Self-organised architectures of foam-intruder systems

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Architected materials have been recently attracting a growing interest due to their outstanding properties compared to bulk materials. Compared to additive manufacturing, allowing to produce customized architectures, polymer foams have the advantage of being produced by bottom-up self-assembly. However, despite their wide industrial use and the recent progress on "liquid foam templating" techniques [1], we still lack methods to explicitly control and customize the geometry and topology of foams, stricly guided by capillarity [2]. To go further in terms of accessible architectures and associated properties, we will study how bubbles rearrange themselves in the presence of rigid and flexible intruders.

The PhD project will combine experiments and modeling to characterise and understand topological and geometrical modifications caused by intruders in liquid foam precursors, resulting in novel solid foam architectures. A model system, alginate foams (Fig. 1a), will be used to produce samples able to undergo X-ray microtomography structural characterisation. Substantial structural modifications have been highlighted by preliminary results from our previous work [3,4]: organisation of bubbles around a single fiber (Fig. 1b), obtention of orientational order in fiber arrays (Fig. 1c), and competition between elasticity and capillarity in a simplified foam-intruder system, namely soap bubbles with an elastic ribbon (Fig. 1d), inviting to further investigations in this direction. The PhD student will use alginate foams to systematically study the self-organisation of bubbles in the presence of intruders of various shapes and bending rigidities (rigid vs flexible intruders) and seek both a fundamental physical understanding of the involved processes and a detailed statistical physics structural characterisation of the topological changes. This work will be undertaken at ICS, under joint supervision of Jean Farago (Theory and Simulation of Polymers team) and Aurélie Hourlier-Fargette (Mechanics of Interfaces and Multiphase systems team). The PhD student will benefit from unique tools (X-ray tomography, mechanical characterisation) and expertise (statistical analysis, physics of 2D and 3D cellular materials, foaming processes, mechanics of elastic solids) present at ICS.

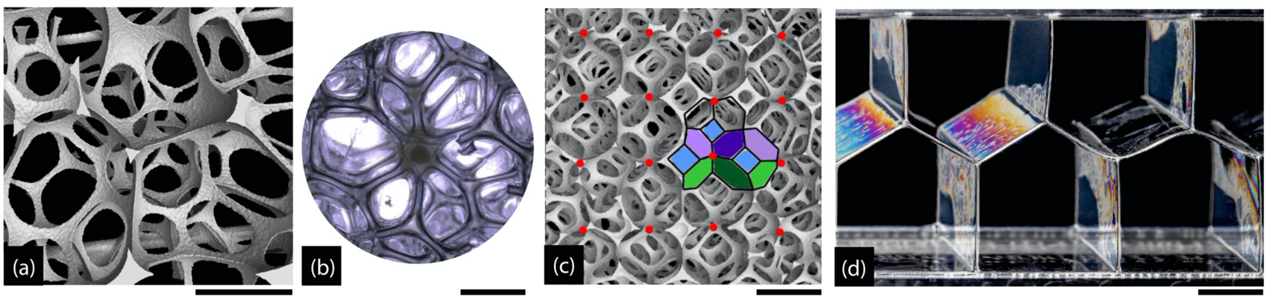

Figure 1 : (a) Alginate foam structure observed at the ICS X-ray tomograph platform. (b) Cross-section of a single fiber (center) inside a polyurethane foam. (c) First observation of long-range orientational order in a foam induced by a minimal array of fibers (fibers are perpendicular to the plane of the figure and highlighted with red dots). (d) Elastic ribbon (right of the image) introduced in a 2D column of soap bubbles.

Image credits: Manon Jouanlanne, Aurélie Hourlier-Fargette & Antoine Egelé. Scale bars: 4mm

[1] S. Andrieux, W.Drenckhan, and C. Stubenrauch. Langmuir, 34(4) :1581–1590, 2018.
[2] I. Cantat et al, Foams: Structure and dynamics. OUP Oxford, 2013.
[3] M. Jouanlanne, A. Egelé, D. Favier, W. Drenckhan, J. Farago and A. Hourlier-Fargette. Soft Matter, 18(12), 2351-2331, 2022.
[4] M. Jouanlanne, PhD thesis, Strasbourg University, 2023.