M1 & M2 internship

(PhD possible, funding to be secured)

In Institut de Physique de Nice
CNRS & Université Côte d'Azur

Synthetic autonomous chemomechanical actuators

Experimental and/or numerical and/or theoretical studies

Context – The existence of living organisms is evidence that functional motile autonomous materials can be built using macromolecules. However, engineering polymeric materials that possess these properties remains a longstanding goal, with sought-after applications in infrastructures inspections, programmable matters and smart medecine [1]. During this internship, we will create synthetic autonomous chemomechanical polymeric materials made of hydrogels doped with an oscillating reaction, such as the Belousov Zhabotinsky (BZ) oscillator or the DNA-enzyme oscillator. In the BZ reaction, an autocatalytic activator drives the catalyst to its oxidized state and generates an inhibitor that returns the catalyst to its reduced state. The cyclic change of the oxidation state of the catalyst induces the oscillatory swelling of the gel [2,3]. A hydrogel containing an oscillating reaction also possesses the ability to sense its environment. Indeed, during its chemical oscillations, the BZ gel releases chemical products through diffusion in its surroundings. A change of its environment, either by imposing a physical boundary or by the presence of neighboring gels, will directly affect its oscillation pattern. Numerous studies are possible on this system and the candidate can choose the topic that motives them most. For example, 1) one can study the chemomechanical energy conversion of these gels by quantifying the cyclic strain and stress they generate, 2) one can make a metamaterial such that the autonomous hydrogel can fully swell and deswell during a chemical oscillation, 3) one can investigate the chemical communication between two or more oscillating hydrogels, 4) one can study numerically and theoretically how to design motile autonomous hydrogels from chemomechanical hydrogels, 5) one can envision to design a chemical language with this oscillating hydrogel microreactor [4].

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[1] Merindol, R., et al. "Materials learning from life: concepts for active, adaptive and autonomous molecular systems." Chemical Society Reviews 46.18 (2017): 5588-5619.
[2] Yoshida, R., et al. "Self-oscillating gel." JACS 118.21 (1996): 5134-5135.
[3] Blanc, B., et al. "Active Pulsatile Gels: From a Chemical Microreactor to a Polymeric Actuator." Langmuir, 40(13) (2024), 6862-6868.
[4] Bollt, E. M., et al. (1997). "Encoding information in chemical chaos by controlling symbolic dynamics." Physical Review E, 55(6) (1997), 6404.