Synthesis and characterization of biobased and biocompatible ionic gels and ionoelastomers for piezoionic skin and ionotronics

(LPPI – CY Cergy Paris Université, France / MML, University of British Columbia, Canada)

In recent years, the field of materials science has witnessed a surge of interest in the development of ionically conducting gels for a myriad of emerging applications, including artificial muscles, electroactive textiles, piezoionic artificial skins, and more generally in ionotronics (ionic cable, electrodes, transistors…). These advanced gels, with their remarkable ion transport properties and unique mechanical characteristics, have the potential to revolutionize various industries, ranging from robotics and healthcare to energy and textiles. Continued research in this field promises to unlock novel functionalities, improves device performances and shapes the future of advanced materials and technologies.

Among these materials, ionic conducting hydrogels, i.e. polymeric networks percolated with an aqueous electrolyte, are by far the most described, combining high ionic conductivity, stretchability and biocompatibility, but suffer from fast drying, incompatible with open-air applications. On the other side, ionogels, where the electrolyte is a room temperature molten salt - also referred as ionic liquid - solve these drying and stability issues, but the increasingly recognized toxicity of some of the ionic liquids restricts the range of chemicals available when considering skin contact.[1,2] Finally, ionoelastomers, based on the crosslinking of polymeric or polymerized ionic liquids (PILs), provide all-solid-state (no liquid electrolyte phase) and stretchable ionic conducting materials but usually present ionic conductivity lower by 2 or more orders of magnitude due to the lower mobility of their free ions. In addition, their biocompatibility remains questionable due to their ionic liquid-like charge carriers. [3,4]

The objective of this 3-years PhD project at LPPI (https://lppi.cyu.fr/) is the development of new air-stable and biocompatible ionic gels and ionoelastomers, based on biobased materials suitable for contact with human skin, for applications such as piezoionic skin and ionotronic devices. Biopolymers (alginate, hyaluronic acid, gelatin, κ-carrageenan, chitosan, agar…) will be combined with or modified by recently described biofriendly ionic liquids (choline lactate, choline acetate, …) or natural deep eutectic solvents. These materials will be synthesized and characterized to provide a better insight on the parameters ruling the piezoionic performances. The best candidate materials will be then optimized to be later integrated in devices such as piezoionic i-skin for soft robotic. The possibility to fabricate these materials by additive manufacturing (3D-printing) will be explored as well. The introduction of dynamic covalent bonds would be finally investigated in order to provide self-healing functionality to these emerging materials, pushing further their biomimetic features.

The PhD work will involve up to 12 month visit in the Molecular Mechatronics Lab in the Department of Electrical & Computer Engineering at the University of British Columbia (UBC) in Vancouver (Canada) under the co-supervision of Pr. John Madden (https://ece.ubc.ca/john-madden/) under the Visiting International Research Student and Joint Doctoral Research Scholar Program. Pr. Madden coined the term “piezoionics”, and is investigating methods of increasing voltage generation in piezoionic materials by employing large ions, as commonly found in ionic liquids. [5,6] The PhD candidate will integrate the best piezoionic materials developed at CY into functional sensing devices, build the low-voltage flexible electronics used to drive the developed devices and characterize their sensing performances. Subsequently, if time allows, efforts will be pushed towards manufacturing ionic cables capable of transducing the electrical signal mimicking nerves. Creating junctions between these artificial nerves with the patient's nervous system would open the doors to the future integration of prostheses equipped with haptic feedback.

Candidate profile.

With a master degree in chemistry (ideally polymer chemistry and/or physical-chemistry), the highly motivated candidate will have an excellent scientific level, a strong multidisciplinary interest and a good adaptation capacity. The candidate must also have excellent communication skills and be fluent in English (both oral and written). An experience in electrochemistry and/or in electrical and mechanical engineering would be an advantage.

Host institution: CY Cergy Paris Université

The recruited PhD student will be enrolled in the doctoral program of the doctoral school Science and Engineering at CY Cergy Paris Université (https://www.cyu.fr/english-version). LPPI gathers 20 staff researchers and between 20 to 30 PhD students and postdocs in a motivating and innovative environment. The team is the result of collaboration between chemists, electrochemists, physico-chemists of polymers and of surfaces and interfaces. LPPI has an internationally recognized experience in the development of electroactive polymers, soft actuators and sensors, especially based on the synthesis and combination of electronic and ionic conducting materials.

How to apply

Send your resume, motivation letter, Master diploma marks and ideally recommendation letters before April 21st 2024 at: cedric.plesse: cedric.plesse@cyu.fr

---

1) Vitrimer ionogels towards sustainable solid-state electrolytes, Fengdi Li, Giao T. M. Nguyen, Cédric Vancaeyzeele, Frédéric Vidal, Cédric Plesse, RSC Advances, 2023,13, 6656-6667

2) Large stroke coiled CNT-based artificial muscle coated with polycationic and polyanionic 1 solid state ionogels for in open air electro-actuation, Bin Ni, Frédéric Braz Ribeiro, Cédric Vancaeyzeele, Giao T. M. Nguyen, Edwin W. H. Jager, Frédéric Vidal, Cédric Plesse, Applied Materials Today, 2023, 31, 101756

3) Highly Stretchable and Ionically Conductive Membranes with Semi-Interpenetrating Network Architecture for Truly All-Solid-State Microactuators and Microsensors, Frédéric Braz Ribeiro, Bin Ni, Giao T. M. Nguyen, Eric Cattan, Alexander S. Shaplov, Frédéric Vidal, Cédric Plesse, Advanced Materials Interfaces, 2023, 10, 10, 202381

4) Healable ionoelastomer designed from polymeric ionic liquid and vitrimer chemistry, Fengdi Li, Giao. T. M. Nguyen, Cédric Vancaeyzeele, Frédéric Vidal, Cédric Plesse, ACS Appl. Polym. Mater., 2023, 5, 1, 529–541

5) Piezoionic mechanoreceptors: Force-induced current generation in hydrogels, Yuta Dobashi, Dickson Yao, Yael Petel, Tan Ngoc Nguyen, Mirza Saquib Sarwar, Yacine Thabet, Cliff L. W. Ng, Ettore Scabeni Glitz, Giao Tran Minh Nguyen, Cédric Plesse, Frédéric Vidal, Carl A. Michal, John D. W. Madden, Science, 2022, 376, 6592, 502-507

6) 3D-Printed Stacked Ionic Assemblies for Iontronic Touch Sensors, Jérémy Odent, Nicolas Baleine, Valentin Biard, Yuta Dobashi, Cédric Vancaeyzeele, Giao T. M. Nguyen, John D. W. Madden, Cédric Plesse, Jean-Marie Raquez, Advanced Functional Materials, 2023, 33, 3, 2210485