
ARACHNO HYDRO

# PHOBIA

## UF materials scientists turn to spiders for a surface that sends water running scared

By Aaron Hoover

When Wolfgang Sigmund launched his battle with water, one of his first moves was to plunk down $30 for 10 Lady's Mantle plants.

A common herb, Lady's Mantle is known for staying dry in the rain. Water balls up atop the fine hairs on its leaves, cascading off in the wind. Sigmund, a professor of materials science and engineering, thought if he could mimic Lady's Mantle hairs on an engineered surface, it might lead to water-shedding roofs, rain gear or boat hulls. It could also make windows and walls self-cleaning, since vanquished water droplets would carry away dirt.

To Sigmund's and doctoral student Shu-Hau Hsu's disappointment, the results fell short of expectations. But, tinkering with the shape and length of the artificial microscopic hairs they created to mimic the Lady's Mantle hairs, they made a discovery. A chaotic blend of hairs of different sizes, bent over randomly, sent water droplets skittering across the surface like ball bearings tossed on ice. When the researchers hunted explanations, they discovered an analogue to their hairy surface in nature. Except it was not a plant. It was an arachnid.

"When we compared our structure to published pictures, we found spider hairs resembled it the closest," Sigmund says. "They have short hairs and longer hairs, and they vary a lot."

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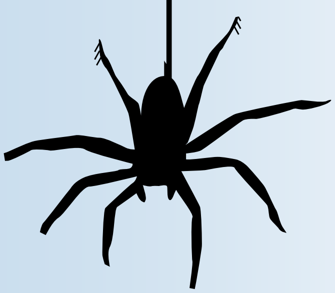


Four years and much research later, Sigmund's and Hsu's discovery has led to a surface on which, in Sigmund's description, water exhibits "no friction within the error of our measurement capabilities."

Water drops placed on his fingernail-sized surfaces flee as if in terror of an invisible pursuer until they reach the edges. Sigmund took the technology public in a February article in the journal *Langmuir*, but UF applied for patents first. By the time the *Langmuir* article appeared, nearly 20 companies, including several major chemical corporations, had already inquired about licensing the technology. Possible applications range from self-cleaning windows to stain-resistant restaurant tables to always-spotless walls.

"Easy-to-clean surfaces are one of the holy grails," says Lenny Terry, an assistant director in UF's Office of Technology Licensing who has been responding to the corporate inquiries.

