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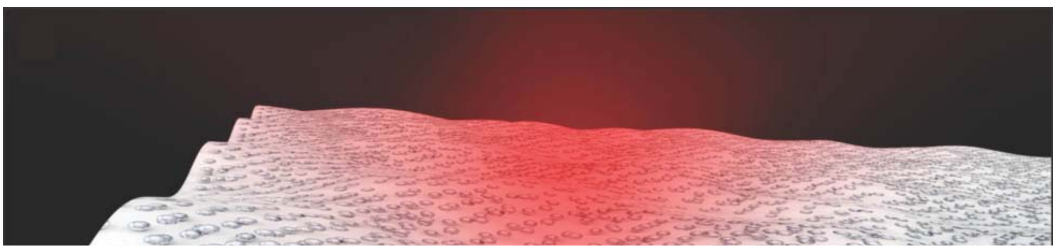
Cost-effective passive cooling

Inexpensive ingredients and scalable processes produce a material that can emit more energy than it absorbs, even under direct sunlight.

Johanna L. Miller

As anyone who's ever paid an electric bill knows, cooling is costly. The second law of thermodynamics dictates that energy can't spontaneously flow from a colder object to a warmer one, all else being equal. Cooling machines such as air conditioners and refrigerators therefore require an energy input to create and sustain an inside temperature lower than that of the outside air.

The second law is inviolate, but it allows for some counterintuitive effects. Earth's atmosphere—greenhouse gases and all—is nearly transparent to IR radiation between 8 and 13 μm, which also happens to be the peak wavelength range of thermal radiation at typical terrestrial temperatures. If a material radiates especially strongly into the atmospheric transparency window, it can shed thermal energy directly to outer space, almost as if the atmosphere weren't there.



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Passive radiative cooling below the ambient air temperature has been demonstrated since the 1970s, but only at night. Daytime cooling is trickier: The cooling material must emit strongly in the IR while absorbing essentially none of the Sun's visible light. Absorption of just a few percent negates the IR radiative cooling power. In 2014 Stanford University's Shanhui Fan and his colleagues found a way to achieve daytime radiative cooling using a nanophotonic material with alternating layers of silicon dioxide and hafnium dioxide. The composite, though, could be made only in small amounts under clean-room conditions.

Now Ronggui Yang, Xiaobo Yin (both of the University of Colorado Boulder), and their colleagues have come up with an effective cooling material that can be produced in large quantities by standard industrial roll-to-roll methods. The material, illustrated here, consists of micron-sized SiO_2 beads randomly distributed in a transparent polymer film. Over the course of their experiment, the researchers made hundreds of square meters of the film. Day or night, the material's cooling power hovers around 100 W/m^2, so a 10–20 m^2 sheet rivals the power of a residential air conditioner. (Y. Zhai et al., Science, in press, doi:10.1126/science.aai7899.)

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Vince Gutschick • 3 days ago

The flow of energy is partly radiative and the surface is cooling to an effective cold space. Interesting. However, practical use outdoors is hard to envision; a slight coating of normal dust would add that few percent of absorptivity to negate the net cooling. Don't count on it being a roof coating.

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Paul Torek → Vince Gutschick • 3 days ago

Bummer! Next question: how good a windshield wiper can be designed to keep it clean?

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andrewbb@gmail.com • 6 days ago

So, is this saying the material changes the frequency of light by absorbing ambient heat? And that light is directional?

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Keith Forsyth → andrewbb@gmail.com • 3 days ago

No, that's not the assertion. Most of the absorbed radiation is converted into heat, and the heated body then re-radiates omni-directionally with a spectrum determined by the Planck (blackbody) distribution. If the body's temperature is near 300 K, the peak wavelength of that distribution will be within the "atmospheric window". In this case the warm body can dump heat directly to the cold heat sink of space

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Just as pavement absorbs certain wavelengths from the sun and dissipates the energy at different wavelengths, so as SiO_2 does the same in reverse?

Its potential for solving global warming and its obvious profit possibilities do warrant further inquiry.

"The second law of thermodynamics dictates that energy can't spontaneously flow from a colder object to a warmer one, all else being equal." This seems backwards to me. Energy flows from warmer to colder and does so when in contact or through a medium within the same 'universe'.

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rational_being → andrewbb@gmail.com • 3 days ago

The way to think about it is like this: The I.R. channel between 8 and 13 μm is a connection to the cold of outer space.

If the sheet is warmed by "mechanical" contact from all around but radiates I.R. to space, it will be a cooling channel because space is much colder than the surface of the earth.

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