2</sup>, Erik Garofalo<sup>3</sup>, Andrew Adamatzky<sup>4</sup>, Loghman Jamilpanah<sup>1</sup>, Alessandro Chiolerio<sup>3</sup>, Giulia Tagliabue<sup>2</sup>, Artur Braun<sup>1</sup>

<sup>1</sup> Swiss Federal Laboratories for Materials Science and Technology – Laboratory of High Performance Ceramics - Dübendorf, <sup>2</sup> École Polytechnique Fédérale de Lausanne – Laboratory of Nanoscience for Energy Technologies - Lausanne, <sup>3</sup> Istituto Italiano di Tecnologia – Genova, <sup>4</sup> University of the West of England Bristol

#### ABSTRACT

COlloIdal demonsTratOR (COgITOR) project aims to build a soft robot which:

- Obtains energy from its ambient environment to maintain a self-sustained life;
- Can withstand harsh conditions to guarantee reliability in any environment;
- Has a liquid core to guarantee softness and high deformability;
- Achieve memory, computing and sensing capabilities for the detection of external stimuli;

# **FUTURE WORKS**

- Enhance heat transfer by modifying the frame materials and geometry;
- Study dependence of generated power on the colloid concentration;
- Enhance photo-thermal conversion by introducing alternative plasmonic materials: transition metal nitrides;
- Realization of multiphase fluids and investigation of their dynamics under the influence of external stimuli.

• Allow self-monitoring of its structure.



## **OBJECTIVES**

The realization of an energetically self-sustained soft robot allows:

- Use in targeted environment for a long period of time;
- Overcome limitation of conventional robotics: enhanced adaptability;
- Reduction of environment impact;
- Distribute sensing  $\rightarrow$  Robot "consciousness".

### **APPROACH AND FIRST RESULTS – ENERGY HARVESTING**



- Possibility of relying on other physical effects for energy harvesting;
- Embed nanoparticles in polymeric soft skin to study the local self-healing capabilities;
- Investigate the sensing capabilities and the dependence on the geometry of nanofluid encapsulated in microstructures.



- Coupling among thermal and magnetic field occurring in a magnetic colloid, thermo-magnetic convection is exploited.
- Temperature dependence of nanoparticles magnetization provokes the coupling among Rayleigh-Bénard convection and magnetic advection.
- Unbalanced mass transport in cold and hot regions which translates in a variation of magnetic flux inside the fluid and consequently to electro-motive force.
- Voltage difference recorded in time shows that, upon heating, an electro-motive force is induced in a coil of wire, proving the quality of our approach



#### **APPROACH AND FIRST RESULTS – LIQUID LOGIC GATE**

• The first investigation aims to achieve the robot to sense of magnetic fields by tuning its optical transmission properties.

#### REFERENCES

- M. Bevione, E. Garofalo, L. Cecchini, A. Chiolerio, "Liquid-state pyroelectric energy harvesting", MRS Energy and Sustainability, vol. 7, 2020
- E. Garofalo, M. Bevione, L. Cecchini, F. Mattiussi, A. Chiolerio, "Waste heat to power: technologies," current applications, and future potential", Energy Technology, vol. 8, 2020
- E. Garofalo, L. Cecchini, M. Bevione, A. Chiolerio, "Triboelectric characterization of colloidal TiO2 for energy harvesting applications", Nanomaterials, vol. 10, 2020
- A. Chiolerio, E. Garofalo, M. Bevione, L. Cecchini, "Multiphysics-Enabled Liquid State Thermal Harvesting: Synergistic Effects between Pyroelectricity and Triboelectrification", Energy Technology, vol. 9 (2021)
- E. Garofalo, M. Bevione, L. Cecchini, A. Chiolerio, "On the pyroelectric and triboelectric phenomena in *ferrofluids*", ACS Materials & Interfaces (*In press*)

#### **ACKNOWLEDGEMENT AND CONTACTS**



The authors acknowledge the European Commission and the project Horizon 2020 for funding the COgITOR project (no. 964388). A particular thank to Dr. Frank Clemens and Somashree Mondal for the 3D printing of the prototype;

matteo.bevione@empa.ch - matteo.bevione@epfl.ch

https://www.cogitor-project.eu/







ISTITUTO



**Poster Day 2021** École Polytechnique Fédérale de Lausanne – Lausanne