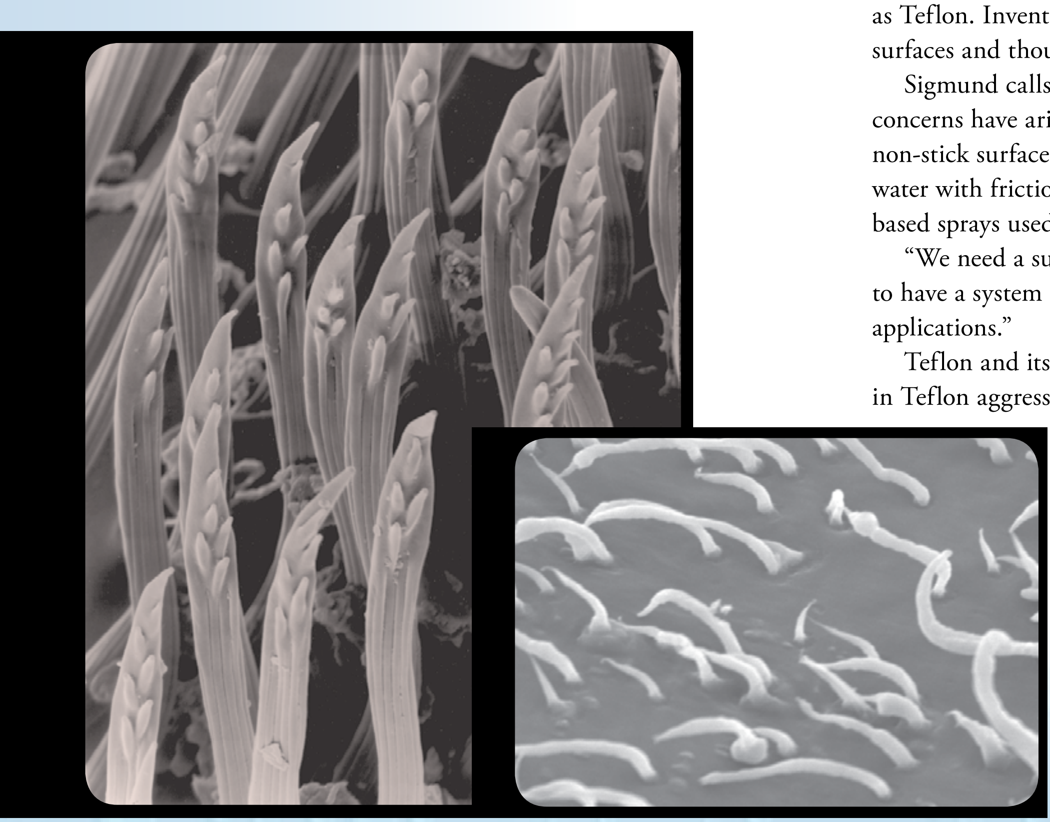
## Dive, Dive

For a material to be easy to clean, it must repel water, oil and, ideally, just about everything else. To date, no material has done that more effectively on a commercial scale than polytetrafluoroethylene, marketed by DuPont as Teflon. Invented in 1938, Teflon has been used on cooking surfaces and thousands of other applications for decades.

Sigmund calls Teflon "very sturdy and robust," but safety concerns have arisen about the chemicals used to adhere the non-stick surface to pots and pans. Also, Teflon does not shed water with frictionless ease, causing problems with Teflon-based sprays used as repellants.

"We need a substitute for Teflon," Sigmund says. "We need to have a system that you can use for outdoor and many other applications."

Teflon and its cousins work by chemical action: the fluoride in Teflon aggressively rejects bonds with other chemicals. For Sigmund, that's also the material's major weakness. What's needed, he believes, are surfaces that repel water, oil and other materials solely by the microscopic physical shapes on their surfaces. Theoretically, such surfaces could transform even the



*Wolfgang Sigmund's team drew inspiration from spider hairs (left) to develop their water-repelling surface (right).*

most water-sopping materials — sponges, for example — into water-shedding ones. They would also be less likely to slough off dangerous chemicals. Provided the surface material itself was safe, making it water repellant would introduce no new risks.

Plants evolved the physical approach long ago. Besides Lady's Mantle, perhaps the best known are lotus leaves, which are covered with a grid of small bumps that shunt water away. But few water-resistant plants are as impressive as spiders.

Many spiders have water-repelling hairs. Most use them to stay dry or avoid drowning. Then there's the diving bell spider, which uses its water-repelling hairs to extreme effect. Native to northern Europe, the diving bell spider manipulates the hairs on its abdomen and legs to capture air, then tows the bubble beneath the surface to a web-covered "diving bell" that serves as its home base. Frequently replenished by the spider, the bell allows the air-breathing creature to nevertheless spend nearly its entire life submerged.

"Spiders have an awesome system," Sigmund says, "based purely on physics."

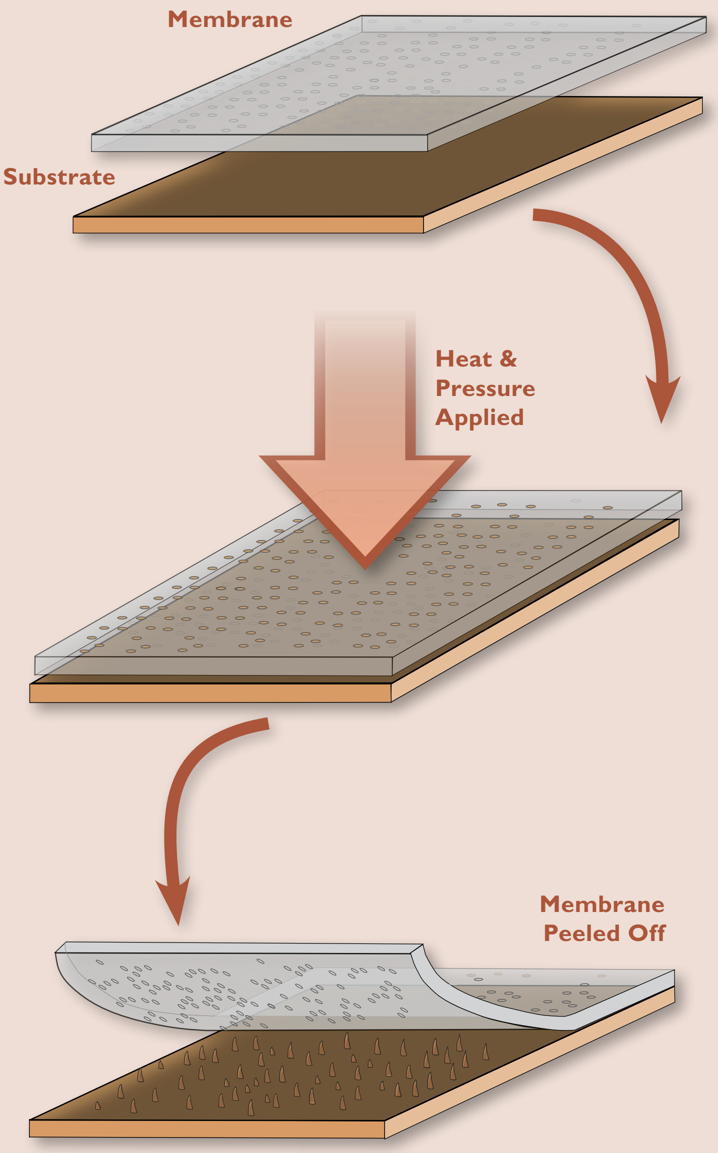
As a scientist and engineer, Sigmund said, his natural tendency was to make all his fibers the same size and distance. His spider-mimicking surface was a leap of faith. Its hairs are spaced close or wide, droop over at various angles and are different lengths, averaging about 10 microns, or millionths of a meter. The opposite of slick or machined, the surface doesn't look like a structure that would repel water. Just the opposite.

