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IMPURITIES IN HIGH-PURITY WATER

Scientists at the University of Magdeburg uncover further causes of the formation of destructive vapor bubbles in liquids

A team of physicists led by Dr. Patricia Pfeiffer and Professor Claus-Dieter Ohl from Otto von Guericke University Magdeburg has found another cause for the formation of vapor bubbles in liquids. The physical effect known as cavitation can lead, among other things, to the destruction of marine screws or propellers on ships but can also be used in medicine for removing tumors or breaking up kidney stones.

The results of the team's research into the causes of cavitation were recently published in the internationally renowned physics journals, *Physical Review Letters* and *Nature Physics*.

In liquids flowing past an object at high speed, tiny structures, known as nuclei, can grow into vapor-filled bubbles, for example in pumps or nozzles and even on artificial cardiac valves. *"If I pull very forcefully on a liquid, then the liquid ruptures and forms bubbles, which we see, for example, when ships' propellers suck in water",* explains Dr. Pfeiffer from the Institute of Physics. *"If I have a ship's propeller that rotates very quickly and thus exercises an enormous local pull effect on the water surrounding it, then the water molecules tear apart, producing a hole in the liquid. This hole is very briefly filled with the water vapor that is generated. After a short while, the bubbles formed in the process implode."* This produces extreme pressures of over a thousand Bar, which is a thousand times the ambient pressure, enormous forces that destroy a ship's propeller.
The scientist goes on to say that this phenomenon also exists in nature. *"When snapping shrimps are hunting for prey, they grasp their victims and shoot them by quickly moving their right claw to generate bubbles that implode with a bang, thus stunning or injuring small creatures. This bang can be as loud as 200 decibels."*

Previously, the formation of these potentially destructive vapor bubbles was explained by microscopically small bubbles adhering to impurities and stabilized as cavitation nuclei.

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However, the team led by Dr. Patricia Pfeiffer and Professor Claus-Dieter Ohl has now discovered that supersaturation of the liquid with gas already constitutes a cavitation nucleus of this kind. It is at exactly this point that a bubble is formed when pulling on the liquid. This can be brought about by local heating of a liquid. But bubbles also form on microscopic droplets of an immiscible liquid that are added to the water by pulling on the boundary between water and droplet. Colleagues from Rome and Ferrara have contributed to an initial attempt at explaining this with molecular dynamic simulations. These show that molecularly dissolved gas from the droplet is transported to the boundary layer precisely when the liquid is under tension.

"Consequently we have to fundamentally rework the existing nucleus model of the formation of destructive vapor bubbles", explains Professor Ohl. *"In future the discovery will make it possible, even in extremely clean water, to detect the very smallest impurities,"* continues Ohl. *"Such ultra-high-purity water is essential for chip production, for example. We are already working with a company in this field that is using the formation of nuclei through bubbles to detect impurities in ultra-high-purity water. Such ultra-high-purity water systems are, among other things, used in semiconductor plants such as Intel."*

Alongside the application in high-purity water analysis, in future the results will also be used to improve the treatment of tumors. Liquid cavitation nuclei made of perfluorocarbon (liquid Teflon) are injected into the bloodstream of patients and bubbles generated with ultrasound. When these bubbles collapse they destroy tumor tissues.

Links to specialist articles:
http://link.ovgu.de/physicalreviewletters
http://link.ovgu.de/naturephysics

Caption: Dr. Patricia Pfeiffer
Photo: Jana Dünnhaupt/Uni Magdeburg

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