Research Topic for the ParisTech/CSC PhD Program

Subfield: Polymer physical chemistry, Polymer physics, Mechanics

ParisTech School: ESPCI Paris

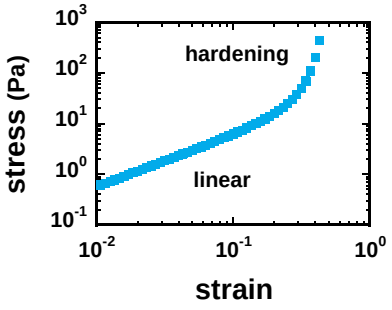
Title: Mechanics and Fracture of Ultrasoft Hydrogels made of Giant Polysaccharide

Advisors: Tetsuharu Narita (tetsuharu.narita@espci.fr)
Costantino Creton (costantino.creton@espci.fr)
Web: https://www.simm.espci.fr/?lang=en
In collaboration with Tatsuo Kaneko (JAIST, Nomi, Japan)

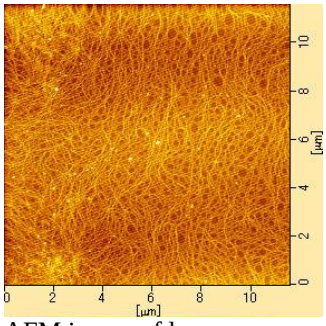
Short description of possible research topics for a PhD:

Hydrogels, networks of crosslinked polymers swollen in water, are important in food and biomedical industries due to their solid-like properties (rubber elasticity of the polymer network) and liquid-like properties (diffusion of the solvent and solutes). When the ratio between the gel surface tension and the elastic modulus is of the same order of magnitude as the sample size, surface tension can deform the soft solid and may play an important role in the way gels break or attach and detach from surfaces. This coupling between capillarity and elasticity has been recently pointed out and has opened the field of ultra-soft solids. The objective of the proposed thesis is to clarify how surface tension of ultra-soft gels controls how they break. The project is composed of three parts: (1) synthesis of well defined ultrasoft hydrogels, (2) Rheological and interfacial properties of the ultra-soft gels, and (3) Fracture mechanisms and properties. The Bio model system will be a novel giant polysaccharide "sacran", extracted from the extracellular matrix of a Japanese fresh water cyanobacteria. This polysaccharide has a Mw > 10^7 g/mol and can be chemical crosslinked at low concentrations (about 0.1 wt%). The chains are semi-rigid and are good model systems for biological gels made of rigid protein filaments, whose fracture properties are not well known. Novel optical rheometry and tensiometry developed in the laboratory will be used.

Typical "pure shear" experiment for fracture of hydrogels developed in the laboratory.



Shear stress vs strain amplitude.



AFM image of long sacran chains.

Required background of the student: materials science, physics, chemical engineering

A list of 5 representative publications of the group:

1. Mayumi, K.; Guo, J.; Narita, T.; Hui, C. Y.; Creton, C. *Extreme Mechanics Letters* **2016,** 6, 52-59.
2. Mayumi, K.; Marcellan, A.; Ducouret, G.; Creton, C.; Narita, T. *ACS Macro Letters* **2013,** 2, (12), 1065-1068.
3. Rose, S.; Dizeux, A.; Narita, T.; Hourdet, D.; Marcellan, A. *Macromolecules* **2013,** 46, (10), 4095-4104.
4. Creton, C.; Ciccotti, M. *Rep Prog Phys* **2016,** 79, (4), 046601.
5. Okajima, M.K.; Kaneko, D.; Mitsumata, T.; Kaneko, T.; Watanabe, J. Macromolecules **2009**, 42(8), 3057-3062.