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Jumping Droplets Make a Heat Trap

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

Engineers at Duke University of Durham, N.C., said they've developed a new way of producing thermal diodes that regulate heat by either bleeding it away or keeping it in. These temperature sensors keep heat flowing in one direction.

The method solves several shortcomings of existing diodes.

While thermal diodes can be made from solid materials, the solid-state diodes are not 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, said Chuan-Hua Chen, Duke assistant professor of mechanical engineering and materials science, who worked on the project.

This limits their use in mobile electronics or solar panels.

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

By videotaping the jumping motion of the droplets, Chen said he found the water literally jumped straight up and off a water-repellant surface. He and his colleagues next placed a super-absorbent plate across from the water-repelling one, creating an asymmetry crucial to 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.

"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; 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 could be used in devices ranging from energy-efficient solar panels to smart skins of thermally adaptive buildings. A thermal diode panel on a building could let summer heat escape but also prevent it from creeping back in, Chen said.

Or, in space vehicles, the diodes could be used to regulate thermal fluctuations from night to day, or even to harvest solar energy for powering satellites, Chen said. JEAN THILMANY

Rare Earth Bottleneck

The use of rare earth minerals may become a logistical bottleneck plaguing the deployment of wind turbines, photovoltaic cells, and electric vehicles, according to a report recently updated by the U.S. Department of Energy.

The *Critical Materials Strategy* focuses on the role that 16 chemical elements will play in several clean-energy technologies expected to experience high growth in coming years. These elements include lithium, cobalt, gallium, and lanthanum. The materials were analyzed in terms of their importance to the so-called clean-energy economy and their vulnerability to supply disruption.

The report found that demand for these sorts of material has grown faster in recent years than the demand in commodity metals such as steel, and that the global supply has failed to meet this new demand. As a result, five elements used in high powered magnets found in wind turbines and electric vehicles or used in the phosphors of high efficiency lighting are in critically short supply. Those materials are dysprosium, terbium, europium, neodymium, and yttrium.

Indeed, as lighting efficiency standards are implemented in the U.S. this year, an increased demand for fluorescent lighting phosphors may lead to shortages of europium, terbium, and yttrium.

On the other hand, while supplies of the rare earth element lanthanum, used in fluid catalytic cracking catalysts, are near-critical, petroleum refiners have been able to work around the resulting increases in prices. The report states that lanthanum shortages have added only one cent to the price of a gallon of gasoline.

The report also found that companies are taking these material shortages seriously enough to proactively design equipment to use fewer materials vulnerable to supply bottlenecks. These companies have found that the reduction in performance may be more than compensated by the resilience against the risk of material shortages.

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