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## **Climbing Walls with Carbon Nanotubes**

A new kind of tape mimics the qualities of gecko feet.

By Kevin Bullis

Researchers have developed a carbon-nanotube-based tape that could prove useful for creating robots that climb walls and special adhesive gloves for astronauts. Unlike ordinary tape, which eventually loses its stickiness, this new material sticks like a permanent glue, but it can be removed and reused. It can also stick to a wider variety of materials, including glass and Teflon.

Dubbed "gecko tape" by researchers, the material works by imitating the nano- and microscale structures on geckos' feet that allow them to quickly scale walls and run across ceilings. The tape is reusable and will not dry up or slide off the wall because, unlike ordinary tape, it does not use viscoelastic glues. Instead, it employs carbon nanotubes to make use of microscale van der Waals forces that occur at very short ranges between surfaces. Bundles of nanotubes conform to the slightest microscopic variations on a surface, the same way that the bundles of nanoscopic keratin fibers that make up the hairs on gecko feet allow them to conform to walls.

Like ordinary tape, gecko tape clings strongly when pulled parallel to a surface; it can support just under 10 pounds per square centimeter. But the tape can be peeled off relatively easily when pulled perpendicular to a surface.

As nanoscale control over materials has grown, so has the number of groups developing versions of gecko tape. But the new tape, made by researchers at the University of Akron and Rensselaer Polytechnic Institute (RPI), is much stronger than those versions and is able to support four times more weight per area than gecko feet. Other researchers have tried using carbon nanotubes in the past, in part because they are very strong and can withstand much higher temperatures than plastic, hence would be useful in more applications. But those nanotubes were too stiff to be practical, says [Manoj Chaudhury](http://www.lehigh.edu/~mkc4/) (<http://www.lehigh.edu/~mkc4/>), a professor of chemical engineering at Lehigh University, who has worked on similar projects. So the Akron and RPI researchers modified the nanotubes by exploiting the fact that they can be chemically grown to have various numbers of walls. The researchers struck a balance between having too many walls, which makes the nanotubes too rigid, and having too few, which makes them weak, Chaudhury says.

To make the tape even stronger while maintaining flexibility, the researchers took a tip

from the geckos. They grew nanotubes in distinct bundles, much like the bundles of fibers that make up the hairs on gecko feet. Nanotubes are made by exposing catalysts to hydrocarbon feedstocks: gradually, carbon builds up on the catalysts in a distinctive atomic arrangement that forms tubes. The researchers grew nanotubes in bundles by depositing the catalyst material in a pattern of separate squares. They then transferred these bundles of nanotubes to a flexible plastic to make the tape.

The tape can still be improved in a number of ways. Right now, it takes a significant amount of pressure to get good contact between the nanotubes and the surface, says [Metin Sitti \(http://nanolab.me.cmu.edu/members/metin/\)](http://nanolab.me.cmu.edu/members/metin/), a professor of mechanical engineering at Carnegie Mellon University, who is developing similar materials. Chaudhury says that ultimately, it would be nice to have a material that sticks with little or no pressure, particularly for use with wall-climbing robots. [Ali Dhinojwala \(http://www2.uakron.edu/cpspe/dhinojwala/dhinojwala\\_research\\_group\\_web.htm\)](http://www2.uakron.edu/cpspe/dhinojwala/dhinojwala_research_group_web.htm), a professor of polymer science at the University of Akron, who led the work, says that the attachment pressure might be decreased by doing things like softening the tape's backing.

The researchers also want to make the tape stronger. Right now, when pulled parallel to a surface, the tape releases not because the carbon nanotubes come off the surface, but because the nanotubes themselves break. The researchers are currently working on a number of ways to strengthen the nanotubes to take advantage of this strong adhesion. They are also working to make the tape reusable thousands of times, rather than the dozens of times it can be used now. To achieve this goal, Dhinojwala and his team will have to make the tape self-cleaning, like gecko feet.

To commercialize the tape, the researchers will also need to make bigger patches of tape. So far, they've only made pieces of tape that are far smaller than a dime.

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