SMART POLYMER STRUCTURES

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Abstract

Gecko has an amazing & peculiar ability to climb with ease on vertical surfaces. The study has shown that this ability is due to the geometry of its feet. Van der waals force is responsible for its climbing ability. In this paper, an attempt has been made to mimic this rarely found geometry which can help us build future climbing robots. Here a novel but a low cost method is developed to fabricate an adhesive non-sticky pad. Co_2 LaserPro laser cutting machine is being used for making the desired mold & silicone rubber (OOMOO 30) as its casting material. Two different types of structures are developed to build a mechanism which can withstand the desired load. Through testing of these structures it was observed that with a preload of 10gms a material weighing 4gms can withstand a load upto 30gms approximately.

Index Terms: silicone rubber, micro-suction cups, adhesive, van der waals force.

I. INTRODUCTION

Nature has evolved a variety of mechanisms to enable species of different kinds to move across (or through) various media, including friction based mechanisms (e.g. Snakes, Birds) and adhesive organ based mechanisms (e.g. Tree, frogs, Bats). Researchers have looked to insects, mammals, and the gecko lizard for insight on how to stick to and maneuver on vertical surfaces. Not surprisingly, nature has evolved a variety of ways to stick to surfaces, from secretions of glue-like substances in ants, slugs, and worms to the sharp, penetrating claws of cats and rodents; from the small spine arrays of cave angel fish to the complicated dry-adhesive pads of geckos. This work seeks to identify the important features of climbing adhesives, to design synthetic adhesives that adhere to those guidelines, and to then apply those adhesives in various applications.

Many attributes of the gecko adhesive system were described, but perhaps most importantly, evidence implicated van der waals forces as the primary mechanism of adhesion, and second, the adhesive strength of this contact was found to be very dependent on the loading trajectory. Synthetic adhesives with gecko-like attributes have great promise for climbing applications where this directional dependence creates a mechanism for controlling adhesion.

The main objective of this work focuses on designing a engineering material that would show gecko like adhesive properties which can be later applied in various possible applications like wall mounts, inspection, cleaning, robot that can scale vertical wall etc.

II. GECKO ANATOMY & RELATED WORK

Studies have shown that gecko setae originate from the β layer of the reptile's epidermis. These proteinaceous structures are a cellular, and are replaced at each molting cycle. Recent biochemical evidence has identified β-keratin as the primary molecule in gecko setae. A further study confirmed this using the gecko foot has evolved a complex structure which is useful to adhere to rough surfaces in its natural habitat [1].

Foot of the Tokay gecko consists of five toes which act as an element in adhesive system. On the largest length scale, the flap like structure is called lamellae. This can be measured at millimeter scale. The typical Tokay gecko has 20 lamellae per toe. Each lamella is covered by setal stalks at an average density of 14400 per square millimeter. Setal stalk at its tip if observed closely is divided into several setae .Setae also vary along the length of the toe. It becomes thinner and shorter at the end of the toe; they are not straight but curved inwards towards palm [2]. The tips of setae branch apart like a tuft of broccoli into 100-1000 terminal spatula. Spatulas are triangular and generally are outwards from the branched setal end. These are generally 10nm thick and 150-275 nm across the widest part [3], [4].

The largest of these fibrillar adhesives was fabricated for the Stickybot robot platform. These posts were cast in a three part mold manufactured using a traditional 3 axis computer numerical controlled (CNC) milling machine. A very soft polymer of Young's Modulus 660 kPa was used for these pillars. 4cm^2 patches of this material were tested, sustaining adhesive forces greater than 1 N [5].

The second generation design generation of the previously mentioned PVS fibers incorporated a mushroom shaped tip with a very thin flared tip only 2 µm thick shown in Figure 2.5. The height remained 100µm and fiber diameter was 40µm. These structures showed higher adhesive pressures with an experimental sample size of 0.07cm^2 sustaining adhesive forces up to 0.4 N [6].

Kim et al [7] presented polyurethane fibers with a 4µm diameter, 20µm height, and a flared tip and base that had a diameter of 9 µm. This mushroom like structure showed 4 to 5 time’s higher adhesion than unstructured polyurethane. Tests were conducted using a 6mm hemispherical probe in a vertical-preload vertical-pull off trajectory and showed adhesive pressures of up to 180KPa and elastic strain of individual fibers greater than 500 percent.

III. METHODOLOGY

Our focus is to develop different kinds of geometry and to look for a low cost and repeatable method for developing a material having gecko like adhesive properties. Casting technique is being used to serve the purpose. CO_2 Laser Pro Laser cutting machine has been used for making the desired mold and Silicone rubber (OOMOO 30) as its casting material. Various structures are developed to build a mechanism which can withstand the desired load.

Two types of structures are being developed

1. Lamellar structures

A lamella is a thin plate-like structure, often one amongst many lamellae very close to one another, with open space between. Aside from respiratory organs, they appear in other biological roles including filter feeding, the traction surfaces of geckos, and chloroplast membranes where high permeability is important. To mimic these lamellae like structures vertical straight cuts are being on the mold material using laser cutter. As there are open spaces between lamellae, while making samples the space between every successive lamellae was varied.

