Nanostructured materials repel water droplets before they have a chance to freeze (w/ Video)

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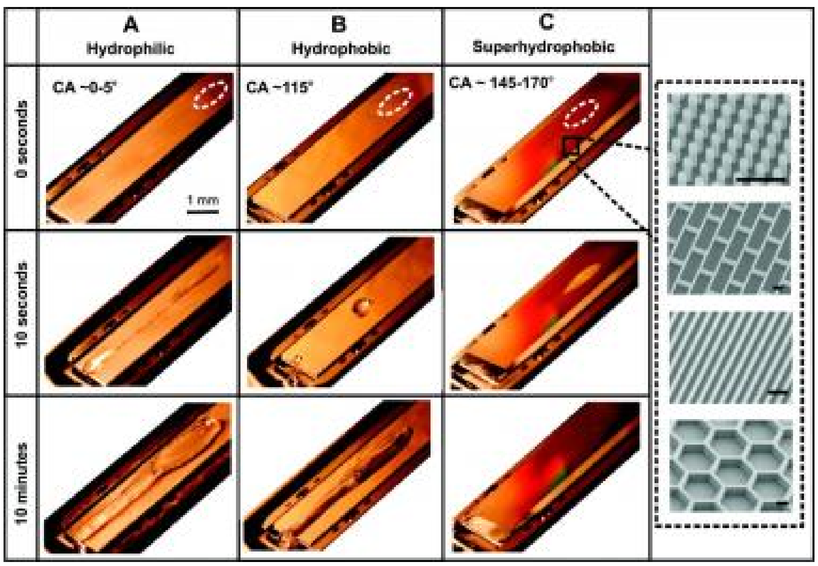


This shows ice accumulation on flat aluminum (A), smooth fluorinated Si (B), and microstructured fluorinated Si (C) surfaces.

(PhysOrg.com) -- Engineers from Harvard University have designed and demonstrated ice-free nanostructured materials that literally repel water droplets before they even have the chance to freeze.

The finding, reported online in *ACS Nano* on November 9th, could lead to a new way to keep airplane wings, buildings, powerlines, and even entire highways free of ice during the worst winter weather. Moreover, integrating anti-ice technology right into a material is more efficient and sustainable than conventional solutions like chemical sprays, salt, and heating.

A team led by Joanna Aizenberg, Amy Smith Berylson Professor of Materials Science at the Harvard School of Engineering and Applied Sciences (SEAS) and a Core Member of the Wyss Institute for Biologically Inspired Engineering at Harvard, focused on preventing rather than fighting ice buildup.

"We wanted to take a completely different tack and design materials that inherently prevent ice formation by repelling the water droplets," says Aizenberg. "From past studies, we also realized that the formation of ice is not a static event. The crucial approach was to investigate the entire dynamic process of how droplets impact and freeze on a supercooled surface."

For initial inspiration, the researchers turned to some elegant solutions seen in nature. For example, mosquitos can defog their eyes, and water striders can keep their legs dry thanks to an array of tiny bristles that repel droplets by reducing the surface area each one encounters.

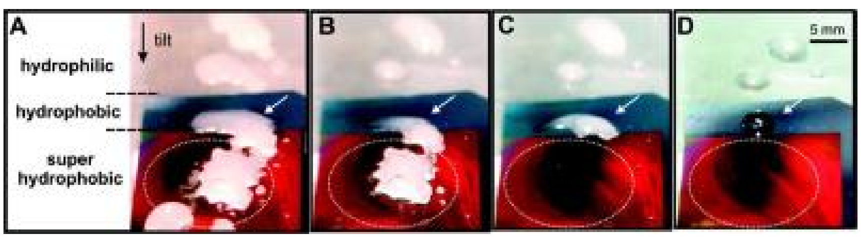
"Freezing starts with droplets colliding with a surface," explains Aizenberg. "But very little is known about what happens when droplets hit surfaces at low temperatures."

To gain a detailed understanding of the process, the researchers watched high-speed videos of supercooled droplets hitting surfaces that were modeled after those found in nature. They saw that when a cold droplet hits the nanostructured surface, it first spreads out, but then the process runs in reverse: the droplet retracts to a spherical shape and bounces back off the surface before ever having a chance to freeze.

By contrast, on a smooth surface without the structured properties, a droplet remains spread out and eventually freezes.

"We fabricated surfaces with various geometries and feature sizes—bristles, blades, and interconnected patterns such as honeycombs and bricks—to test and understand parameters critical for optimization," says Lidiya Mishchenko, a graduate student in Aizenberg's lab and first author of the paper.

The use of such precisely engineered materials enabled the researchers to model the dynamic behavior of impacting droplets at an amazing level of detail, leading them to create a better design for ice-preventing materials.



Sequential images of ice layer removal from hydrophilic Al, fluorinated hydrophobic Si, and microstructured fluorinated Si (SHS).

Another important benefit of testing a wide variety of structures, Mishchenko adds, was that it allowed the team to optimize for pressure-stability. They discovered that the structures composed of interconnected patterns were ideally suited for stable, liquid-repelling surfaces that can withstand high-impact droplet collisions, such as those encountered in driving rain or by planes in flight.

The nanostructured materials prevent the formation of ice even down to temperatures as low as -25 to -30 degrees Celsius. Below that, due to the reduced contact area that prevents the droplets from fully wetting the surface, any ice that forms does not adhere well and is much easier to remove than the stubborn sheets that can form on flat surfaces.

"We see this approach as a radical and much needed shift in anti-ice technologies," says Aizenberg. "The concept of friction-free surfaces that deflect supercooled water droplets before ice nucleation can even occur is more than just a theory or a proof-of-principle experiments. We have begun to test this promising technology in real-world settings to provide a comprehensive framework for optimizing these robust ice-free surfaces for a wide range of applications, each of which may have a specific set of performance requirements."

In comparison with traditional ice prevention or removal methods like salting or heating, the nanostructured materials approach is efficient, non-toxic, and environmentally friendly. Further, when chemicals are used to de-ice a plane, for example, they can be washed away into the environment and their disposal must be carefully monitored. Similarly, salt on roads can lead to corrosion and run-off problems in local water sources.

The researchers anticipate that with their improved understanding of the ice forming process, a new type of coating integrated directly into a variety of materials could soon be developed and commercialized.

Provided by Harvard University