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Gecko Stick

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ABSTRACT : *Irony of nature's incredible fact's led us to delineate about a remarkable natural capability of Gecko, a type of lizard. This paper dwells around the anatomy of Gecko's foot whose capability of sticking and clinging to any surface whether vertical or upside down and walking over. This has led the scientists around the world to captivate its supernatural qualities and implement it in today's world. The paper also outlines about its application in today's world carving out niche technology on various frontiers.*

Keywords: *Setae, Spatulae, van-der Waals force, geckel, lithography.*

I. INTRODUCTION

Being able to climb like spider man is every child's fantasy. But today's technology is only one step behind from achieving this due to GECKOSTICK. The term geckostick is derived from the gecko which actually is a species of lizards.

Fig. 1 Gecko

Geckos are a superhero's envy when it comes to their ability to climb rapidly up just about any vertical surface. Unlike other climbing animals and insects, the small lizards have no need for suction cups, velcro-like hooks, electrostatic attraction or sticky secretions.

Despite a century of anatomical studies, nobody could ever figure out just how the lizard does it. Now, researchers at the University of California at Berkeley, Stanford University and Lewis & Clark College in Portland, Ore., are taking interest on these species and their remarkable ability to climb any kind of surfaces.

II. GECKO FOOT STRUCTURE

Researchers have discovered that a gecko uses an elaborated array of toe hairs that form intermolecular bonds with the surface as it walks. Gecko uses these intermolecular bonds to climb a vertical wall, stick upside down or even cling to polished glass

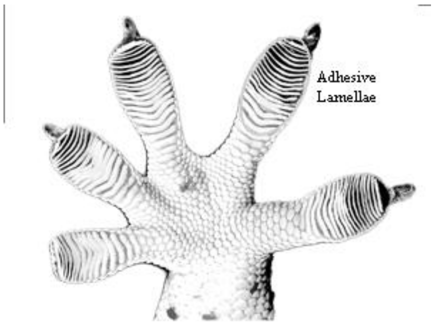

Fig. 2 Gecko's Foot

Each five-toed foot of the GECKO has about 500,000 microscopic foot-hairs called ``**SETAE**". Each seta is no more than about 5 microns in diameter –i.e. about one-tenth the diameter of a human hair. These setae are lined up in rows on the gecko's toes.

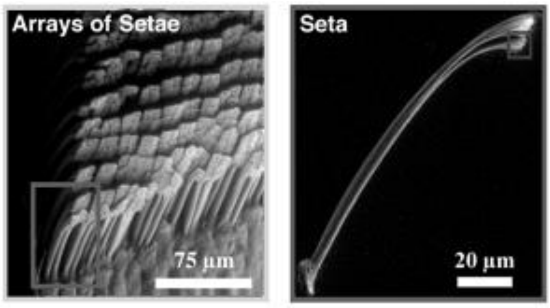

Fig. 3 Setae

Further each of this single seta divided to form an array of split ends which are bunch of 400 to 1,000 tiny structures. These submicroscopic, funnel-shaped pads, or spatula as it is called, measure about 200 nanometers.

Fig. 4 Spatulae

These spatulae, numbering perhaps a billion per gecko, are around 10 millionths of an inch across, and when spread out, begin to interact with a surface at a molecular level.

III. GECKO's ADHESION

The gecko moves with a peculiar motion of curling and uncurling its toes, up to 15 times a second.

A climbing gecko moves in such a way that when it presses a foot down, the toe hairs splay out and the spatulae spread out. This allows the spatulae to get extraordinarily close to the target surface so that subtle intermolecular attractions initiate. Essentially, the lizards may be grabbing onto walls with the same atomic-scale ``glue", known as van der Waals forces, that make enzymes biochemically `'sticky."

The gecko tries to find the proper angle and pressure by moving its toes. The adhesive force of one spatula may not amount to much, but collectively they generate an impressive force. As the gecko begins curling its feet again, an angle of around 30 starts to break the molecular force and the bond is released, leaving no residue.

IV. 'VAN--DER WAALS' FORCES

In physical chemistry, the **Van der Waals** force is the attractive or repulsive forces between molecules (or between parts of the same molecule) other than those due to covalent bonds or to the electrostatic interaction of ions with one another or with neutral molecules.

The ability of geckos to climb on sheer surfaces is due to van der Waals force. These "van der Waals" forces arise when unbalanced electrical charges around molecules attract one another. The cumulative attractive force of billions of setae allows geckos to scurry up walls and even hang upside down on polished glass. The reptile's grip is only released when it peels its foot off the surface.