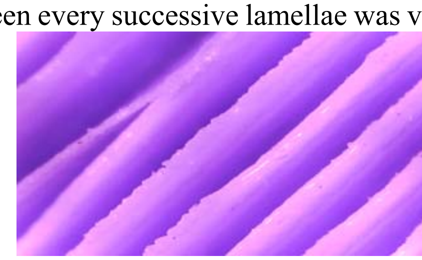

Fig1. Lamellar Structure

2. Cantilever beam Structures

Here as the name states actual cantilevers were not developed but this is tiny hair like structures which has length bit longer than the width which helps to increase the overall surface area of the material recreated. To design the mold for this structure points were paced at a particular spacing and then cut with a laser cutter.

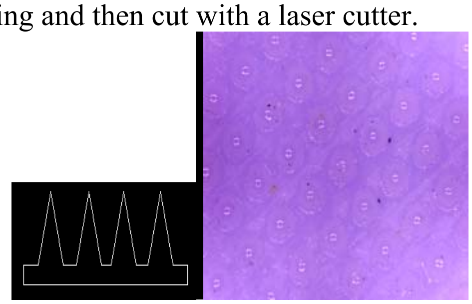

Fig2. Cantilever beam structure

A. Experimentation

Once the molds were created with the help of a laser cutter silicone rubber compound (Fig 2.) was made using smooth-on OOMOO -30 and casted into the mold created.

Then for complete curing of the material it was kept for 10hrs and extra 4 hrs for easy extraction of the material without any wear and tear. Then the material was extracted from the mold and testing was done. For the testing two different setups were made.

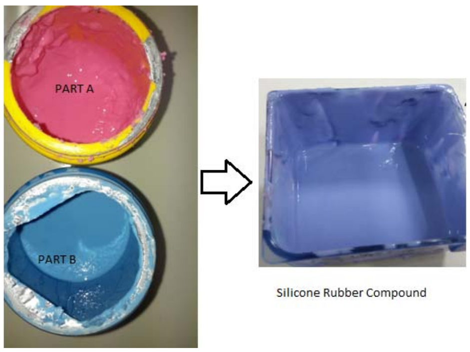

Fig3. Silicone Rubber Compound

Then for complete curing of the material it was kept for 10hrs and extra 4 hrs for easy extraction of the material without any wear and tear. Then the material was extracted from the mold and testing was done. For the testing two different setups were made.

Fig4. Test setup

IV. RESULT AND DISCUSSION

A. Lamellar structures

The first structure was made with a spacing of 0.6mm. Then the spacing was reduced till 0.2mm. Further it was not possible to decrease the spacing as the cuts started to overlap. So we had five structures with varying spacing i.e. 0.2mm, 0.3mm, 0.4mm, 0.5mm, 0.6mm. Later based on the results few more structures were tested with varying spacing between 0.2-0.3.

Table 1: Results for space between Lamellas ranging from 0.2mm-0.6mm

Sr. no.	Gap between two successive lamellae (mm)	Weight Lifted (gms) (Weight actually lifted + weight of the pan)
1.	0.2	10
2.	0.21	9.51
3.	0.23	13
4.	0.25	14
5.	0.27	10
6.	0.29	12
7.	0.3	11.5
8.	0.4	3
9.	0.5	2
10.	0.6	0

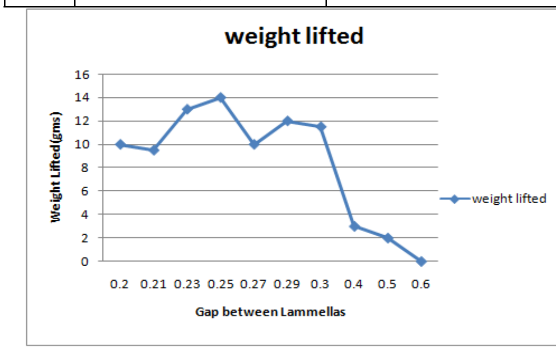

Fig5. Gap between Lamella v/s weights lifted

B. Cantilever beam structure

Cantilever beam is a type of structure in which looks like tiny hairs or beams which is in micro scale. Here the horizontal and vertical spacing is varied. The readings are also taken with the varying speed and constant power Laser cutter.

i. Varying horizontal and vertical spacing

For the first kind of cantilever beam structure the horizontal and vertical spacing between the micro hairs is varied. Here the horizontal spacing is kept as 0.3mm and vertical spacing is 0.5mm. Also here the reading is taken with the varying speed of the Laser cutter and the spacing is kept constant throughout.

