PhD position in Polymers and Supramolecular Chemistry
Oct 2023 – Sept 2026 – Le Mans (France)

Title : Janus nanorods by supramolecular self-assembly of polymers in solution	
Supervisor :	Olivier Colombani (50%), PhD supervisor Erwan Nicol (50%), PhD co-supervisor

Summary of the project

Janus nanorods (JNR) are asymmetrical polymeric nanoparticles consisting of two faces with different chemical natures. Their anisotropic shape, nanometric dimensions and different faces make such particles exciting for many potential applications, including the storage of information by nanolithography, which corresponds to the overall objective of the collaborative research project *JASUR* this PhD is part of. However, both the elaboration and properties of JNR have little been explored because of their extremely difficult preparation. Indeed, prior to our work,[1] only two methods existed in the literature to prepare Janus nanocylinders.[2,3]

We have very recently proposed an original strategy[1] to prepare JNR by supramolecular self-assembly in solution of two different polymers bearing complementary hydrogen bonding units. The hydrogen bonding units have been designed not only to drive the self-assembly into one-dimensional structures (nanorods), but also to force each polymer on either-side of the rods (Janus character) independently of the chemical structure of the polymer arms (Figure 1).

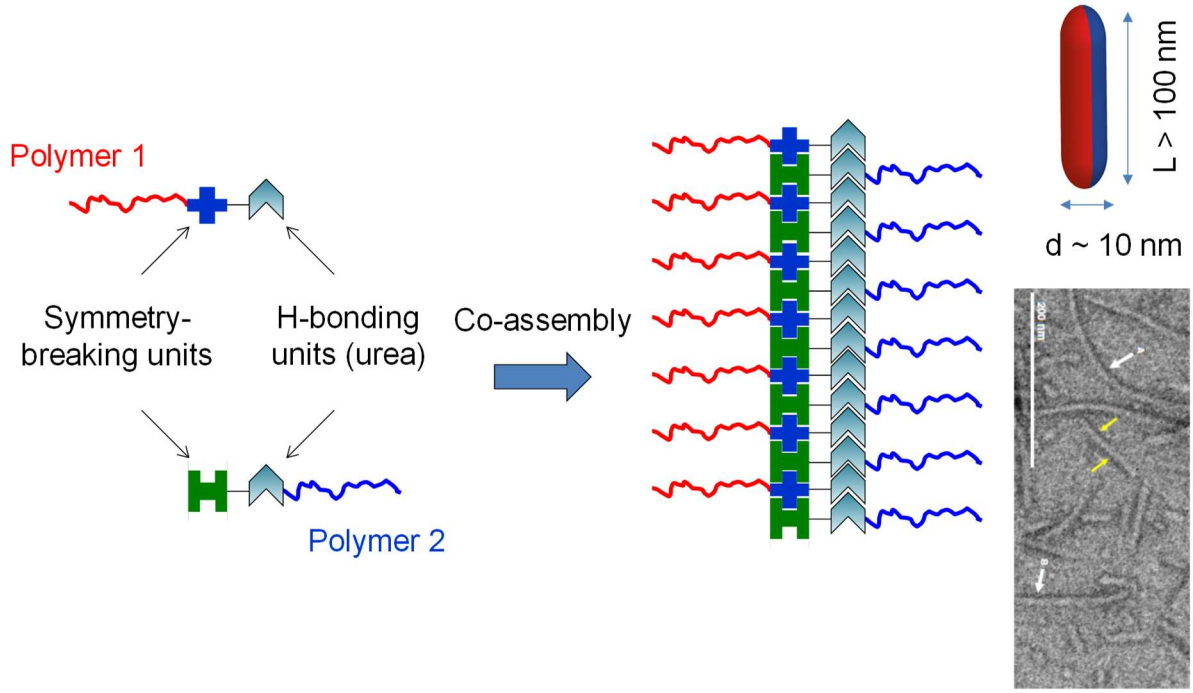

Figure 1. Schematic concept leading to JNR by supramolecular self-assembly in solution of hetero-complementary hydrogen bonding units driving the formation of nanorods and forcing each different polymer on either side of the JNR. The image corresponds to a Transmission Electron Microscopy picture where one type of arm has more contrast, proving the Janus character (the JNR possess one dark side and a lighter one).