V. ARIFICIAL SATAE

Inspired by the remarkable hairs that allow geckos to hang single-toed from steep walls and scamper along ceilings, a team of researchers led by engineers at the University of California, Berkeley, has created an array of synthetic micro-fibers that uses very high friction to support loads on smooth surfaces i.e. 'geckel'.

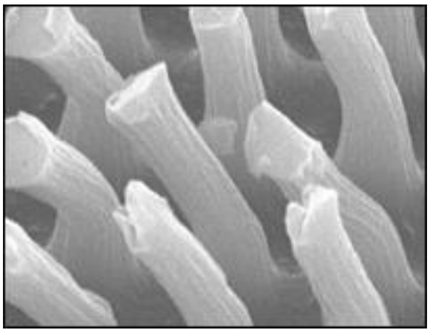

Fig. 5 Geckel is composed of millions of mushroom-shaped hairs

Each synthetic fiber in geckel is made from a material called kapton having dimensions same as gecko hairs. The hair-covered tape is made using a mould created by a lithographic process.

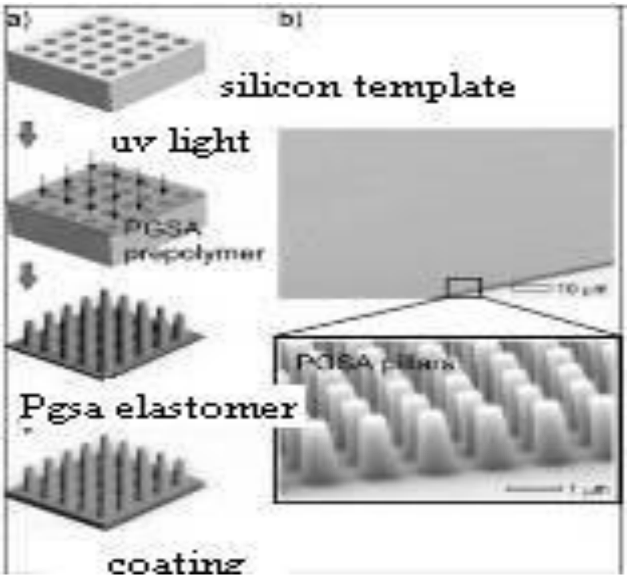

Fig. 6 Process of lithography

A piece of tape one centimeter square holds around 100 million of these artificial setae and could support a weight of one kilogram. Its staying power comes from coating fibrous silicone, similar in structure to a gecko's foot, with a polymer that mimics the "glue" used by mussels.

Unlike other adhesives inspired by the nimble reptiles, "geckel" can attach to both wet and dry surfaces and even in vacuums.

Tests showed that the material could be stuck and unstuck more than 1,000 times, even when used under water. The researchers said that other materials had only demonstrated "a few contact cycles". Removing the polymer coating drastically reduced its efficiency.

VI. APPLICATIONS

The adhesion of the gecko finds its applications in various fields especially in medical and technology field. Scientists just can't resist trying to copy the remarkable way these animals stick to walls using feet covered in millions of microscopic hairs. Moreover the fact that gecko adhesion works in a vacuum means the system could be used for space works.

A. Mecho-Gecko:

One small step for a gecko is proving to be one giant leap for robot designers. iRobot has built gecko-inspired robots called 'Mecko-gecko'.

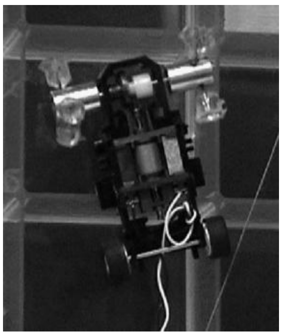

Fig. 7 Mecho-Gecko

The Mecho-Gecko's three legs are tipped with a pressure-sensitive adhesive to mimic the unroll-and-peel-off manner in which geckos climb.

B. Stickybot:

Stickybot, developed by Mark Cutkosky and his team at Stanford University in California, has feet with synthetic setae made of an elastomer. These tiny polymer pads ensure a large area of contact between the feet and the wall, maximizing the van-der Waals stickiness.

Fig. 8 Stickybot

The Pentagon is interested in developing gecko-inspired robots. A Stickybot-type robot would also make an adept planetary rover or rescue bot.

C. Robot crawlers:

Robot crawlers, used in aviation to check for flaws or defects, currently use suction to attach themselves to the wings or fuselage, but they also have hoses and other peripherals attached. 'Synthetic Gecko' would eliminate the need for this.

D. Disaster Rovers:

After the big earthquake hits, emergency responders must have the superhero-like skills of the gecko for keeping them safe from collapsing buildings as they try to find survivors.

