Two distinct physical mechanisms identified for how simple foams collapse

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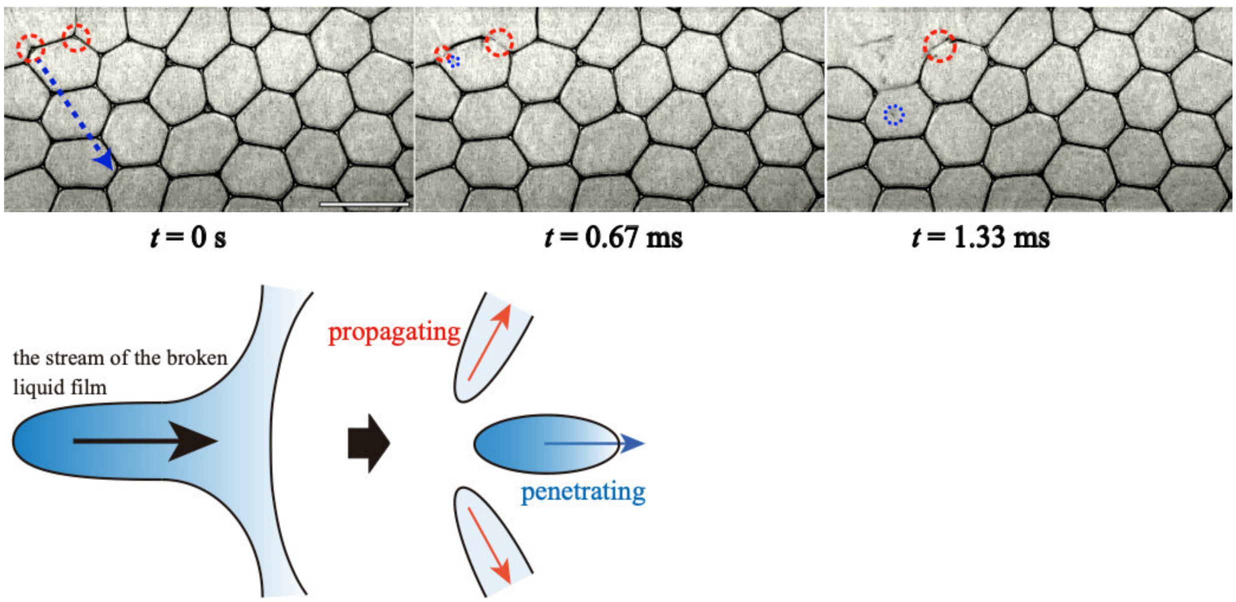

The film is seen to recede into surrounding films, while a droplet is released which penetrates other films and causes further collapse. Credit: Rei Kurita

Researchers from Tokyo Metropolitan University have discovered two distinct mechanisms by which foams can collapse, yielding insight into the prevention/acceleration of foam rupture in industrial materials, e.g., foods, cosmetics, insulation and stored chemicals. When a bubble breaks, they found that a collapse event propagates via impact with the receding film and tiny scattered droplets breaking other bubbles. Identifying which mechanism is dominant in different foams may help tailor them to specific applications.

Foams play a key role in a wide range of industrial products, including foods, beverages, pharmaceuticals, cleaning products and cosmetics. They have material applications such as building insulation, aircraft interiors and flame-retardant barriers. They might also be an unwanted property of a product of frothing in stored chemicals during transit. From a scientific perspective, they also constitute a unique form of matter, a fine balance between the complex network of forces acting on the liquid film network that makes up its structure and the pressure of the gas trapped inside. Understanding how foams behave may yield new physical insights, as well as better ways to use them.

Naoya Yanagisawa and Associate Professor Rei Kurita set out to observe how foams collapse. They took a solution of water, glycerol and a common surfactant (a film-stabilizing agent) and created a two-dimensional foam squashed between two pieces of glass. Using an ultra-fast camera and a needle, they were able to controllably break a bubble at the edge of the foam raft and observe collective bubble collapse (CBC). They identified two distinct ways in which the breakage of one bubble at the edge led to a cascade of breakage events around it, a propagating mode due to the absorption of the film of the broken bubble into surrounding liquid film, and a "penetrating" mode due to the release of droplets from the rupture event flying away and breaking other bubbles.

As the investigators changed the amount of water in the film, they identified several key trends in how the bubbles react at a microscopic level. For example, they found that more liquid in the foam led to the release of slower droplets, which are unable to penetrate surrounding films. This was correlated with a drastic drop in the number of bubbles collapsed; CBCs were thus crucially underpinned by the penetrating mode of collapse. Droplet speed was determined by the speed at which the film receded; this streaming velocity was found to be proportional to the osmotic pressure of the film, i.e., the pressure at which a liquid brought into contact with the foam is driven into the film network. The team showed that the Navier-Stokes equations, key relations describing how fluids behave over time, could be used to explain these trends.

A key finding was that changing the viscosity of the fluid did not lead to a significant change in the number of bubbles broken. Methods to stabilize foams commonly rely on changing the viscosity, yet the team's findings clearly show how both the number of bubbles collapsed and the velocity of the receding film are unaffected. Coupled with the dominant role played by the penetrating mode, future strategies to prevent foam collapse may instead focus on combining multiple surfactants to make the film more resistant to droplet impact.

The study has been published online in the journal *Scientific Reports*.

More information: Naoya Yanagisawa et al, In-situ observation of collective bubble collapse dynamics in a quasi-two-dimensional foam, *Scientific Reports* (2019). DOI: 10.1038/s41598-019-41486-6

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