Colorful films could help buildings, cars keep their cool

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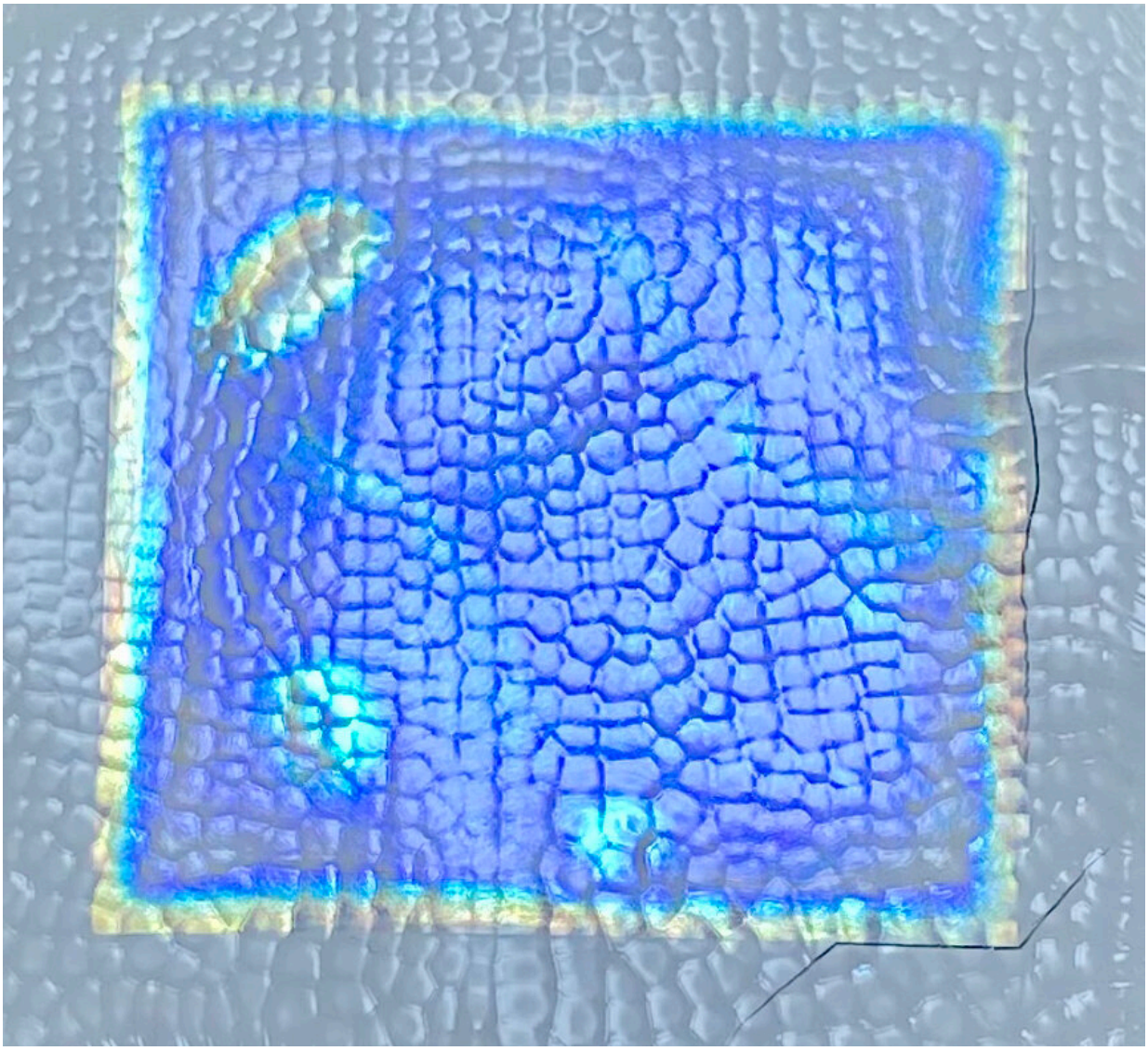

A colorful, textured bi-layer film made from plant-based materials cools down when it's in the sun. Credit: Qingchen Shen

The cold blast of an air conditioner can be a welcome relief as temperatures soar, but "A/C" units require large amounts of energy and can leak potent greenhouse gases. Today, scientists report an eco-friendly alternative—a plant-based film that gets cooler when exposed to sunlight and comes in a variety of textures and bright, iridescent colors. The material could someday keep buildings, cars and other structures cool without requiring external power.

