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Jumping droplets take a lot of heat

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Microscopic water droplets jumping from one surface to another may hold the key to a wide array of more energy efficient products, ranging from large solar panels to compact laptop computers.

Duke University engineers have developed a new way of producing thermal diodes to regulate heat by bleeding it away or keeping it in. The method solves several shortcomings of existing devices.

While thermal diodes can be made from solid materials, these solid-state diodes are not nearly as effective as "phase-change" thermal diodes that rely on vaporization and condensation to transport heat. Existing phase-change diodes can transfer over a hundred times more heat in the forward direction than the reverse, but with major limitations: they are dependent on gravity or restricted to a one-way direction. This limits their use in mobile electronics or solar panels.

The Duke engineers believe they have figured out a way to overcome these limitations by exploiting tiny self-propelled water droplets, or condensate, that can jump from a water-repellent, or superhydrophobic, surface to a highly absorbent, or superhydrophilic, surface, but not the other way around.

The results of the Duke experiments were published online in the journal *Applied Physical Letters*.

Videotaping the jumping motion of the droplets, Chuan-Hua Chen, assistant professor of mechanical engineering and materials science, found that the water literally jumped straight up and off a water-repellant surface. In current experiments, he and his colleagues placed a super-absorbent plate across from the water-repelling one, creating an asymmetry that is crucial to forming heat flow in their thermal diode.

"When the water-repellant surface is colder than the super-absorbent surface, the heat transport is very effective, much like sweat taking away body heat. When the repellant surface is hotter, the heat flow is blocked and the diode behaves like a double-paned window," Chen said.

Typical phase-change thermal diodes rely on evaporating water to transfer heat from one surface to another, with gravity pulling the subsequent condensation down to restart the cycle again. This kind of "thermosyphon" is in use in the Alaskan oil pipeline to prevent the heat in the pipes from melting the permafrost.

"Because the jumping droplets in our system are very small, gravity has a negligible effect on them," so they can be oriented in any direction, Chen said. This new approach is also scalable, which means technology based on this design can be used for thermal management of devices as small as a computer chip and as large as a building roof, he said.

The thermal diodes, he said, could be used in devices ranging from energy-efficient solar panels to smart "skins" of thermally adaptive buildings. During summer, a thermal diode panel on a building could let heat escape out but also prevent it from creeping in. Or, in space vehicles, they could be used to regulate thermal fluctuations from night to day, or even to harvest solar energy for powering satellites, he said.

Provided by Duke University