But with a smooth surface, Sigmund explained, much of the surface area of the water droplet makes contact. The droplet bulges down on the surface, dragging a kind of tail as it moves, if it moves at all. With the spider surface, the hairs catch and buoy the droplet, barely touching yet holding it aloft. As a result there is no perceptible bulge in the droplet, which remains spherical as it slaloms along the hairs.

"Most people that publish in this field always go for these perfect structures, and we are the first to show that the bad ones are the better ones," Sigmund said.

Ray Carson

*Wolfgang Sigmund demonstrates how water drops retain their shape on the almost frictionless surface his team developed, instead of bulging out as they do on an untreated surface in the lower inset.*




*The technique Sigmund uses to make the surfaces involves applying a hole-filled membrane to a polymer, heating the two and then peeling off the membrane. Made gooey by the heat, the polymer comes out of the holes covered with the desired fibers or hairs.*

## Oil and Water

Sigmund says there is friction between the water droplets and his surface, but it is so small he cannot measure or observe it in even the tiniest bulge. "It cannot be 100-percent frictionless," he says, "but it is one of the lowest friction surfaces for water."

The surface also works for hot water — and, tantalizingly, offers promise for oil. Sigmund says oil poses a daunting challenge for self-cleaning surfaces because unlike water it has negligible binding energy, which means it does not want to form drops. However, he has found he can tweak the hairs on this surface to repel oil, though not without introducing new problems.

"Currently when we can do oil, water is not so good. If we can do water extremely well, then oil is not doing so well," so more work is needed, he says.

Even if Sigmund can solve that challenge, he or other developers of the technology still face hurdles. His technique to make the surfaces involves applying a hole-filled membrane to a polymer, heating the two and then peeling off the membrane. Made gooey by the heat, the polymer comes out of the holes covered with the desired fibers or hairs.

While inexpensive, different techniques may be needed to manufacture the surfaces in the many sizes needed for commercial production, he says.

"We actually can make these surfaces again and again. So we have reproducibility and reliability," Sigmund says. "However, we are limited in size at this moment due to the 'mold' that we use."

More work is also required to make the fibers hardier: too much water or other pressure causes the hairs to collapse.

Still, the possibilities are exciting.

While Sigmund doesn't believe new forms of non-stick pans are in the offing — the heat and scrubbing would likely damage the hairs beyond repair — he foresees dozens of

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other applications. Boats could ride on a cushion of air, making them faster and more efficient. The surfaces could also line the insides of pipes, accelerating liquids along their path. They could keep dust and grime off solar cells and windows, making cleaning unnecessary. All would reduce water consumption and the energy needed to pump the water, Sigmund notes.

There are numerous other possibilities: The food industry, for example, could tap the surfaces in plastic food packaging that would always be clear and free of oils and waters, giving consumers a better view of products on display.

"If this system works well enough, Teflon may disappear in a lot of applications," Sigmund says. "We already have enough knowledge now. I can see that with an interested company, within two years we could have something on the market."

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*Sigmund and doctoral student Shu-Hau Hsu examine a piece of their water-repelling surface.*

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