Robots inspired by the gecko's multi-purpose tail and incredible sticky feet could be the first ones to explore the unstable, potentially dangerous rubble in search of life, saving time and the lives of rescuers.

E. Biodegradable tape:

- Biodegradable tape could replace surgical sutures and staples.
- It could also be used to deliver drugs to organs, including the heart.
- The tape could be laid down in one motion, potentially shortening patients' time in surgery.
- It could also help doctors during laparoscopic surgeries, which are performed through a small incision.
- The tape might also be used to reinforce sutures and staples used when a segment of the gastrointestinal tract is removed during gastric bypass surgery.
- The tape could release drugs that promote healing as it seals the incision.
- After heart attacks, patients often have regions of damaged tissue that don't get enough oxygen. This can lead to heart failure. Injecting a stem-cell-attracting factor encourages tissue regeneration, but sticking needles into the heart is dangerous. A patch of medical tape might deliver these factors at lower risk.

F. Parking:

A patch of the material one-meter-squared would hold the weight of a family-sized car.

G. Athletics:

From this type of material we can also make super-grip shoes for athletes.

H. Automobiles:

Tyres could be made that can hold the road better in all weathers.

I. Geckobot

Inspired by the unparalleled characteristic of gecko i.e. Stickiness of its spatula, over a decade research and development is being carried out to build Geckobot- A climbing Robot. This is built using simple features using Peeling mechanism, stable climbing of bots using active tail for centre of gravity balance during its ascent and descent.[1,2]

For these geckobot to stick to the surface different attachment methods have been employed over a period,

1. Suction adhesion
2. Magnetic adhesion
3. Grasping technique

Of the late, recently evolved mechanism is Passive attachment mechanism. The typical Tokay gecko weighs 300g and 35cm in length has a footpad of fibrillar dry adhesive. The geckobot's footpad is built with synthetic dry adhesive to achieve this passive attachment mechanism.[3]

A typical rough surface has an average roughness value of 10, in which case the contact area of the mating surface is very small. For better adhesion the mating surface area has to be divided into minute contact areas. Surface Energy method can be employed to gauge the adhesion force in-order to calculate the effect of division of contacts.

Based on the Johnson-Kendall-Roberts (JKR) theory the spatula of a gecko is considered as a hemisphere of radius R. The adhesion force of a single contact is Fad given by:[4]

$$Fad = 3/2*\pi*Wad*R, [4]$$

Where Wad is the work of adhesion (energy per unit area).

Based on the principal of contact splitting, for a constant area and 'n' number of spatula, the radius of one spatula

$$R' = R/sqrt(n).$$

The total adhesion force for the multiple contacts

Fad' = Fad*n = 3/2* π*Wad*R'*n = 3/2* π*Wad* R/sqrt(n)*n = Fad*sqrt(n).

In order to realize the relation a bit more in depth let us consider three case studies which helps us visualizing the variation of adhesion force, energy required per unit area and the radius of spatula.

For this let us consider three cases as mentioned below:

Case 1:

Let us consider the number of contacts i.e. spatula varies in steps for 200 from 200 to 1000. The radius of spatula varies from 0.1µm to 0.5 µm in steps of 0.05 µm. Let the energy required per unit area be unity. The figure 1 depicts the adhesion force vs radius of spatula plotted against the number of contacts.

Case 2:

The radius of spatula varies from 0.1µm to 0.5 µm in steps of 0.05 µm. Let the energy required per unit area be unity. The adhesion force required varies from 5µN-50µN in steps of 5µN. The figure 2 shows the variation of energy required per unit area vs the adhesion force plotted against the different radius of spatula.

Case 3:

Let us consider the number of contacts i.e. spatula varies in steps for 200 from 200 to 1000. The adhesion force required varies from 5µN-50µN in steps of 5µN. The figure 3 shows the variation of total adhesion force vs number of spatula plotted against single contact adhesion force required.

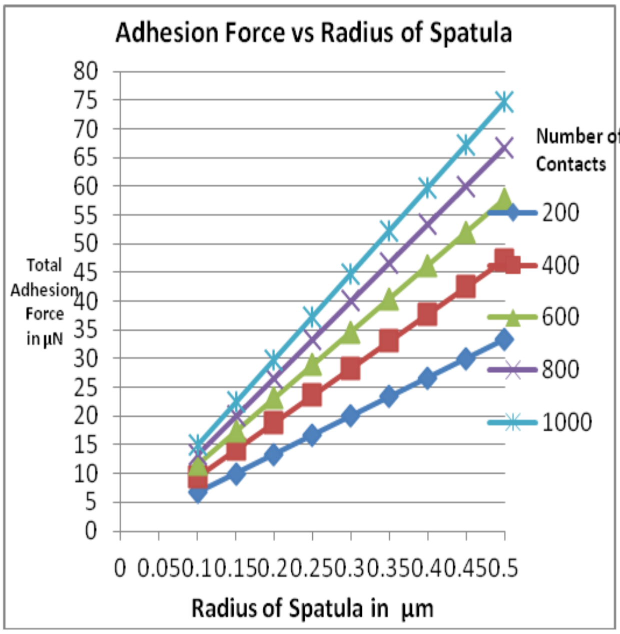

Fig. 7 Adhesive Force vs Radius of Spatula

From the above figure it is clearly evident that the adhesion force linearly varies with the radius of spatula.

