PhD thesis in programmable materials from cellulose

INRAE Biopolymers, Interactions and Assemblies, Nantes (France)

Co-directed by: Ana VILLARES and Bernard CATHALA

Starting date: September 2020

Employer: INRAE

Workplace: Biopolymers, Interactions and Assembly (UR 1268 INRA), Nanostructured Assemblies team.

This PhD will be developed at the Biopolymers Interactions and Assemblies (BIA) unit from the French National Institute for Food, Agriculture and Environment Research (INRAE) located in Nantes (France), more precisely in the Nanostructured Assemblies (Nano) team under the supervision of Ana Villares. Nano team focuses on the preparation of materials/arrangements with biopolymers from agricultural sources and the structural characterization of such nanostructures. The main research question deals with the structuration of elementary biobricks at nano and microscale in order to develop new properties (optical, transfer, controlled delivery, biological, etc.).

Context:
Cellulose consists of a linear chain of glucopyranose units linked by β-(1-4) glycosidic bounds. The formation of hydrogen bonds and van der Waals interactions promote parallel stacking of multiple cellulose chains forming elementary fibrils that further aggregate into larger microfibrils. Fibrillation releases long flexible and semi-crystalline cellulose nanofibers (CNF) consisting of alternating crystalline and amorphous regions, which are around 5-20 nm in width and several microns in length. The disordered twists and kinks (amorphous regions) can be hydrolyzed by acid treatments to isolate cellulose nanocrystals (CNC). CNC can be viewed as rigid rod-like crystallites whose dimensions are around 5-20 nm in width and 200-1000 nm in length, depending on their biological origin. Both CNC and CNF are used in many applications thanks to their amazing properties such as strengthening effect, and good mechanical and barrier properties to be exploited in nanocomposites, paper making, packaging, coating additives, membranes, or gas barriers.

PhD project:
This project aims at fabricating nanomachines from cellulose. The project will focus on the modification and assembly of nanocelluloses to obtain tailored architectures that respond to stimuli. For this purpose, we propose the following objectives:

1. To patchy modify nanocelluloses for introducing the desired functionalities and facilitating the supramolecular arrangement.

2. To assembly nanocelluloses onto ordered nanoarchitectures (dense hairy layers, graded films, controlled pore sized networks, and patterned surfaces) sensitive to external stimuli.

3. To fabricate programmable materials for applications as actuators (tweezers, levers…), in separation (filtration), and drug release and retention.

One strategy for the fabrication of nanomachines is the introduction of anisotropy in order to obtain an asymmetric response to stimuli. Anisotropy can be generated at different levels: (i) molecular, by the patchy modification of the structure; (ii) supramolecular, by the controlled and specific assembly; or (iii) macromolecular, by different approaches of structuration, such as the fabrication graded films (Figure 1).

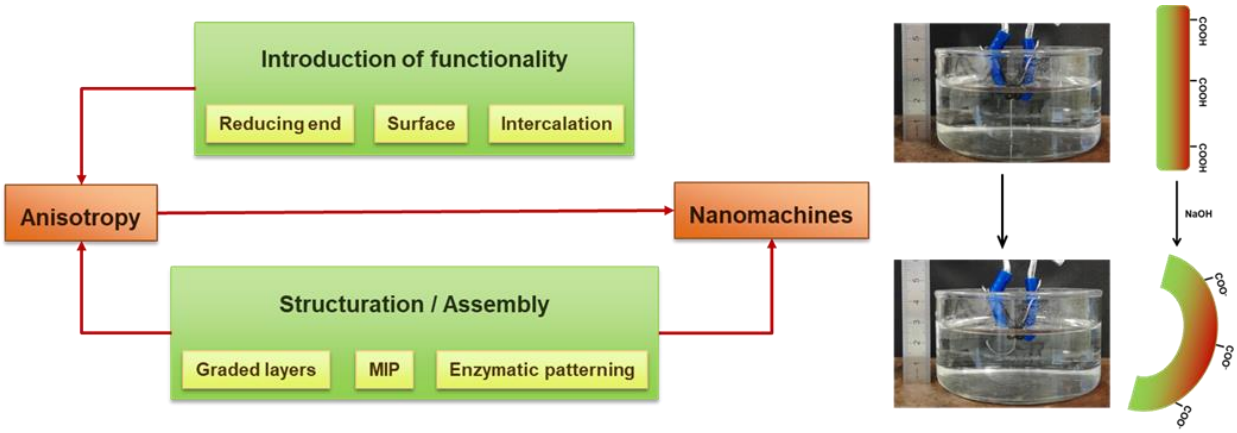

Figure 1. Left: Strategies for the fabrication of nanomachines driven by anisotropy. Right: Example of the bending of asymmetric films fabricated with graded layers of nanofibers de cellulose.

Candidate profile:

We look for a candidate having a strong team working ability, with education in physical chemistry or related. Knowledge of at least one of the following topics is particularly welcome: biopolymers, physical chemistry of biopolymers, nanotechnology.

Application procedure: Send a brief CV (maximum 2 pages), master grades and a cover letter to Ana Villares (ana.villares@inrae.fr) and Bernard Cathala (bernard.cathala@inrae.fr) including two references for possible recommendation.

Application deadline: March 27th

Selected candidates will be invite to oral selection on April 10th.

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