# New water vapor condenser takes cues from darkling beetle

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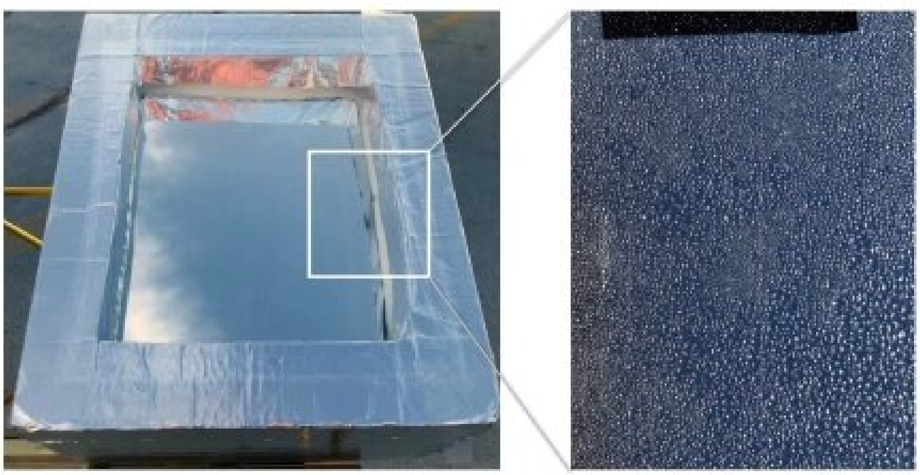

On the left, a look at the condenser unit. On the right, a closeup view of the water the unit is shedding. Credit: Ming Zhou, UW-Madison

Access to clean water is a huge issue across the globe. Even in areas with water resources, a lack of infrastructure or reliable energy means purifying that water is sometimes extremely difficult.

That's why a water vapor condenser designed by University at Buffalo and University of Wisconsin-Madison engineers could be revolutionary. Unlike other radiative vapor condensers which can only operate at night, the new design works in direct sunlight and requires no energy input.

"We have worked on solar-driven water evaporation technologies in the past years," says Qiaoqiang Gan, Ph.D., professor of electrical engineering at UB and a leading corresponding author. "We are now addressing the second half of the water cycle, condensation."

"Water sustainability is a global issue," says Zongfu Yu, Ph.D., associate professor of electrical and computer engineering at UW-Madison, another leading corresponding author. "You can't set out to solve the water problem without addressing energy."

Yu, Gan and their students described the new radiative vapor condenser in the journal *Proceedings of the National Academy of Sciences*, published online March 31.

## Tech borrows from darkling beetle

The idea of radiative cooling is not new. In fact, it's used in nature by insects like the darkling beetle found in the Namib Desert in southwest Africa. During clear nights when ambient temperatures are cool, darkling beetle shells shed extra heat in the mid-infrared range, also known as the atmospheric-transparency window. That heat naturally radiates toward the cool upper atmosphere of Earth and the chilly void of space.

This heat loss lowers the beetle's temperature below the dew point, or the temperature at which water vapor in the air condenses into droplets on cooler surfaces (think of a glass of iced tea on a hot day). The beetle is then able to harvest that water, using special grooves and structures to direct the moisture toward its mouth.

Over the last few decades, researchers have designed dew collectors based on the same principle, using special materials that efficiently shed heat like the beetle shell does. The problem is that those collectors only work at night since sunlight produces more heat than the materials can give off.

In this project, the team, led by UW-Madison postdoctoral researcher Ming Zhou, constructed a small vapor condenser using a thin film of material called polydimethylsiloxane (PDMS) which is very efficient at releasing thermal radiation in the atmospheric-transparency window. They layered that over silver, which reflects sunlight. The combination of the two is able to cool the condenser below the dew point, leading to condensation.

## Made from widely available, inexpensive materials

Zhou tested the device by placing it inside a box-like condensation chamber alongside chambers containing a commercially available dew-collecting material as well as a simple black body. The team pumped humidified air into the three chambers, which they positioned on top of a UW-Madison building and, during another test, a parking garage. The polydimethylsiloxane was the only material that condensed water vapor while in direct sunlight.

"Fundamentally, our radiative condenser is engineered to be in 'thermal contact' with the vast cold reservoir in the upper atmosphere and in outer space," says co-author Mikhail Kats, a UW-Madison electrical and computer engineering associate professor. "The cooling power obtained via this thermal contact enables daytime water condensation with no need for an external power source."

Another benefit is that polydimethylsiloxane is a widely available, relatively cheap material and the silver backing is not necessary for the condenser to work.

"The cost and availability of materials has been the barrier for this type of application. But that's not the case in our system, which is much closer to reality," says Gan.

## Startup Sunny Clean Water is commercializing the tech

Currently, Yu and Gan are hoping to commercialize the condenser through their company Sunny Clean Water LLC by pairing it with another passive process they've researched, solar vapor generation. Their idea is to create a system in which untreated water or even sea water is vaporized, then run it through the condenser to purify it using the sun as the only energy source.

Eventually, the team hopes that the system is efficient enough to produce water directly from the air. It's a process they are working to optimize. "This experiment was done using some controlled water vapor," says Yu. "Now, the next step is to pull the water directly out of the air. That's very, very exciting to us—to get water from the air for free using no energy."

**More information:** Ming Zhou et al. Vapor condensation with daytime radiative cooling, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2019292118

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