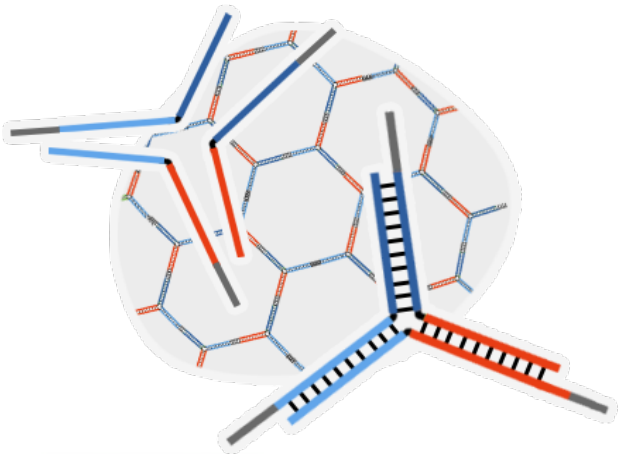
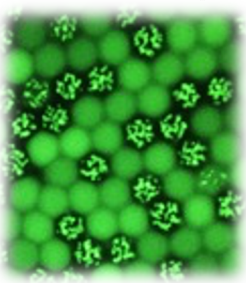
DNA Nanotechnology

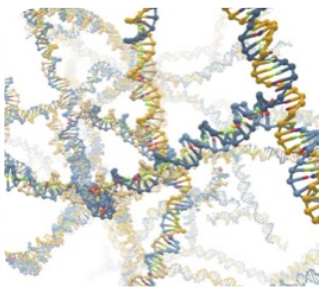
PhD thesis between CNRS and University of Tokyo
Mechanical designs of DNA hydrogels

Keywords: **DNA gels, rheology, microfluidics**

By programming DNA strands to mutually bind to each other, one can assemble DNA into an extended molecular network: a DNA gel. These hydrogels hold great promises in domains ranging from drug delivery to regenerative medicine. Yet we do not have a clear understanding of how their structures at the nanoscale impact their mechanical properties at the macro scale.







In this PhD, the student will mobilize physical techniques (micro and macro rheology, microfluidics, calorimetry) to understand the mechanical behaviors of DNA gels, and build on this understanding to design new DNA hydrogels with innovative mechanics

This PhD will be carried out between **Grenoble**, **Lyon** and **Tokyo**, with a timing of stays in Japan to be discussed with the candidate.

New skills to be learned:

- ❑ **DNA nanotechnology**
- ❑ **Droplet microfluidics**
- ❑ **High-throuput data analysis**

Skills and Experience

- Motivated by working in an international environment
- Physics background
- Interest in data analysis

References:

[1] Genot, et al, *Nature Chemistry 2016*
[2] Okumura et al. Nanomaterials, 2021

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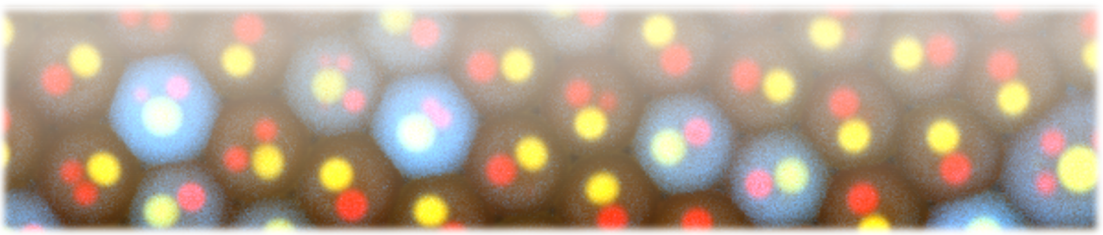
Want more background ?

Hydrogels are a major material for bioengineers to deliver drugs or grow tissue. However most gels have poor resistance to fracture and little self-healing properties. Conferring better mechanical properties to polymer gels is an ongoing struggle. In that respect, DNA has emerged as an ideal polymer to build hydrogels - being mechanically robust, chemically stable and enzymatically replicable. In its canonical form, a DNA gel is assembled by simply mixing 4 mutually complementary DNA strands. The strands bind to each other to form a X-shaped motif, and these X motifs bind to each other through sticky ends, forming an extended polymeric network: a gel. The nanoscale structure can be tuned by design, for instance by changing the number of arms or the length of the sticky ends.

Yet we lack a clear understanding of how the gel structure at the nanoscale relates to its physical properties at the macroscale, such as the resistance to fracture or energy dissipation. When submitting a gel to mechanical stimuli, the elastic regime is mostly entropic, but enthalpy plays a major role near fracture. DNA gels differ from usual polymer gels in that they are highly ordered and precisely self-assembled at the nanoscale by their sequence. DNA gels offer at the same time the entropic softness of soft-matter and the rigorous clockwork of top-down programming.

We propose to bridge the nano to the macro scale, by systematically investigating how the design of DNA motifs at the nanoscale influences the mechanics and thermodynamics of DNA gels at the micro and macro scales. Macroscale measurements will help design new pathways for gels to dissipate mechanical energy, to heal from fracture or to reconfigure when stressed. By working simultaneously at nano, micro and macro scales, we will establish a method for the rational design of functional DNA gels.



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