Although this strategy has been proven successful, its full potential is far from being explored and many questions remain. For that reason, the objective of this PhD will be to:
- Explore the role of the preparation process on the characteristics of the JNR (length, diameter, dispersity) and determine the mechanism by which the JNR are formed in solution through hydrogen bonding.
- Investigate how changing the chemical structure and molar mass of the polymers affects their characteristics (length, diameter, dispersity, and functionality).
- Study new types of polymer arms and self-assembling units to provide ICMN, one of the partners of the project, with JNR suitable for exploring surface patterning in view of nanolithography applications.
To treat these questions, state-of-the art physico-chemical characterization techniques of polymers will be used including: light, X-ray and neutron scattering, Transmission Electron Microscopy (also in cryo-mode), UV-Vis and DOSY/NOESY NMR spectroscopy in particular.

Three partners will work in close collaboration during this research project: IPCM (L. Bouteiller's team, Paris) is in charge of the synthesis of the polymers and has already designed some of the polymers which will be used during the project. IMMM (our team, Le Mans) and the PhD recruited on this position will be in charge of the elaboration of the JNR by supramolecular self-assembly in solution as detailed above. ICMN (Christophe Sinturel's team, Orléans) will be in charge of the deposition of the JNR onto surfaces to pattern them for potential applications in nanolithography for information storage. The PhD recruited at IMMM will have the opportunity to visit the other partner's laboratory to get some knowledge about the scientific expertise of the other partners and will communicate his/her results on a regular basis to the other partners.

Dates and salary
Acquired financial support: French National Research Agency ANR-PRC 2022-2026
Salary: 1400-1600 euros / month
Ideal starting date: October 2023
Expected profile
Polymer scientist and/or physical chemist having an interest in the characterization of polymer supramolecular self-assemblies in solution.
Experience in light, X-ray or neutron scattering, Transmission Electron Microscopy, or supramolecular self-assembly would be an asset.
Key words
Polymer physical-chemistry, Self-assembly in solution, Supramolecular chemistry, Nanocylinders, Janus particles, light/X-ray/neutron scattering, Transmission Electron Microscopy.

Polymer-related research skills acquired during the project
Supramolecular self-assembly of polymers in solution
Polymer chemical structure / Polymer self-assembling behaviour relationships
Light/X-ray/neutron scattering, Electron microscopy
General polymer knowledge
General research skills acquired during the project
Bibliographic survey, analysis and interpretation of results, autonomy, critical thinking, teamwork, oral and written presentation of results (English/French), writing of articles.

Location, contact

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References

1. Han, S.; Pensec, S.; Yilmaz, D.; Lorthioir, C.; Jestin, J.; Guigner, J.-M.; Niepceron, F.; Rieger, J.; Stoffelbach, F.; Nicol, E.; Colombani, O.; Bouteiller, L., *Straightforward preparation of supramolecular Janus nanorods by hydrogen bonding of end-functionalized polymers*. **Nat. Commun.** 2020, 11, 4760.
2. Danial, M.; My-Nhi Tran, C.; Young, P. G.; Perrier, S.; Jolliffe, K. A., *Janus Cyclic Peptide-Polymer Nanotubes.* **Nat. Commun.** 2013, 4, 2780.
3. a) Liu, Y.; Abetz, V.; Müller, A. H. E., *Janus Cylinders*. **Macromolecules** 2003, 36, 7894-7898; b) Walther, A.; Drechsler, M.; Rosenfeldt, S.; Harnau, L.; Ballauff, M.; Abetz, V.; Müller, A. H. E., *Self-Assembly of Janus Cylinders into Hierarchical Superstructures.* **J. Am. Chem. Soc.** 2009, 131 (13), 4720-4728.