2024-2025

# Master thesis proposal

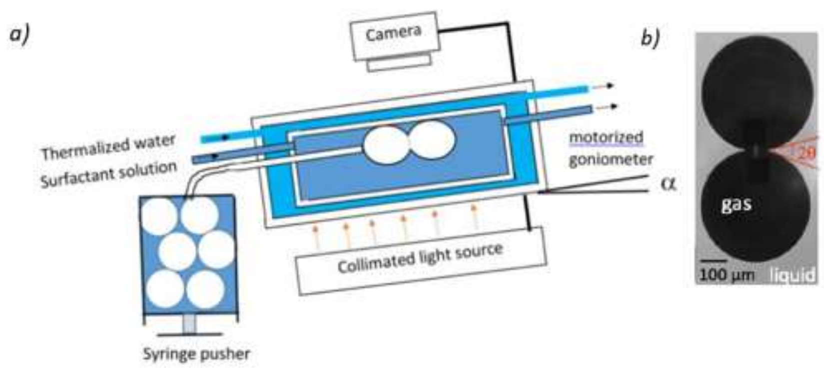
Campus Pierre et Marie Curie
Tower 23 – 3rd floor – 23-22
Director: Massimiliano Marangolo

## **Title**: Adhesive interactions between bubbles

**Keywords**: Soft Matter, interfacial adhesion, microfluidics

**Scientific description**:

Applications ranging from food production to the treatment of wastewater polluted by PFAS chemicals that are not decomposed naturally use bubble or droplet dispersions[1,3]. When two immersed bubbles touch, they experience a repulsive interaction, as if they were elastic objects. Depending on the composition and physicochemistry of the surrounding solution, they can also stick to each other. It has been proposed that ionic correlations at the nanometre scale in the thin liquid films separating bubbles can produce such an adhesion[4]. Immersed bubbles can thus behave as elastic as well as adhesive objects, but the laws relating the interaction force to the displacement are qualitatively different from those for adhesive soft solid spheres (Hertz law, JKR model). This is because the potential energy of a deformed bubble is stored in its interfaces, in contrast to a solid sphere where it is stored in the bulk material. The interaction law for adhesive bubbles is not yet well known or predicted theoretically. The aim of the internship is to provide experimental evidence helping to answer this open question.




a) *Side view of two bubbles immersed in a surfactant solution, confined under a transparent plate inclined by an angle α.*
*b) Two bubbles observed from the top in a similar setup with α=0.*
*Their interaction is adhesive, and they are therefore slightly deformed at the contact.*

To start the experiment, monodispersed bubbles with a size close to 100µm will be produced using microfluidics. They will be injected in a cell, which is filled with an ionic surfactant solution and covered by a transparent plate (see figure a). Accurate tilting of the cell by a goniometer sets the part of the buoyancy force that acts tangentially to the plate and that pulls the bubbles apart. The induced deformation and displacements will be observed using a microscope, depending on temperature, the solution physicochemistry and the inclination angle. The results will be compared to the predictions of a theory which we have recently developed[2], extended to account for adhesion.

1 *Foams, Struture and Dynamics, I. Cantat, S.Cohen-Addad,F.Elias, F.Graner, R.Höhler, O.Pitois, F.Rouyer, A. Saint Jalmes, Oxford University Press (2010).*
*2. R.Höhler, D.Weaire, Can liquid foams and emulsions be modelled as packings of soft elastic particles? Advances in Colloid and Interface Science 263, 19-37 (2019).*
*3. Morrison et al Ind. Eng. Chem. Res. 62, 5635−5645 (2023).*

*4. R. Netz Eur. Phys. J. E **5**, 557{574 (2001).*

**Techniques/methods in use**: Microfluidics, optical microscopy, contact angle and surface tension measurements.
**Applicant skills**: Experimental physics skills
**Industrial partnership**: No

**Internship supervisor**(s) Reinhard Höhler, hohler@insp.upmc.fr, 01 44 27 46 94

**Internship location**: Institut des NanoSciences de Paris, Campus Pierre et Marie Curie

**Possibility for a Doctoral thesis**: YES (financed by ANR)