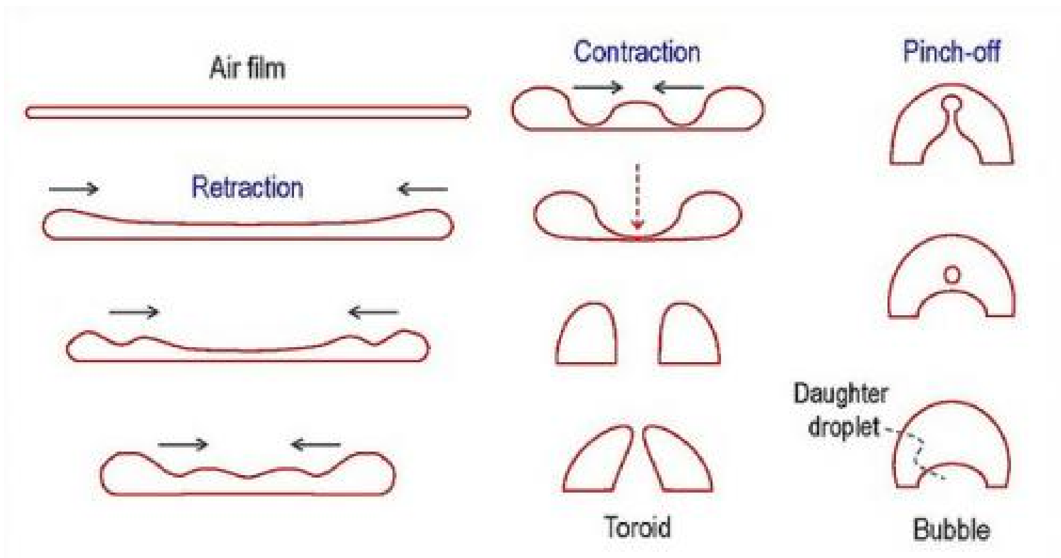
Bubble study could improve industrial splash control

December 13 2012, by Tona Kunz



The evolution process during drop impact: inertial retraction of an air film, contraction of the top air surface into a toroidbubble, and pinch-off of a daughter droplet in the bubble. The solid-line arrows denote the propagation of capillary waves, and the dashed-line arrow indicates the contact between the crest and the substrate.

(Phys.org)—For the first time, scientists witnessed the details of the full, ultrafast process of liquid droplets evolving into a bubble when they strike a surface. Their research determined that surface wetness affects the bubble's fate.

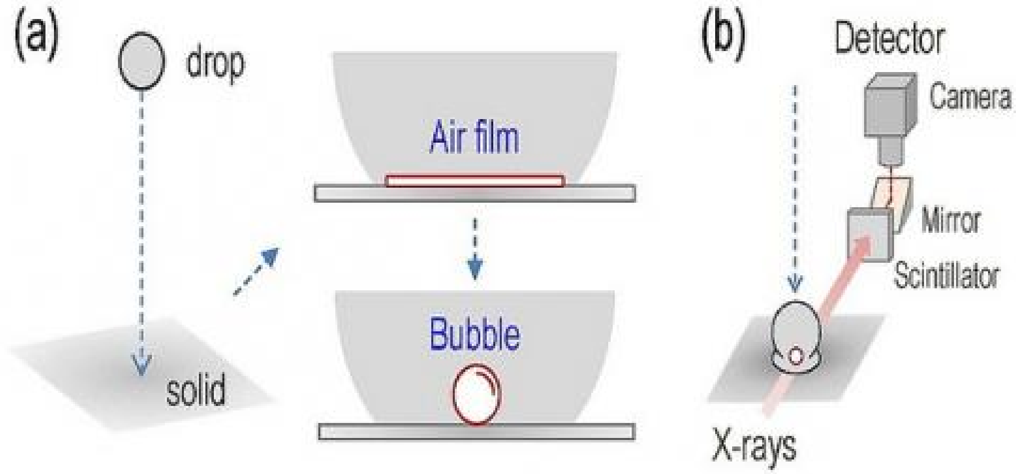
This research could one day help eliminate bubbles formed during spray coating, metal casting and ink-jet printing. It also could impact studies on fuel efficiency and engine life by understanding the splashing caused by fuel hitting engine walls.

"How liquid coalesces into a drop or breaks up into a splash when hitting something solid is a fundamental problem in the study of fluid dynamics ," said Jung Ho Je, one of the lead authors on the result "How Does an Air Film Evolve into a Bubble During Drop Impact?", published in the journal Physical Review Letters, and a physicist at Pohang University of Science and Technology in Korea.

A team of Korean and U.S. scientists used the Advanced Photon Source at the Department of Energy's Argonne National Laboratory to profile the film of air that gets trapped between a droplet and a surface and to study how it evolves into a bubble. Visualizing this process required the use of ultrafast X-ray phase-contrast imaging done at the APS's 32-ID beamline. The APS is the only synchrotron light source currently providing this technique, which is key for bubble research.

The bubble formation was captured at a speed of 271,000 frames per second. For comparison, a camera needs to shoot at 600 frames per second to capture a bullet fired from a .38 Smith & Wesson Special handgun.

"This is the first time we can clearly visualize the detailed profile of air dynamics inside of a droplet, which made understanding what forces are at play much easier," said Kamel Fezzaa, a physicist working at the APS.



The complicated evolution of an air film during drop impact. (a) Schematic description of air film evolution; namely, when an air film is entrapped during drop impact on a solid surface, it should evolve into a bubble to minimize its surface energy. (b) Schematic of ultrafast x-ray phase-contrast imaging, which enables the tracking of dynamic changes of air- liquid interfaces in real time.

It is known that the surrounding air pressure influences splashing, but it also leaves an air layer under the drop that evolves into a bubble. The researchers found that a sweet spot exists for controlling whether the emerging bubbles stay attached to the substrate or detach and float away. This sweet spot is a combination of the wetness of the surface material and the fluid properties of the droplet.

X-rays are an ideal tool for studying bubble formation. Visual-light imaging techniques have proved challenging because of reflection and refraction problems, and interferometry and total internal-reflection microscopy techniques can't track changes in the air thickness. Scientists used the APS's unique combination of phase-contrast imaging and ability to take 0.5 microsecond snapshots at intervals of 3.68 microseconds, or 3.68 millionths of a second, to create a new technique for tracking changes at the interface of air and liquid in real time.

Numerous studies during the last few years have revealed the trapped air under the droplet, but this is the first time the bubble profile and cause of collapse has been visualized and explained. The planned APS upgrade will enable viewing of even faster occurrences and a wider field of view to capture the droplet and smaller bubble formation in the same video.

In future experiments, scientists plan to test whether other conditions such as the temperature of the impact surface or the pressure and nature of surrounding gases affect the bubble formation.

More information: prl.aps.org/abstract/PRL/v109/i20/e204501

Provided by Argonne National Laboratory