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The natural bubble size distribution of coarsening liquid foams

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Foams are dense packings of bubbles in a surfactant solution. Their structure strongly depends on the liquid volume fraction φ they contain. In the limit where φ->0, in so-called dry foams, bubbles are polyhedral with thin film separating them. As φ increases, bubbles become less compressed, their shape tends towards that of a sphere which is reached at the jamming transition φ^* where contacts between bubbles vanish. Foam structure is intrinsically unstable. It may evolve with time due to gravity drainage, bubble coalescence or coarsening. The latter, similar to Ostwald ripening in dilute emulsion, arises from gas exchanges between neighbouring bubbles driven by Laplace pressure differences. Mean field models predict that foams and bubbly liquids should converge towards a scaling state with characteristic growth laws of average bubble size and distribution of bubble sizes [1,2]. We present a study of the coarsening of foams where drainage and coalescence have been suppressed. We show the natural bubble size distributions of a coarsening foam in the scaling state, which depend on its liquid content.
In order to suppress gravity effects, we performed experiments with wet foams in microgravity, on board the International Space Station [3], and dry foams on ground using a clinostat. Coalescence was prevented by the large concentration of surfactant of the foaming solution. From image analysis of the foam surface [4], we determine the probability distribution functions of the bubble radii.
Our results unveil an unpredicted feature of the distributions as they exhibit a sharp peak of bubbles much smaller than the average size, which introduces hierarchy in the foam structure. We call these "roaming" bubbles since they appear to lose contact with their neighbours and just roam through the interstices between the bubbles. We show that the characteristic size of the roaming bubbles can be predicted by a scaling law taking into account the foam permeability, which sets the opening of the interstices with the increase of φ. The roaming bubbles persist up to the jamming transition. We study the impact of foam polydispersity on the random close packing fraction and compare it to that numerically predicted for hard sphere polydisperse packings. Since liquid foams are precursors of solid ones, their hierarchical structure may be interesting for the synthesis of aerated cellular materials where such a microstructure is desired.

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