Research Topic for the ParisTech/CSC PhD Program

Subfield: Polymer materials and chemistry, Mechanics, Material science
ParisTech School: ESPCI Paris-PSL
Title: Bridging Chemistry, Physics and Mechanics: Understanding how needles and blades damage chemical bonds in soft materials
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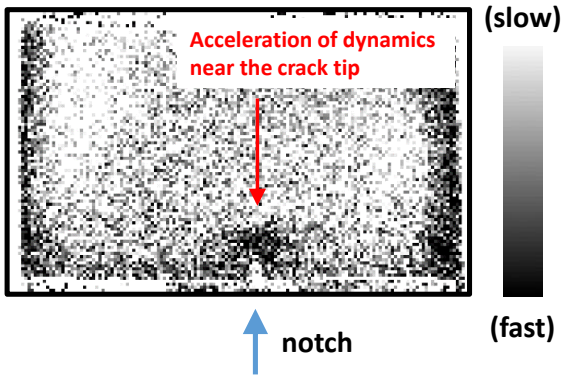
Short description of possible research topics for a PhD:
Hydrogels, networks of crosslinked polymers swollen in water, are soft squishy solids abundant in nature and everyday life and in food and biomedical industries. Although hydrogels are generally brittle, some tough hydrogels that are resistant to fracture have been developed. Especially for medical applications, biological tissues or artificial implants need to be incised, sutured and punctured by sharp blades or needles. While very common, this kind of mechanical damage combining very large deformations and chemical bond scission of the polymer is poorly understood and very multiscale. (1) molecules break at the nanometric scale, (2) local damage occurs at the microscopic scale, and (3) stress strain relation are at the macroscopic scale.

Recently our laboratory developed a low-force indentation by sharp needles, and a non-invasive optical technique MSDWS (multi-speckle diffusing-wave spectroscopy), to map the local dynamics change felt by probe nanoparticles in the network, related to the damage at the microscopic scale.

The objective of this thesis is to combine mechanical (see left figure) and dynamic light scattering optics (right figure), to map the local damage (to know when and where chain breaking occurs) of the gel as it is indented or cut with a sharp object like a needle, blade or sharp edged cylinder and ultimately design better puncture and cutting resistant gels.

The overall thesis project involves preparing well defined model soft hydrogels, developing an original setup combining the two techniques, and characterizing the fracture properties of the model systems.



Required background of the student: polymer materials, mechanics, soft matter physics

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. Ducrot, E., Chen, Y., Bulters, M., Sijbesma, R.P., Creton, C. Science 2014, 344(6180), 186.