The researchers will present their results at the spring meeting of the American Chemical Society (ACS). ACS Spring 2023 is a hybrid meeting being held virtually and in-person March 26–30.

"To make materials that remain cooler than the air around them during the day, you need something that reflects a lot of solar light and doesn't absorb it, which would transform energy from the light into heat," says Silvia Vignolini, Ph.D., the project's principal investigator. "There are only a few materials that have this property, and adding color pigments would typically undo their cooling effects," Vignolini adds.

Passive daytime radiative cooling (PDRC) is the ability of a surface to emit its own heat into space without it being absorbed by the air or atmosphere. The result is a surface that, without using any electrical power, can become several degrees colder than the air around it. When used on buildings or other structures, materials that promote this effect can help limit the use of air conditioning and other power-intensive cooling methods.

Some paints and films currently in development can achieve PDRC, but most of them are white or have a mirrored finish, says Qingchen Shen, Ph.D., who is presenting the work at the meeting. Both Vignolini and Shen are at Cambridge University (U.K.). But a building owner who

wanted to use a blue-colored PDRC paint would be out of luck—colored pigments, by definition, absorb specific wavelengths of sunlight and only reflect the colors we see, causing undesirable warming effects in the process.

But there's a way to achieve color without the use of pigments. Soap bubbles, for example, show a prism of different colors on their surfaces. These colors result from the way light interacts with differing thicknesses of the bubble's film, a phenomenon called structural color. Part of Vignolini's research focuses on identifying the causes behind different types of structural colors in nature. In one case, her group found that cellulose nanocrystals (CNCs), which are derived from the cellulose found in plants, could be made into iridescent, colorful films without any added pigment.

As it turns out, cellulose is also one of the few naturally occurring materials that can promote PDRC. Vignolini learned this after hearing a talk from the first researchers to have created a cooling film material. "I thought wow, this is really amazing, and I never really thought cellulose could do this."

In recent work, Shen and Vignolini layered colorful CNC materials with a white-colored material made from ethyl cellulose, producing a colorful bi-layered PDRC film. They made films with vibrant blue, green and red colors that, when placed under sunlight, were an average of nearly 40 F cooler than the surrounding air. A square meter of the film generated over 120 Watts of cooling power, rivaling many types of residential air conditioners. The most challenging aspect of this research, Shen says, was finding a way to make the two layers stick together—on their own, the CNC films were brittle, and the ethyl cellulose layer had to be plasma-treated to get good adhesion. The result, however, was films that were robust and could be prepared several meters at a time in a standard manufacturing line.

Since creating these first films, the researchers have been improving their aesthetic appearance. Using a method modified from approaches previously explored by the group, they're making cellulose-based cooling films that are glittery and colorful. They've also adjusted the ethyl cellulose film to have different textures, like the differences between types of wood finishes used in architecture and interior design, says Shen. These changes would give people more options when incorporating PDRC effects in their homes, businesses, cars and other structures.

The researchers now plan to find ways they can make their films even more functional. According to Shen, CNC materials can be used as sensors to detect environmental pollutants or weather changes, which could be useful if combined with the cooling power of their CNC-ethyl cellulose films. For example, a cobalt-colored PDRC on a building façade in a car-dense, urban area could someday keep the building cool and incorporate detectors that would alert officials to higher levels of smog-causing molecules in the air.

More information: ACS Spring 2023: Structurally colored radiative cooling cellulosic films, www.acs.org/meetings/acs-meetings/spring-2023.html

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