Synthetic nanoadhesive mimics sticking powers of gecko and mussel

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Geckos are remarkable in their ability to scurry up vertical surfaces and even move along upside down. Their feet stick but only temporarily, coming off of surfaces again and again like a sticky note. But put those feet underwater, and their ability to stick is dramatically reduced.

Water is an enemy of adhesives, which typically do not work well in wet environments -- think of how long a bandage on your finger lasts. Now two Northwestern University biomedical engineers have successfully married the gecko's adhesive ability with that of an animal well known for its sticking power underwater: the mussel.

Combining the important elements of gecko and mussel adhesion, the new adhesive material, called "geckel," functions like a sticky note and exhibits strong yet reversible adhesion in both air and water.

The findings, which could lead to applications in medical, industrial, consumer and military settings, will be published as the cover story in the July 19 issue of the journal Nature.

"The geckel material should be useful for reversible attachment to a variety of surfaces in any environment," said Phillip B. Messersmith, professor of biomedical engineering at Northwestern's McCormick School of Engineering and Applied Science and an author of the paper.

"I envision that adhesive tapes made out of geckel could be used to replace sutures for wound closure and may also be useful as a waterresistant adhesive for bandages and drug-delivery patches. Such a bandage would remain firmly attached to the skin during bathing but would permit easy removal upon healing."

A gecko's strong but temporary adhesion comes from a mechanical principle known as contact splitting. Each gecko foot has a flat pad that is densely packed with very fine hairs that are split at the ends, resulting in a greater number of contact points than if the hairs were not split. (The diameter of one of the split hairs is as small as 200 nanometers.) More contact points between hairs and surface result in a significant increase in adhesion force. Flies, bees and other insects also use this strategy.

Many researchers before Messersmith have attempted to mimic the gecko foot but have had limited success in replicating the reversible property over many contact cycles. No synthetic mimics have been able to stick past two contact/release cycles, and none work underwater.

In contrast, the geckel material created by Messersmith and Haeshin Lee, one of his graduate students and lead author of the Nature paper, sticks through 1,000 contact/release cycles (like a gecko) and performs extremely well underwater, with high adhesion strength (like a mussel). The material performs similarly in dry environments.

"I was reading a research paper about the drop of adhesion in geckos when underwater, and it hit me -- maybe we could apply what we know about mussels to make gecko adhesion work underwater," said Messersmith.

In earlier work, he and his research group created mussel-mimetic polymers and have studied extensively an amino acid called 3,4-L-dihydroxyphenylalanine (DOPA), which is found in high concentration in the "glue" proteins of mussels.

Messersmith and Lee imitated a gecko's foot by nanofabricating arrays of silicone pillars that exhibit enough flexibility to adapt to rough surfaces. Next they brought in the mussel power, coating the pillars with a very thin layer of a synthetic polymer, designed by the researchers, that mimics the wet adhesive mussel proteins.

The researchers measured the performance of the geckel material using an atomic force microscope. They found that pillar arrays coated with the mussel-mimetic polymer improved wet adhesion 15-fold over uncoated pillar arrays. (The pillars in the arrays tested were 400 nanometers in diameter and 600 nanometers high.)

In a control experiment, the researchers took the DOPA out of the polymer coating and found the adhesion strength dropped rapidly, illustrating the importance of the synthetic amino acid. DOPA, said Messersmith, is critical to the polymer sticking both to the pillars and to the surface with which the pillars are interacting.

"We have demonstrated a proof of concept, but it will be necessary to develop a patterning approach that works on a large scale," said Messersmith, who believes they can produce a material with even better adhesion. "The challenge will be to scale up the technology and still have the geckel material exhibit adhesive behavior."

Source: Northwestern University

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