

**RESEARCH TOPIC FOR THE PARISTECH/CSC PHD PROGRAM**

**Field:** *Materials Science, Mechanics, Fluids*

**Subfield:** Bio-based polymers, Biomaterials, Aerogels, Fluid mechanics

**Title:** 3D printing of gels and aerogels for biomedical applications

**ParisTech School:** MINES ParisTech | PSL

**Advisor(s) Name:** Tatiana BUDTOVA, Co-advisors: Sijtze BUWALDA and Rudy VALETTE

**Advisor(s) Email:** [Tatiana.Budtova@mines-paristech.fr](mailto:Tatiana.Budtova@mines-paristech.fr)

**Research group/Lab:** *Center for Materials Forming (CEMEF), Biobased Polymers and Composites group (BIO) and Computing and Fluids group (CFL)*

**Lab location:** *Sophia Antipolis*

**(Lab/Advisor website):** <https://www.cemef.mines-paristech.fr/en/homepage/>

**Short description of possible research topics for a PhD:**

Additive manufacturing is a very promising technology for biomedical applications such as regenerative medicine, tissue engineering and drug delivery. In this project 3D printing will be used to make bio-based gels in complex shapes, which will then be transformed into bio-aerogels. The goal is to use bio-aerogels as matrices for drug delivery in smart patches. Bio-aerogels are 100% bio-based ultra-lightweight nanostructured materials with a high internal surface area.

Two approaches for printing gels from polysaccharide solutions will be considered: either printing in a fluid in which the polymer is cross-linked, or printing in a non-solvent which induces phase separation. The rheology of solutions in the capillary of the printer nozzle and near its exit will be studied experimentally and modelled using finite element analysis approaches developed in CEMEF. Special attention will be paid to solution liquid-“solid” (gel) transitions. Bio-aerogels will be characterized, loaded with drugs and their release kinetics studied.

**Required background of the student:** polymer chemical physics; materials science

**A list of 5 (max.) representative publications of the group:** (Related to the research topic)

1. F. Chen, W. Xiang, D. Sawada, L. Bai, M. Hummel, H. Sixta, T. Budtova «Exploring Large Ductility in Cellulose Nanopaper Combining High Toughness and Strength », *ACS Nano*, 14, 11150 (2020)
2. S. Buwalda, T. Vermonden, W. Hennink, «Hydrogels for therapeutic delivery: current developments and future directions», *Biomacromolecules*, 18, 316 (2017)
3. L. Druel, P. Niemeyer, B. Milow, T. Budtova, “Rheology of cellulose-[DBNH][CO<sub>2</sub>Et] solutions and shaping into aerogel beads”, *Green Chem.*, 20, 3993 (2018)
4. S. Zhao, W. J. Malfait, A. Demilecamps, Y. Zhang, S.L Brunner, L. Huber, P. Tingaut, A. Rigacci, T. Budtova, M. M. Koebel “Strong, Thermally Superinsulating, Biopolymer-Silica Aerogel Hybrids by Cogelation of Silicic Acid with Pectin”, *Angew. Chemie Intl. Edition*, 54, 14282 (2015)
5. A. Pereira, R. Valette, E. Hachem, « Inertia-dominated coiling instabilities of power-law fluids”, *J. Non-Newt. Fluid Mech.*, 282, 104321 (2020)