Nanotechnology in Nature: Mimicking the properties of the Gecko Foot

One of the most popular examples of Nanotechnology is Nature is the well-known, well-discussed animal, Gecko.
The gecko's ability to adhere to vertical surfaces--even walk upside down on ceilings---is due to the special hierarchical structure of its toes.

There is no glue involved; instead, the traction results from a physical property known as the Van-der-Waals forces, a transient attraction that can occur from atom to atom at the scale of molecules.

When a gecko places its foot on the wall and curls its toes, the tiny spatulae get so close to the nooks and crannies on the wall's surface that their atoms interact with the atoms of the wall, bringing the van der Waals forces into play. Van-der-waals forces are relatively weak forces when compared to normal bonding forces.

But for such weak forces to work, there must be an enormous intimate contact area between foot and surface, so that enough individual weak forces can add up to a very strong force.

Though the Gecko foot is an example that is used very often in talks as well as exhibits and demonstrations on nanotechnology, there has been a lack of hands on activities that could demonstrate the physical properties/attributes/phenomenon.

There are numerous research groups in the United States as well as in other countries that having been trying to mimic the behavior of the Gecko foot by creating an non-adhesive sticky tape that utilizes the van-der-waals forces rather than any type of glue.

The activity outlined here explains in detail how a working 'nanotechnology based Gecko-foot tape' can be synthesized with easy to obtain materials. This work has been adapted almost in its entirety from the research work of Prof. Ronald Fearing at University of California, Berkeley [1], one of the leading researchers in the gecko foot bio-mimicry. Also described is an easy setup using LEGO for testing the 'gecko tape'.

Materials:

Silicone RTV Mold-Making System (http://www.tapplastics.com/)
-Side A 1 lb $20.50
-Side B Fast Catalyst (Blue) 0.1 lb $3.95
Polycarbonate Millipore Track etched Isopore membrane filter (http://www.millipore.com/)
- TMTP04700, 5µm pore size, 47 mm diameter $84.00 for pack of 100 filters

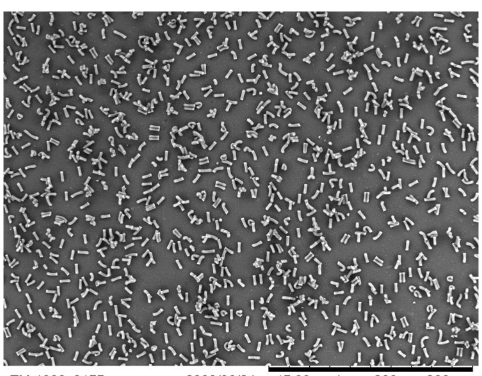
Double sided sticky tape
Weigh boat (or any disposable smooth glass/plastic wide mouth container)
Petri dish
Stirrer sticks or plastic disposable knives
Weighing machine

<u>Procedure:</u>

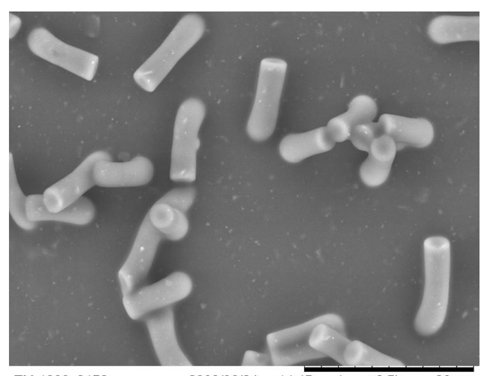
1. Put the double-sided sticky tape on the back of the Petri dish. Now carefully take one of the filters (note that the filters are very thin and clear and are separated by blue colored paper), handle with gloved hands and tweezers and carefully place it on the sticky tape. Press down on the filter to ensure that there are no trapped air bubbles. This step is very essential to avoid overfilling the pores. It is also important that there are no folds or creases in the filter and it is completely flat and smooth.
2. In your mixing container or weigh boat, carefully mix the two parts of the silicone. The ratio is 1 part Side B to 10 parts Side A **<u>by weight</u>** or 1 part Side B to 9 parts Side A **<u>by volume</u>**.
3. Stir very well; make sure all of the material on the sides of the container is mixed well. It is ready when no blue streaks can be seen and the color is a uniform blue (hint: look from the bottom of the container for any spots that have been missed). Also note that you have a total of 30 minutes of working time once you start mixing (before the mixture starts to set).
4. Carefully pour the mixture onto the filter that has been taped down on the back of the Petri dish from a height of 4-6 inches; this helps in expelling the air bubbles. Make sure that a uniform layer is covering the filter. To cover one filter completely with the silicone, 0.5 gm of Side B to 5gm of Side A is sufficient.
5. Set the Petri dish aside to cure overnight, it will be ready for use in about 24 hrs. After 24hrs it can be very easily peeled of the Petri dish and filter.