Table 2: weight lifted according to varying speed of the Laser cutter

Sr. no.	Speed(ips)	Weight Lifted (gms) (Weight actually lifted + weight of the pan)
1.	12	7
2.	6	2
3.	3	2

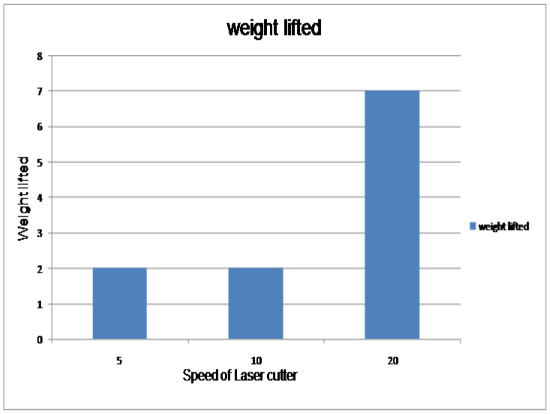

Fig6. Speed of Laser cutter v/s weight lifted

ii. Constant horizontal and vertical spacing

For the second kind of cantilever beam structure the horizontal and vertical spacing between the micro hairs are kept constant. Here both the horizontal spacing and vertical spacing is 0.5mm. Here also the reading is taken with the varying speed of the Laser cutter and the spacing is kept constant throughout.

Table 3: weight lifted according to varying speed of Laser Cutter in Cantilever beam type structure

Sr. no.	Speed(ips)	Weight Lifted (gms) (Weight actually lifted + weight of the pan)
1.	12	4
2.	6	3.3
3.	3	2

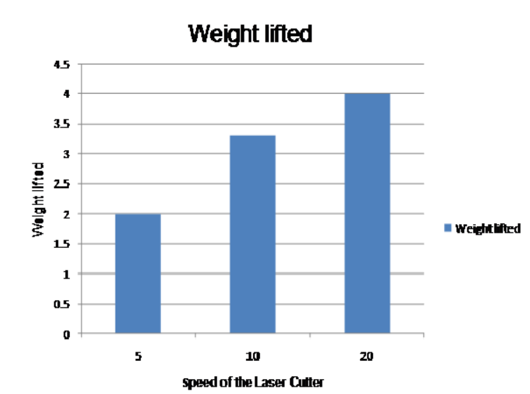

Fig7. Speed of laser cutter v/s Weight lifted

iii.Cantilever beam structure with preloading 10gms

After trying out different combination s of speed and power it was clear that at speed 1 and power 0.1 we get the lowest depth possible. Also after studying further on Gecko feet, preloading came out to be very important in order to adhere to surfaces. So henceforth preloading is taken into consideration and the testing was carried out with the constant preloading of 10gms. As in previous results we found that between 0.2mm to 0.3mm better results were observed. Here speed of the laser cutter is kept constant and spacing between micro hairs is kept constant.

Table 4: weight lifted according to the internal spacing in a cantilever beam structure

Sr no.	Spacing (mm)	Weight Lifted (gms) (Weight actually lifted + weight of the pan)
1.	0.2	21.714
2.	0.3	32.714

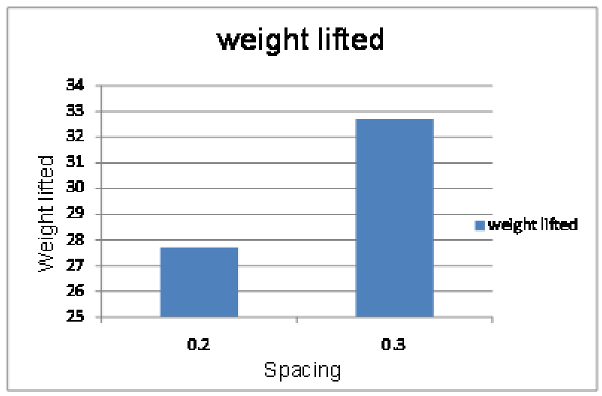

Fig8. Spacing v/s Weight lifted

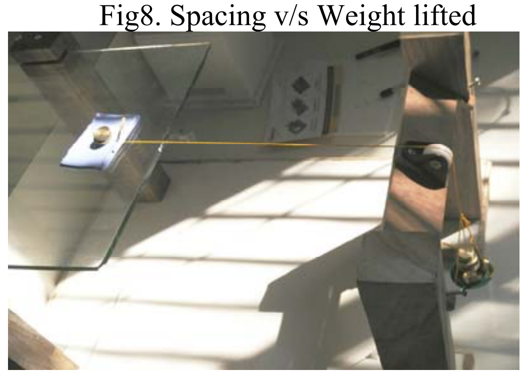

Fig9. Testing

V. CONCLUSION AND FUTURE WORK

With the lamellar spacing of 0.2mm-0.3mm the results were considerable. The minimum feature size that can be achieved in a Spirit Laser Pro is 200 micron. With Lower speed and Lower power combination better feature size were achieved for the mold. Power of the laser cutter happened to be crucial for determining depths of the cuts. At 0.3mm spacing we got remarkable results using preload.

In future a material having Micro-suction cups is planned

And frictional force is to be calculated for all the structures.

VI. REFERENCES

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