PhD offer

Foams beyond capillarity: Physics of fiber-bubble assemblies

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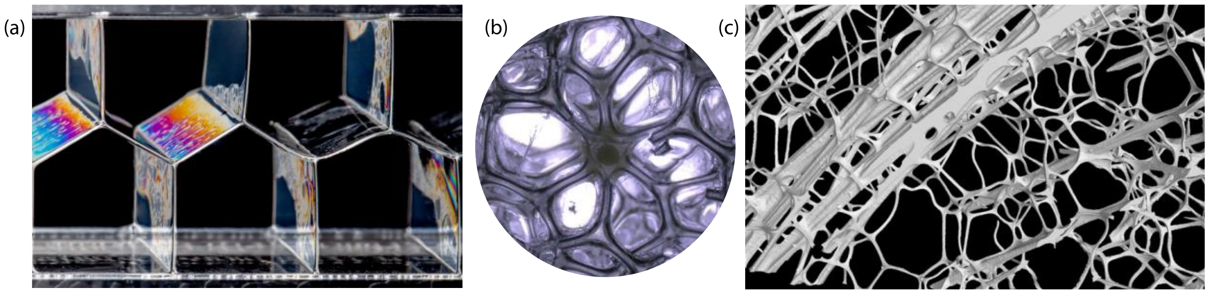
At: Institut Charles Sadron, Strasbourg, France
Starting date: 01/10/2022 (3 years)

The mechanical assembly of bubbles in a liquid carrier matrix generates foams, whose resulting structure is imposed by the minimization of interfacial energies [1], i.e. by capillarity. The solidification of such assemblies to obtain materials results in architectures that are inherently soft [2].

The goal of this PhD project is to push the physics of foams beyond capillarity and to investigate the mechanical assembly of bubbles mixed with elastic intruders such as fibers. The addition of elastic bending and stretching energies to the interfacial energies modifies the usual equilibrium structures of foams. An illustrative example is shown for a two-dimensional system (elastic ribbon in a 2D assembly of bubbles) in Figure (a), from our recent work [3]. The presence of elastic intruders also modifies the dynamical evolution of the foam, by acting on the different ageing mechanisms such as drainage, coarsening and coalescence [1]. In a "liquid-foam templating approach", i.e. when using the structure of a liquid foam as a template for cellular materials upon solidification [4], both structure and dynamics of foam-fiber systems in the liquid state are crucial to control the resulting solid structure.

One key task of the PhD student will be the study of model foam-fibers systems specifically designed to answer the following questions: How exactly do interfacial and elastic energies compete to modify foam structure? What are the appropriate tools to perform a statistical structural analysis to identify the location of the fibers and their influence on the foam structure? What is the temporal evolution of foam-fiber assemblies and how are they modified with respect to ordinary foams? Two key challenges will be to (1) develop an experimental setup allowing systematic investigation of the mechanical self-assembly of fibers and bubbles using microfluidics, and to (2) analyze the obtained structures using lab-based high-end tomography. The thesis will be largely experimental but may be accompanied by computer simulations and advanced computational analysis. First experiments will be conducted with aqueous foams [1], before working on systems able to solidify. A preliminary result showing the modification of foam structure with one single fiber in a solidified system is shown in Figure (b): bubbles arrange differently around the fiber than in the bulk.

This approach merges in a unique way two fields with a continuously growing scientific community: interactions between liquids and elastic solids (elasto-capillarity) and foam physics. This PhD will thus provide opportunities of interactions with multiple fields and with researchers of various backgrounds. The PhD student will also have the possibility to explore applications of such systems in the emerging fields of stretchable electronics (via the use of conductive fibers), and of biomimetic materials (via foam templating that mimics natural lightweight architectures - structures such as Figure (c) are reminiscent from natural cellular solids).



(a) Elastic ribbon (right) introduced inside a 2D aqueous bubble column. (b) Cross-section of a single fiber (center) inside a polyurethane foam. (c) artificial hair inside a polyurethane foam, visualized with ICS X-ray microtomograph. (© M. Jouanlanne, A. Hourlier-Fargette, D. Favier)

[1] Cantat, I., Cohen-Addad, S., Elias, F., Graner, F., Höhler, R., Pitois, O., ... & Saint-Jalmes, A. (2013). Foams: structure and dynamics. OUP Oxford.
[2] Ashby, M. F. (2006). The properties of foams and lattices. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 364(1838), 15-30.
[3] Jouanlanne, M., Egelé, A., Favier, D., Drenckhan, W., Farago, J., & Hourlier-Fargette, A. (2022). Elastocapillary deformation of thin elastic ribbons in 2D foam columns. Soft Matter, 18(12), 2325-2331.
[4] Andrieux, S., Quell, A., Stubenrauch, C., & Drenckhan, W. (2018). Liquid foam templating–A route to tailor-made polymer foams. Advances in Colloid and Interface Science, 256, 276-290.

Professional environment

The PhD student will be part of the ERC project "Metafoam", and will become member of the MIM team which unites 10 permanent researchers, 3 permanent engineers and about 10 non-permanent staff (postdocs, PhD students and engineers). He/she will be fully involved in the scientific life of the laboratory, including weekly meetings of all people working around foams at ICS, and will also work in collaboration with people from different teams, including (but not limited to):

- Jean Farago (professor, TSP team, theory of systems involving capillarity and elasticity)
- Thierry Charitat (professor, MCube team, physics of fibers and of model systems)
- Engineers of the ICS MINAMEC platform (X-ray tomography and mechanical characterization)

Main activities

The thesis is largely experimental. The PhD student will

- develop experimental set-ups (model experiments, microfluidics, imaging, etc.)
- use a range of commercial devices (microscopy, interfacial tension measurements, X-ray tomography, etc.), working with engineers on some aspects of the analysis
- analyse and interpret results (using analytical and computational tools)
- develop models/work jointly with theory team (TSP) researchers to compare experimental results with modelling
- potentially perform some computer simulations using finite element tools (Surface Evolver or Marc)
- communicate results (in writing and oral form)
- work as part of a team (English and French spoken)
- collaborate with researchers and engineers in the institute and beyond

Required competences

- Background in physics
- Taste for experimental work
- Independence
- Capacity and desire to work as part of a project team
- Good level of English

Required diploma

M2 or equivalent in physics

Salary

2135 € brut

Application procedure

Applications should be sent before June 1st 2022 through the CNRS portal:
https://emploi.cnrs.fr/Offres/Doctorant/UPR22-WIEDRE-004/Default.aspx?lang=EN ,
accompanied by a detailed CV, motivation letter and at least one recommendation letter of a former supervisor. To contact us by email if you need additional information: hourlierfargette@unistra.fr or drenckhan@unistra.fr