GECKO INSPIRED SUPER ADHESIVES

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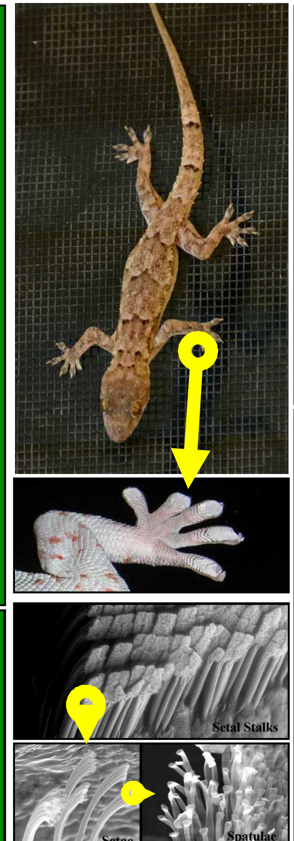
Introduction

A gecko's extraordinary ability to suspend itself from walls and ceilings of varied surface roughness has interested humans for hundreds of years. Many theories and possible explanations describing this phenomenon have been proposed including sticky secretions, microsuckers, and electrostatic forces; however, today it is widely accepted that van der Waals forces play the most important role in this type of dry adhesion. Inarguably, the vital feature that allows a gecko's suspension is the presence of billions of tiny hairs on the pad of its foot called spatulae. These features are small enough to reach within van der Waals distances of any surface (spatula radius ~100nm); thus, the combined effect of billions of van der Waals interactions is more than sufficient to hold a gecko's weight to surfaces such as smooth ceilings or wet glass.

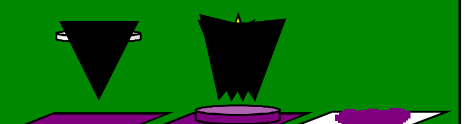
We attempt to recreate such tiny hairs using two different methods; microcasting involves filling a porous alumina disk with a polymer and etching away the alumina mold; photolithography is a process in which a UV treated, patterned polymer yields well ordered nanostructures. With these two methods, we were able to construct media with which to perform force analyses of our artificial arrays. Our force measurements were performed using the novel Interfacial Force Microscope that is well suited for such experiments. After measuring forces inherent to our fabricated arrays, we compared these results to those found in gecko setal arrays.

The objectives of this research endeavor are to construct well ordered arrays of nanohairs with similar dimensional features to those of a gecko's foot in attempt to design a new class of synthetic adhesive surfaces of potential interest for conferring gecko-like functionality to artificially made devices. Particular interest arises in the field of robotics where these arrays could allow robots to easily climb walls to perform covert or rescue missions; space applications also inspire great interest since vacuum conditions do not affect van der Waals interactions, maintaining artificial an array's adhesive properties.



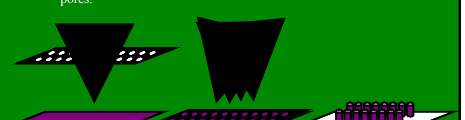
Artificial Setal Array Fabrication Methods

Method One : Microcasting. This process involves spin coating photoresist onto a substrate and applying a porous alumina disk that acts as a mold for the nanohairs. The photoresist fills the disk's pores and ultraviolet light treatment cross links the polymer. Finally, the support disk is etched away using a sodium hydroxide etch, resulting in an array of nanohairs 60um in height and 200nm in diameter.



Drop Anodisc on wet substrate. SU8 wicks through the anodisc, effectively filling the pores. | Cure SU8 with UV radiation. | Etch away the alumina anodisc with NaOH.

Method Two : Photolithography. For this method, a mask was applied to a polymer coated substrate effectively shielding an area of polymer from ultraviolet radiation. The entire assembly was treated with UV light, cross linking only the uncovered areas. Upon removal of the mask, the unpolymerized areas were washed away resulting in our nanostructures with 0.5um in height and 1um in diameter.



Apply a UV mask above the dried photoresist. | Cure SU8 with UV radiation through the mask. | Remove the unpolymerized photoresist using a wash.

