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How to boil water without bubbles

Coating helps hot metal hang onto protective vapour layer that prevents explosive boiling.

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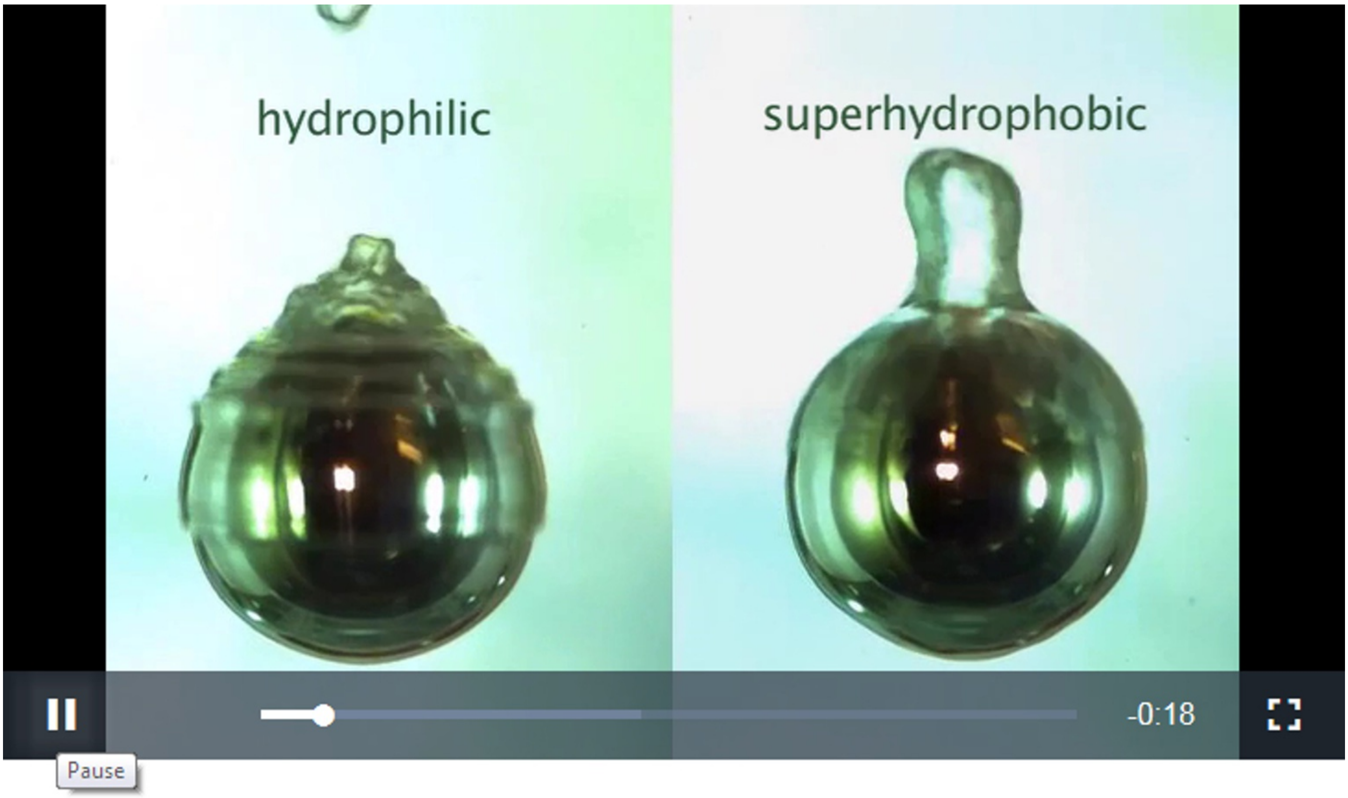

One trick to test whether a frying pan is hot enough is to sprinkle water on it. If the surface is sufficiently above the boiling point of water, droplets will skip across the pan. Those jittery beads of water are held up from the hot pan by a cushion of steam. The vapour cushion collapses as the surface falls below the 'Leidenfrost temperature', causing furious bubbling and spitting when the water droplet hits the surface and boils explosively.

The Leidenfrost effect lies behind the discovery, published today in *Nature*[1], that water can be made to boil without any bubbling if a surface is specially treated so that the vapour cushion does not break down. The key is to make the surface very water-repellent, according to Ivan Vakarelski, an engineer at the Clean Combustion Research Center at the King Abdullah University of Science and Technology in Thuwal, Saudi Arabia, and his colleagues. The effect might be used to carefully control how metals are cooled and heated, or to reduce drag on ships.

The rough with the smooth

Vakarelski's team covered metal spheres with a commercially available coating that made the surface rough and strongly water-repellent, and heated these superhydrophobic spheres to 400 °C (any higher and the coating would deteriorate). For comparison, they heated a set of smooth, water-attracting spheres to 700 °C.

Each hot sphere was dropped into room-temperature water, where a layer of water vapour formed around it. The vapour layers around the water-loving spheres quickly collapsed, leading to explosive bubbling. The coated spheres, by contrast, kept their vapour layers as they cooled down, with no bubbling or explosive boiling.

"We thought we could improve the transition" from the Leidenfrost regime to bubbling, says Vakarelski, "but we are not only lowering the transition, we are completely avoiding it".

"It was really dramatic," says Neelesh Patankar, a theoretical mechanical engineer at Northwestern University in Evanston, Illinois, and a co-author of the paper. "As the temperature goes down, this vapour phase nicely settles down."

The implications of the work could be far-reaching, says Vincent Craig, an applied mathematician at the Australian National University in Canberra, who studies the physics of surface forces and bubbles. “They’ve shown that by keeping the surface rough you can keep that vapour layer at low temperature.” The effect could be used to reduce drag on surfaces such as the tiny channels in microfluidic devices, he suggests.

Hot stuff

In a related experiment, the team dipped metal rods with the same water-loving and water-hating surfaces into water. Heaters inside the rods warmed them, while probes monitored their temperature. The water-loving rods could only ever reach 106 °C, because the water was always coming into contact with the metal and cooling it. But the coated spheres got up to 250 °C, because they were constantly protected from the cool water by the vapour layer.

The next step, says Patankar, is to try to get the vapour layer to form at temperatures much lower than the boiling point of water. Water can exist as either liquid or vapour at room temperature, but it requires energy to stay in the vapour state. Patankar thinks that a surface could be designed that would make the vapour state more stable. A coating could then be used to form a vapour layer round a ship’s hull to reduce drag or discourage organisms such as algae or barnacles from attaching themselves to the ship, he suggests. “It will be mind-blowing,” says Patankar. “Who thinks of getting a vapour without heating?”

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References

1. Vakarelski, I. U., Patankar, N. A., Marston, J. O., Chan, D. Y. C. & Thoroddsen, S. T. *Nature* **489**, 274–277 (2012).