Notes:
It can be very readily seen that the side of the tape with the fine hair structure is rough in appearance and the other (without any structures) is smooth and shiny. It is better to handle the 'rough' side or the side that has the fibrillar structure with either gloves or by its edges since contamination of the 'gecko tape' will not yield good results during testing. The structures or fibers that are formed on the tape are typically around 15-20 µm in height and about 5 µm in diameter. The following images were taken with a Table Top Hitachi Scanning Electron Microscope (TM-1000). It is also possible to observe them with good optical/light microscopes.

<u>SEM Images of Gecko Tape:</u>



TM-1000_9155 2009/06/24 15:08 L x300 300 um



TM-1000_9152 2009/06/24 14:45 L x2.5k 30 um

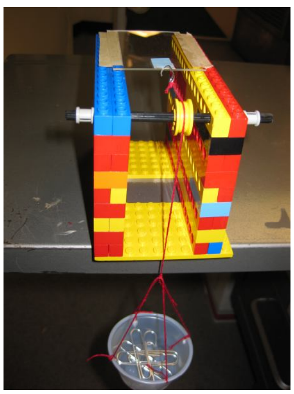
<u>Gecko Tape Testing:</u>

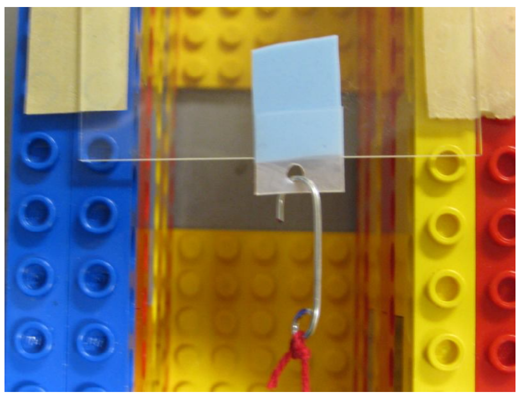
It is possible to test the tape with different configurations; the following setup uses Lego pieces. The setup should be designed so that the shear forces will act on the tape as the load hanging from the

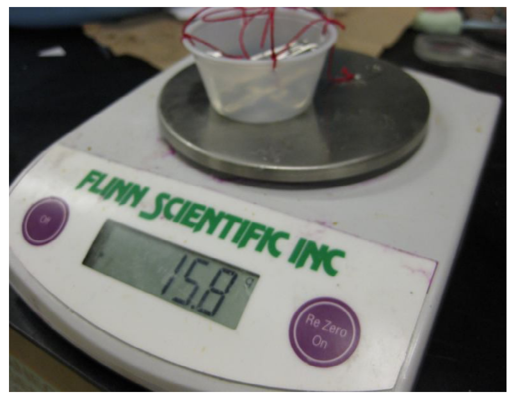
tape is increased thereby increasing the contact between the surface (in our setup it was glass) and the fibrillar structure on the tape. To detach the tape, the force can be applied in a direction perpendicular (normal) to the tape. The load bearing capability of a sample can be determined by increasing the load until the tape detaches itself from the surface.
As the load hanging off the tape is increased, it is possible to observe that the contact between the fibers on the tape and the glass increases by using a mirror on the underside: Lighter areas on the tape (observed from the underside of glass) can be seen as the load is increased indicating more contact and the light spots reducing as the load is decreased.
To build the setup shown we used a combination of 2x4, 2x8 and 2x10 Lego bricks and an appropriately sized large Lego plate/brick to hold the base of the setup. To hold the large glass slide onto the Lego setup, a double-sided sticky tape was used. The pulley ensures that the forces due to the hanging load acts in a direction parallel to the glass surface/tape.

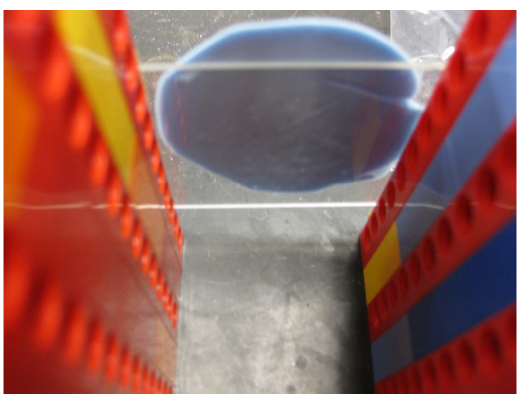
Note: If contamination is observed on the surface of the tape, it can be cleaned with ethanol and air drying.

Gecko Tape Testing Images:









1. Gecko tape setup
2. Close-up of Gecko tape
3. Measuring load after testing
4. Observing contact spots from the underside of the Gecko tape-on-glass (large sample).

References:

“Nanomolding Based Fabrication of Synthetic Gecko Foot-Hairs” M. Sitti and R.S. Fearing
IEEENano-2002