To de-ice planes on the fly, researchers aim to control rather than combat ice formation

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How do you control ice formation on a plane, even when it's in flight? Jonathan Boreyko, associate professor in the Department of Mechanical Engineering, is leading a team working with Collins Aerospace to develop an approach using ice itself. In a study published in *Physical Review Letters*, they created a de-icing method that exploits how frost grows on pillar structures to suspend ice as it forms into a layer that's easier to remove.

Ice formation on airplanes can be both an aggravation and a health hazard. Watching an airport departure board for delays because of ice is familiar territory for winter travelers, and the National Transportation Safety Board reports a total of 52 in-flight accidents attributed to ice formation between 2010 and 2014, resulting in 78 fatalities.

De-icing a plane at the airport prior to takeoff is possible, but planes also experience plummeting temperatures and rapid ice formation in flight. Once ice forms on the wings, it can greatly inhibit a pilot's ability to safely operate the aircraft. Equipping planes with the ability to remove ice while flying at altitudes between 35,000 and 42,000 feet would provide a better set of tools to maintain safety, the researchers believe.

Putting ice on a pedestal

Boreyko's team worked from the knowledge that water droplets behave in different ways, depending on the surface. They aimed to leverage a principle known as Cassie's Law, which shows that air can be trapped under water drops if the drops are suspended atop a structure that is bumpy and water-repellent. With a structure that could trap air underwater in this "Cassie state," the researchers sought to make ice form in a layer with lower adhesion to the surface.

Making a surface water-repellent typically requires a chemical coating that must be periodically replenished, Boreyko explained, and the bumpy surface also tends to wear over time. The team opted for a novel approach, with the goal of making a water-repellent surface that doesn't require fragile chemical coatings or ultra-fine bumps. Instead, they opted for a simple and durable structure in the form of aluminum, millimeter-sized pillars.

Boreyko's team created an array of pillars, each one millimeter tall by half a millimeter wide. The tiny pedestals were machined into a pattern with a millimeter between. As the temperature dropped, frost preferentially grew on the tops of the pillars, resulting in elevated frost tips. As more water was added, it was absorbed into this porous frost layer. When water drops were subsequently impacted on the surface, they were caught on the frost pedestals.

These freezing drops created tiny "ice bridges," as lead author Hyunggon Park described, that sealed the gaps of air in the valleys between the frost-tipped pillars. "When impacting water drops froze on the surface, we made an interesting observation: The water drops were being caught by the frost tips and building ice bridges to trap air pockets underneath," Park said. Over time, a continuous and air-trapping ice canopy formed over the frost-tipped pillars.

Whereas other de-icing methods may still allow a sheet of ice to adhere more directly to a large surface area, these trapped air gaps cause the sheet to be suspended, lowering the amount of adhesion ice has to the surface.

"By using larger pillars in place of nanostructures, and frost tips in place of a hydrophobic coating, we found we can get the same benefit of trapping air underneath the forming ice while avoiding the durability concerns," Boreyko said. "This should make our approach practical for enhancing de-icing on aircraft or heat exchangers."

With a weaker bond, it's possible to use the air pockets to then push ice away. This will be the next step in the researchers' process, as Boreyko's team continues to develop their method.

More information: Hyunggon Park et al, Using Frost to Promote Cassie Ice on Hydrophilic Pillars, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.127.044501

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