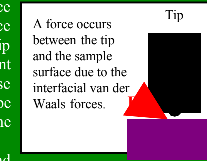
**materials included Anodisc by Whatman®, andSU8 type photoresist

Theory and Advantages of IFM

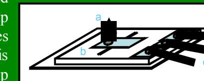
Almost all surfaces attract or repel approaching objects with vastly increasing force intensity with respect to decreasing spatial separation. The Interfacial Force Microscope measures surface adhesion and repulsion effects on a calibrated tip induced by the sample being measured. The IFM's advantage over similar instrument is its ability to withstand large adhesive or repulsive forces that occur within close proximity to a sample. Existing instruments such as the Atomic Force Microscope would be overcome by large attractive forces and would crash into the surface of the sample –ruining the experiment.

The IFM overcomes this effect using differential capacitors mounted behind each side of a cantilever beam using a Wheatstone bridge circuit. When the tip (attached to one side of the cantilever) approaches the sample and experiences adhesive or repulsive interactions, the cantilever is subject to a torque, which is countered by an applied voltage across one of the capacitors, thus keeping the tip sensor in equilibrium. This voltage is read and the force characteristics of the sample can be accurately measured.

For our purposes, a diamond tip with radius of 200nm was used. Tip size and makeup can be changed depending on the purpose, but this particular setup seemed to work most efficiently for our experiments.

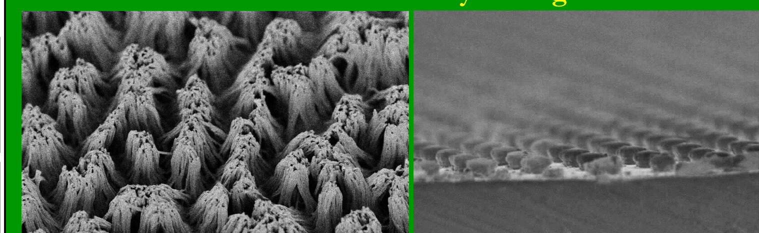


A force occurs between the tip and the sample surface due to the interfacial van der Waals forces.



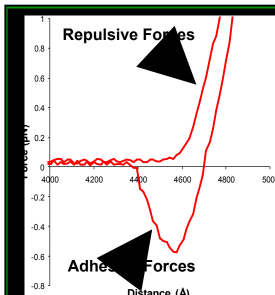
The tip (a) is mounted on a cantilever beam (b) behind which are two capacitors controlled by three leads (c).

Characterization of Fabricated Arrays Using SEM



Both of the two techniques demonstrate high similarities to a gecko's setal array. The microcasting method resulted in hairs with very similar hierarchical features to those of a gecko with hair radii of 200nm and heights of 60um; albeit the hairs demonstrated remarkable resemblance to their biological counterparts, they characteristically formed "clumps", drastically decreasing their effectiveness towards dry adhesion.

The method involving photolithography resulted in extremely well ordered nanostructures with easily controllable heights and widths (pictured with 0.5um and 1.0um respectively). In this case, the small heights are due to the initially thin surface thickness of the photoresist and are easily variable. Due to their lower aspect ratios, these arrays did not clump as did the nanohairs.



Force Calculation

Force profiles of our first artificial setal arrays reveal extremely promising results. Pictured is a force profile of the nanostructures created with photolithography. With feature heights of 0.5um, we noticed attractive forces of 0.6uN per area of $2.5x10^{-9}cm^2$. For the x axis, 0 Å is located at an arbitrary distance from the sample surface or ~4600Å in this case.

Conclusion and Future Research

Both the micromolding and photolithography techniques produced nanostructures with similar dimensional characteristics (0.2um and um respectively) to hairs found on a geckos foot. The success of our fabrication methods with respect to initial force measurements promises many possible paths for research in the future. Furthermore, the suitability of the IFM towards our purposes has allowed us to observe far greater force measurements for artificially fabricated setal arrays than have previously been reported in literature. For example, a two square centimeter patch of our hair array ideally would be able to support one heavy human! For future research, we would like to make efforts towards increasing the aspect ratio of our nanostructures and decrease the clumping effects characteristic of our nanohairs. Furthermore, we would attempt to fabricate our hairs using materials more biologically similar to that found in a Gecko's foot (keratin).

Photos courtesy of http://www.lclark.edu/-autumn/gecko.html

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