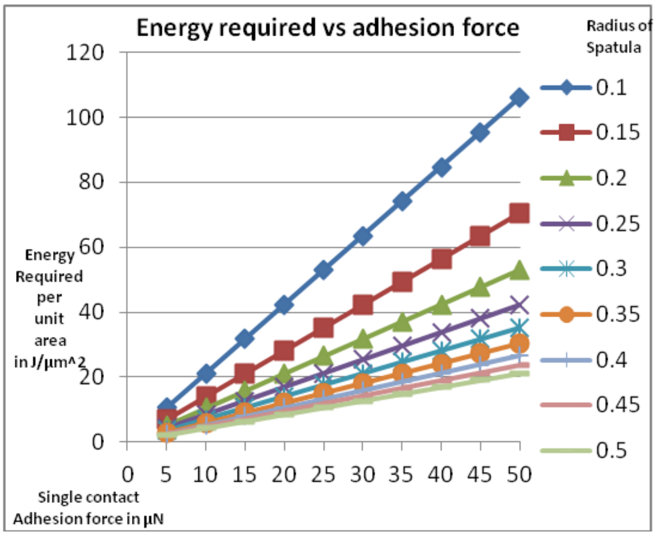

Fig. 8 Energy required vs adhesive force

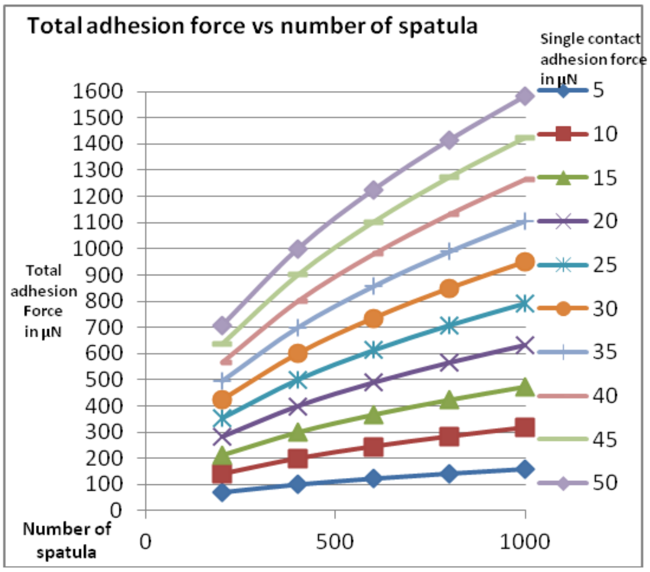

Fig. 9 Total adhesive force vs number of spatula

VII. Discussion

- The adhesion force varies linearly with radius of spatula and energy required per unit area.
- The total adhesion force varies exponentially with multiple contact points.
- These case studies give us a glimpse of adhesion force exerted by the gecko footpad for their movement. This study can be carried out further for the synthetic dry adhesive of different material by applying JKR theory, Derjaguin-Muller-Toporov Hypothesis, Maugis and Barquins Models.
- The charisma of this geckobot is its ability of independency, safe sticking and walking mechanism for enriched job skill.
- To built a geckobot an extensive analysis has to be carried out before building a virtual prototype of Gecko and testing it. This involves structural, thermal, dynamic, kinematics analysis. Later the life cycle testing and evaluation has to be carried out on the prototype to check the feasibility and performance.
- These Geckobot are built as scaled climbing robots employed for many applications such as wall cleaning, Boiler drum cleaning in thermal power

plant, rescue of people, exploration of hazardous places, analysis of navy dock.

- This is just one of the application that's been cited by studying the natural aspects of a gecko-foot.

VIII. CONCLUSION

The advent of geckos has proved to be a boon in both the technological and medical fields, hence opening a new horizon. This shows that Nature is awe-inspiring. There is so much engineering knowledge to be gained from studying biological systems. One as Gecko led us to ruminate about its application in various fields. Recent advents have taken place in Nanotechnology based on this gecko-foot sticky concept.

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