Tiny vibrating bubbles could lead to better water treatment

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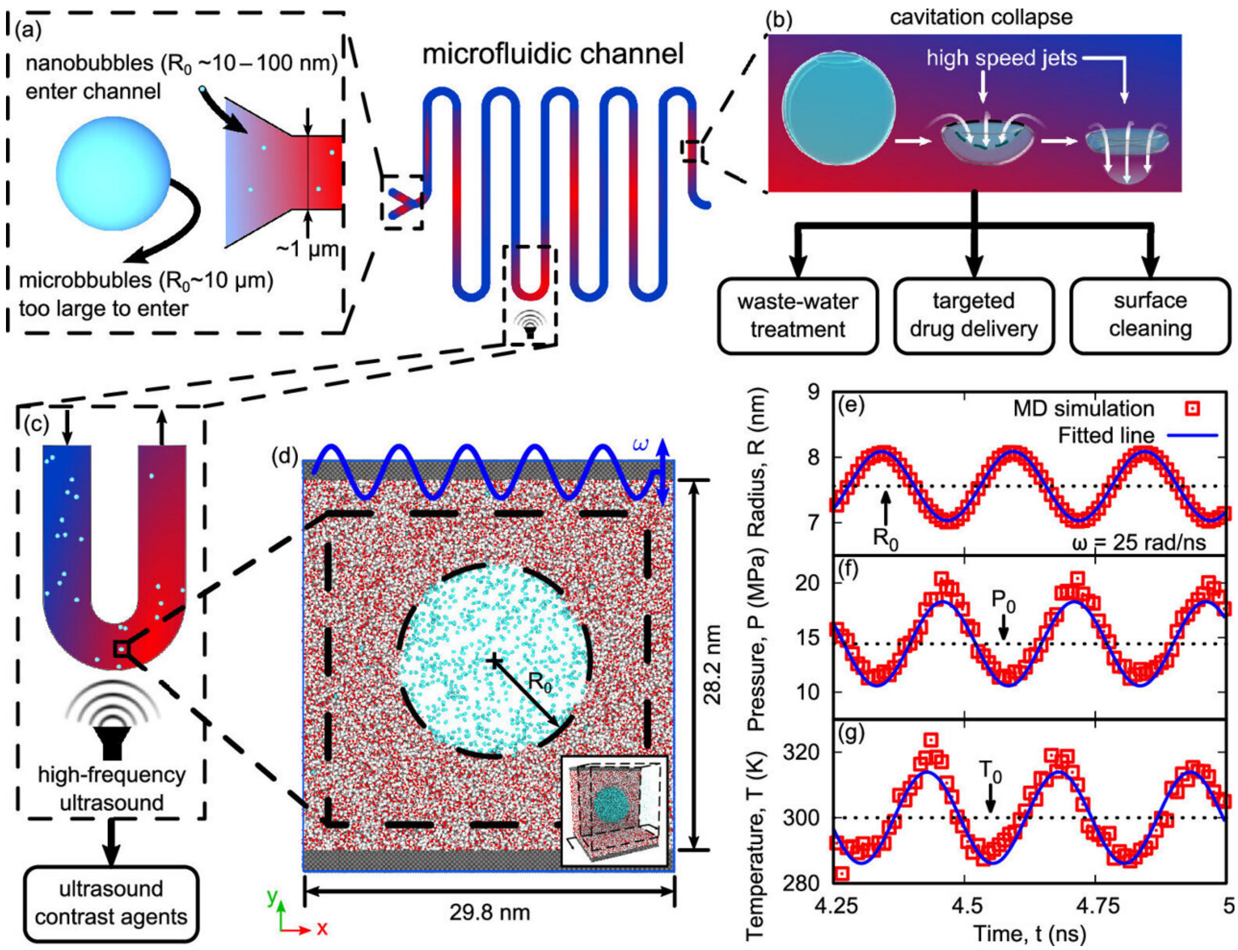

Schematic showing nanobubbles being employed in a microfluidic channel for cavitation applications. Insets show enhanced views of (a) nanobubbles entering microfluidic networks, that microbubbles are too large to reach, (b) the high-speed jets released during the final collapse stage, which have been proposed for the novel cavitation applications shown, and (c) nanobubbles being stimulated to oscillate using high-frequency ultrasound, such as in ultrasound contrast agents.

(d) Molecular dynamics (MD) simulation setup for our nanobubble simulations, forced to oscillate using a vibrating piston, shown with a sliced view. The oxygen atoms are shown in red, hydrogen atoms in white, nitrogen atoms in cyan, and wall/piston atoms in gray. The inset shows an orthographic view of the three-dimensional domain, with some water molecules in the dashed box removed for clarity. Variation in (e) nanobubble radius R, (f) mean internal gas pressure P, and (g) mean internal gas temperature T, with time t, for the $\omega = 25$ rad/ns oscillation case. Credit: *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.3c03052

Fresh research into the physics of vibrating nanobubbles reveals that they do not heat up as much as previously thought. The work appears in *Nano Letters*.

Vibrating nanobubbles have surprising uses as ultrasound contrast agents in cancer diagnosis. They can also be forced to collapse—destroying nearby microscopic contaminants—for waste-water treatment and surface cleaning of delicate microfluidic devices. The stiffness of a nanobubble as it vibrates is strongly related to its internal temperature, and being able to understand this relationship leads to better predictions of nanobubbles' size in experiments and their design in these applications.

Using ARCHER2, the UK's national leading supercomputer hosted at the University of Edinburgh, the research found two distinct nanoscale effects that influence bubbles with diameters less than one-thousandth of a millimeter across.

The high density of the gas inside the bubbles leads to molecules bouncing off each other more frequently, resulting in an increased bubble stiffness, even at constant temperatures. Another effect from the nanoscale dimensions of the bubble was the emergence of an insulating layer around the bubble, which reduced the ability of the bubble to dissipate the internal heat, which modified the way it vibrated.

The study revealed the true pressure and temperature distributions inside nanobubbles, using high-detail molecular dynamics simulations, and found a better model to describe their dynamics.

Study lead, Dr. Duncan Dockar, RAEng Research Fellow, School of Engineering, University of Edinburgh, said, "The results of these findings will allow us to employ nanobubbles for better efficiencies in water-treatment processes and precise cleaning of microelectronic devices. This work also highlights the roles of bubbles in future nanotechnologies, which have been seeing a lot of interest in recent years. Our upcoming research focuses on the unusual nanoscale effects that influence these bubbles, which are not common in everyday engineering."

More information: Duncan Dockar et al, Thermal Oscillations of Nanobubbles, *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.3c03052

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