Ultrafast deformation of colloid monolayers at fluid interfaces: microstructural evolution and particle expulsion

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Droplets and bubbles stabilised by a monolayer of colloidal particles are central in catalysis, encapsulation, and drug delivery. Particle-stabilised bubbles are also the elementary building blocks of more complex materials such as foams, important for instance in enhanced oil recovery and lightweight composites. Despite their importance in applications, our fundamental understanding of the behaviour of particle-laden interfaces under dynamic deformation is still limited. While shear deformation has been the focus of recent research [1-2], the effect of compression, a leading-order mode of deformation of fluid interfaces, remains largely unexplored. To impart controlled, dynamic compression of a particle-laden interface, and access the far-from-equilibrium behaviour of the colloid monolayer, we use ultrasonic driving of particle-coated bubbles. Exposing a particle-coated bubble to ultrasound waves enables us to achieve ultrafast compression-expansion of the monolayer in the frequency range 10-100 kHz. We make bubbles (30-500 µm) stabilised by microparticles (3-5 µm) by mechanical agitation. We use high-speed video microscopy to track the trajectories of individual particles during ultrafast interface deformation (Figure 1, top). For oscillations of sufficiently small amplitude, we can characterise the evolution of the 2D microstructure through the order parameter, inter-particle distance, pair correlation function, and topological irreversible changes (Figure 1, bottom). Above a certain threshold in amplitude of oscillations, which depends on the surface coverage by particles, we observe expulsion of the particles from the monolayer into the surrounding fluid [3]. Control over the conditions for particle expulsion is desirable in order to prevent this phenomenon when characterising monolayer deformation, but also to exploit it in applications, for instance in controlled release. We therefore performed a comprehensive analysis of the conditions for particle expulsion. Local interfacial curvature and radial amplitude are identified as the key parameters controlling expulsion. Experiments with bimodal size distributions provide insights into the effect of contact forces between the particles [4] on out-of-plane deformation and particle desorption.

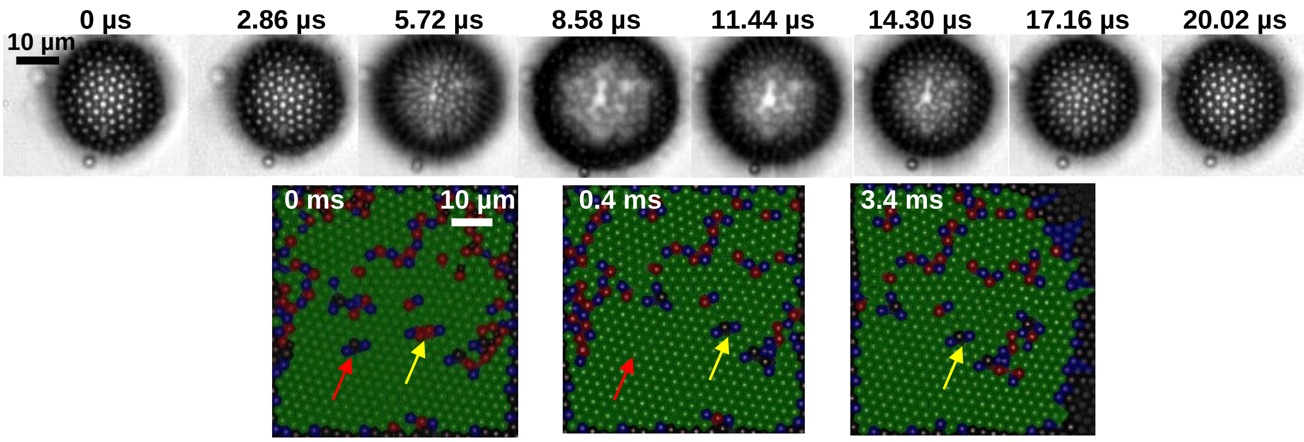

Figure 1 Top: Particle-coated bubble undergoing a compression-expansion cycle at 50 kHz. Bottom: close-up of a colloid monolayer on a large bubble. Rearrangements around defects are observed over several cycles of oscillation at 7 kHz. Color coding: green corresponds to 6 nearest neighbours, blue to 5, red to 7, black to more than 7.

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