Fully funded PhD

Physics of "armored" soap films: from particle interaction to surface rheology

Laboratory

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Description

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The control of the mechanical properties of foams and their stability is a daily and industrial problem. Sometimes, the goal is to make the foam disappear rapidly (in sewage sludge for example), but more often we try to make it as stable as possible, for example in the food industry (when formulating ice cream or chocolate mousse) or cosmetics (shaving cream). Interestingly, there is a simple and very effective technique that dramatically increases the stability of foams: the addition of small solid particles. When the foam is created, the grains get trapped in the liquid films that separate the bubbles, which dramatically improves mechanical properties of the film. Films stabilized in this way are slower to refine (better resistance to drainage), less permeable to gases (which limits the aging of the foam) and much more resistant to mechanical stress.

The properties of grain-filled films have been the object of recent research, but there is still a lot to be understood on the phenomena that take place at the scale of a few particles. Preliminary work carried out in our laboratory has shown unexpected results. For example, the force of attraction between two particles of a few hundred micrometers confined in a film is typically one hundred times greater than the one measured when the particles are placed at the liquid/air interface. In addition, the particles suck in the liquid around them, which profoundly changes the film thickness distribution over time. The capillary forces between the particles could therefore lead to a reversal of the drainage process and cause a thickening of the film with time, in contrast to what happens for free films.

In this thesis, we want to understand how grains locally deform soap films and interact with each other, an approach which combines dynamics, wetting and capillarity. In particular, we are interested in how particles modify the aging of the film, and how they impact its rheology. The originality of the approach will be to use magnetic solicitations to control the displacement and the forces between the beads.

This work will connect the small-scale dynamics (the interactions between the particles and between particles and the film) and the global rheological and mechanical properties of the bubbles, including their stability. It will be mainly experimental and completed by a theoretical modeling. To carry out this project, we will use a tool that is currently being installed in the laboratory: triaxial Helmholtz coils that generate strong magnetic fields (of the order of 250 Gauss). Using paramagnetic particles, we will use this tool to measure (with a precision of the order of 1 nN) the interaction force between two grains suspended in the film. This system will also be used to measure the local rheology of the bubble, by rotating a needle formed by two magnetic particles attached together. These measurements will be completed by an optical analysis (interferometric measurements, fast camera imaging). The complexity of the system will be gradually increased, from one particle to a particle raft and then armored bubbles.

The student will benefit from the crossed competences of Anaïs Gauthier for the study of particles at interfaces and capillary interactions, and of Isabelle Cantat for the physics of flows in bubbles.