SORBONNE UNIVERSITÉ

CHINA SCHOLARSHIP COUNCIL

Appel à projets
Campagne 2022
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Title of the research project :

Bioinspired Smart Fibre Processing

Thesis supervisor (HDR) :

Name :

Surname :

Title : Professor

email :

Professional adress :
(site, dresse, bulding, office…)

Research Unit

Name : INstitut des NanoSciences de Paris

Code *(ex. UMR xxxx)* :

Doctorate School

Thesis supervisor's doctorate school (candidate's futur doctoral school) : ED397

PhD student currently supervised by the thesis supervisor (number, year of the first inscription) :

SORBONNE UNIVERSITÉ

Joint supervisor :

Name : Surname :

Title :

email :

Professional adress :
(site, dresse, bulding, office…)

Research Unit

Name :

Code *(ex. UMR xxxx)* :

École doctorale

Joint supervisor's doctorate school : Or, if non SU :

PhD student currently supervised by the joint supervisor (number, year of the first inscription) :

Joint supervisor :

Name : Surname :

Title :

email :

Professional adress :
(site, dresse, bulding, office…)

Research Unit

Name :

Code *(ex. UMR xxxx)* :

École doctorale

Joint supervisor's doctorate school : Or, if non SU :

PhD student currently supervised by the joint supervisor (number, year of the first inscription) :

2021-2022

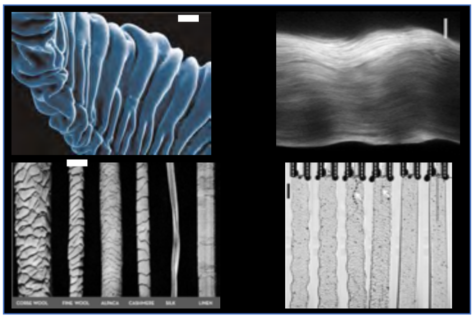
PhD proposal

Campus Pierre et Marie Curie
Tower 22 – 3rd floor – 22-23
Director: Massimiliano Marangolo

Title: BIOINSPIRED SMART FIBRE PROCESSING

Keywords: Biomimetic material processing, Biopolymers, Strength of Materials, elastic and fluid instabilities

Context: Nature remains a highly inspirational source of *structures* with remarkable properties suitable to meet the strong demand for innovative smart soft materials for tissue engineering, soft robotic, energy harvesting.... Unfortunately, natural *processes* involving cells and their extracellular matrix are generally too complex to be directly implemented. This project proposes to rely on purely physical processes in order to mimic remarkable structural features of natural fibres.
Fibres are ubiquitous in Nature. Spider silk, mussel byssus, tendons, wool, among others, are examples of slender, flexible threads which fulfil desirable structural functions: shock absorption, mechanical impedance adaptation between hard and soft substrates, resistance to environmental aggression such as fluid erosion or dehydration, adhesion control, self-assembly (felting)... These properties can often be traced down to supramolecular features such as fibril alignment or waviness (crimp), axial or radial gradient structuration, wrinkles or scales tessellation (see figures A–C). Whereas the bio-chemical role of the molecular building bricks – usually proteins – cannot be overlooked, larger scale *physical mechanisms* are certainly involved in the overall spinning process.



A: Wrinkled cuticle of a mussel byssus (SEM) Pocivasek et al 2018. B: Crimped collagen fibrils of rat-tail tendon (SHG microscopy. Houssen et al 2011. C: Scale patterns of wool fibres (SEM) https://www.woolmark.com/fibre/what-is-merino-wool/. D: Surface patterns ("shark skin") and helical shape development of extruded alginate fibres upon increasing rate (from right to left) Picaut et al 2017.

Scientific goal: Strikingly, the above-mentioned fibre structures are characteristic of symmetry-breaking dynamical processes occurring in soft matter systems, such as extrusion instabilities of viscoelastic fluids (see figure D), buckling of thin films… This project aims at reproducing some inspirational structures found in Nature using merely *physico-chemical and mechanical instabilities*, and to assess to which extent this original approach enables to mimic the outstanding specifications of natural fibres. Our main target consists of the bulk and surface instabilities occurring during the extrusion of a viscoelastic fluid such as a biopolymer pregel. The approach is original and to our knowledge has remained quite untouched up to now.

Scientific environment: INSP is a major condensed mater physics institute on Campus Jussieu of Sorbonne University where it benefits from a highly stimulating scientific environment, including chemistry and biology labs and facilities.
For the past 15 years the Baumberger lab at Institut des nanoscience de Paris has developed expertise in the field of processing biopolymer gels (collagen, gelatin, alginate…), characterizing and modelling their rheological properties, with strong emphasis on the various instabilities occurring

during gelation. Recently, the lab has been involved in biomaterial science projects, in collaboration with chemists from Laboratoire de Chimie de la Matière Condensée and biologists of Laboratoire de Biologie du Développement of Sorbonne University. In addition, the lab possesses a wide range of testing facilities (AFM, nanoindenter, rheometer, traction force apparatus).

Recent related PhD thesis from the supervisor's lab:

[1] Picaut, L. (2017). *Synthesis of an artificial tendon* (Doctoral dissertation, Université Pierre et Marie Curie-Paris VI).

Relevant publications co-authored by the supervisor:

[1] Souguir, H., Ronsin, O., Larreta-Garde, V., Narita, T., Caroli, C., & Baumberger, T. (2012). Chemo-osmotically driven inhomogeneity growth during the enzymatic gelation of gelatin. *Soft Matter*, *8*(12), 3363-3373.

[2] Guerquin, M. J., Charvet, B., Nourissat, G., Havis, E., Ronsin, O., Bonnin, M. A., ..., Baumberger, T., ... & Duprez, D. (2013). Transcription factor EGR1 directs tendon differentiation and promotes tendon repair. *The Journal of clinical investigation*, *123*(8).

[3] Picaut, L., Ronsin, O., Caroli, C., & Baumberger, T. (2017). Experimental evidence of a helical, supercritical instability in pipe flow of shear thinning fluids. *Physical Review Fluids*, *2*(8), 083303.

[4] Picaut, L., Trichet, L., Hélary, C., Ducourthial, G., Bonnin, M. A., Haye, B., ... Baumberger, T., ... & Mosser, G. (2021) Core–Shell Pure Collagen Threads Extruded from Highly Concentrated Solutions Promote Colonization and Differentiation of C3H10T1/2 Cells. *ACS Biomater. Sci. Eng.* 2021, 7, 2, 626–635

[5] Wang, X., Ronsin, O., Gravez, B., Farman, N., Baumberger, T., Jaisser, F., ... & Hélary, C. (2021). Nanostructured Dense Collagen-Polyester Composite Hydrogels as Amphiphilic Platforms for Drug Delivery. *Advanced Science*, 2004213.

[6] Baumberger, T., & Ronsin, O. (2020). Environmental control of crack propagation in polymer hydrogels. *Mechanics of Soft Materials*, *2*(1), 1-38.

Techniques/methods in use: Microfluidic extrusion, coating, rheometric and tensile tests.

Applicant skills: Candidates with a solid background in continuum mechanics and soft matter physics must be strongly motivated by experimental physics and creative experimental design.