Getting into the thin-skinned emulsion drops stressed by elasticity and capillarity

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The physical properties of fluid-fluid interfaces is a well-known topic in surface science. The interface between two immiscible fluids is endowed with an interfacial energy whose thermodynamically intensive quantity is the interfacial tension γ. Surface energy minimisation gives rise to complex behaviours (e.g. in foams and emulsions) that have been studied for a long time using Surface Evolver [1], a finite element software solving surface energy minimisation problems. However, modern foam and emulsion science exploits increasingly complex interfaces, including polymeric skins with solid elastic properties. These form interesting granular systems with new interactions [2], and deserve careful investigations in terms of interfacial elasticity. The latter is usually studied through the lens of material science [3] with tensorial expression of surface stresses. Because of their complexity, their application in the field of foams and emulsions is far from straightforward.

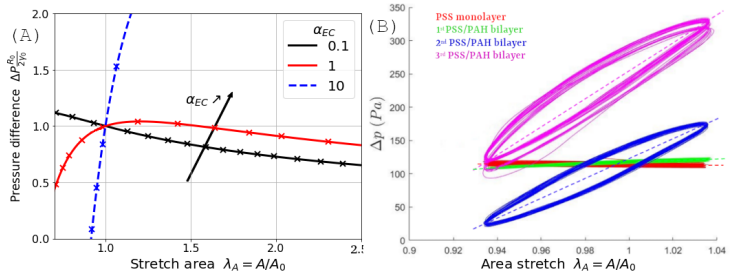

Figure 1. A) Simulations and theory of pressure-deformation relation for three different elastocapillary number α_{EC} for a sphere. B) Pressure-deformation relation for PSS/PAH poly-electrolyte multilayers.

Here we present a Surface Evolver study of elastic liquid-liquid interfaces and how to characterise them experimentally in a pendant droplet setup via pressure measurements of bubbles/drops undergoing sinusoidal variations of the surface area A with respect to a reference state A_0. We first show that the onset of interfacial elasticity modifies the previously monotonic Young-Laplace relation, and that competition between capillarity and elasticity can be conveniently captured by an elastocapillary number α_{EC} (see figure A). Within this framework, the mechanical properties of the interface can be described using the total surface stress like an effective surface tension, leaving the opportunity to adapt existing droplet interaction laws to interfacial elasticity [4]. Secondly, we show that the complex pendant droplet geometry can be approximated by a sphere whilst predicting pressure-curvature relation with a reasonable accuracy in the limit of a small fluid density mismatch (i.e. Bond number $Bo \to 0$). We show that our simplified model is suited to describe interfaces created by layer-by-layer deposition of polyelectrolytes at a gas-liquid interface (figure B). Finally we show first experimental results on the structural properties of PEG-in-Silicone emulsions whose elastocapillary number is tuned systematically using a micro-fluidic set-up.

Références

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