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Secrets of the gecko foot help robot climb

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The science behind gecko toes holds the answer to a dry adhesive that provides an ideal grip for robot feet. Stanford mechanical engineer Mark Cutkosky is using the new material, based on the structure of a gecko foot, to keep his robots climbing.

L.A. Cicero

Paul Day and Alan Asbeck worked on adhesives for the feet of the gecko-like Stickybot.

BY CHRISTINE BLACKMAN

A Stanford mechanical engineer is using the biology of a gecko's sticky foot to create a robot that climbs. In the same way the small reptile can scale a wall of slick glass, the Stickybot can climb smooth surfaces with feet modeled on the intricate design of gecko toes.

Mark Cutkosky, the lead designer of the Stickybot, a professor of mechanical engineering and co-director of the Center for Design Research, has been collaborating with scientists around the nation for the last five years to build climbing robots.

After designing a robot that could conquer rough vertical surfaces such as brick walls and concrete, Cutkosky moved on to smooth surfaces such as glass and metal. He turned to the gecko for ideas.

"Unless you use suction cups, which are kind of slow and inefficient, the other solution out there is to use dry adhesion, which is the technique the gecko uses," Cutkosky said.

Wonders of the gecko toe

The toe of a gecko's foot contains hundreds of flap-like ridges called lamellae. On each ridge are millions of hairs called setae, which are 10 times thinner than a human's. Under a microscope, you can see that each hair divides into smaller strands called spatulae, making it look like a bundle of split ends. These split ends are so tiny (a few hundred nanometers) that they interact with the molecules of the climbing surface.

The interaction between the molecules of gecko toe hair and the wall is a molecular attraction called van der Waals force. A gecko can hang and support its whole weight on one toe by placing it on the glass and then pulling it back. It only sticks when you pull in one direction – their toes are a kind of one-way adhesive, Cutkosky said.

"It's very different from Scotch tape or duct tape, where, if you press it on, you then have to peel it off. You can lightly brush a directional adhesive against the surface and then pull in a certain direction, and it sticks itself. But if you pull in a different direction, it comes right off without any effort," he said.

Robots with gecko feet

One-way adhesive is important for climbing because it requires little effort to attach and detach a robot's foot.

"Other adhesives are sort of like walking around with chewing gum on your feet: You have to press it into the surface and then you have to work to pull it off. But with directional adhesion, it's almost like you can sort of hook and unhook yourself from the surface," Cutkosky said.

After the breakthrough insight that direction matters, Cutkosky and his team began asking how to build artificial materials for robots that create the same effect. They came up with a rubber-like material with tiny polymer hairs made from a micro-scale mold.

The designers attach a layer of adhesive cut to the shape of Stickybot's four feet, which are about the size of a child's hand. As it steadily moves up the wall, the robot peels and sticks its feet to the surface with ease, resembling a mechanical lizard.

The newest versions of the adhesive, developed in 2009, have a two-layer system, similar to the gecko's lamellae and setae. The "hairs" are even smaller than the ones on the first version – about 20 micrometers wide, which is five times thinner than a human hair. These versions support higher loads and allow Stickybot to climb surfaces such as wood paneling, painted metal and glass.

The material is strong and reusable, and leaves behind no residue or damage. Robots that scale vertical walls could be useful for accessing dangerous or hard to reach places.

Next steps

The team's new project involves scaling up the material for humans. A technology called Z-Man, which would allow humans to climb with gecko adhesive, is in the works.

Cutkosky and his team are also working on a Stickybot successor: one that turns in the middle of a climb. Because the adhesive only sticks in one direction, turning requires rotating the foot.

"The new Stickybot that we're working on right now has rotating ankles, which is also what geckos have," he said.

"Next time you see a gecko upside down or walking down a wall head first, look carefully at the back feet, they'll be turned around backward. They have to be; otherwise they'll fall."

Cutkosky has collaborated with scientists from Lewis & Clark College, the University of California-Berkeley, the University of Pennsylvania, Carnegie Mellon University and a robot-building company called Boston Dynamics. His project is funded by the National Science Foundation and the Defense Advanced Research Projects Agency. The research is described in a paper published online Aug. 2 in *Applied Physics Letters*, "Effect of fibril shape on adhesive properties."

Christine Blackman is a science-writing intern at the Stanford News Service.

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