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# Modeling Fabrication and Testing of Artificial Gecko Adhesion using Multi Layer Fbrillar Structure

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**Abstract- The idea of designing a micro level artificial gecko adhesive structure is inspired from ability of geckos to climb any surface. Gecko can climb any rough or smooth surface because of its hierarchical structure present on feet which functions as a smart adhesive [1]. The key parameter that affects gecko adhesion are pattern periodicity of a synthetic setae, hierarchical structure, length, diameter, angle, size, stiffness of end tips and flexibility of a base [2]. The design and fabrication of number of single and multi-level hierarchical pattern were performed. CO2 LASER cutting machine having power of 60 W is used to manufacture moulds. The mould is fabricated from methyl methacrylate sheets of different thickness 3 mm to 10 mm. Liquid silicone polymer PDMS is used as a cast material. Various patterns having dimensionsupto200 micrometer with different tip shapes and geometries were fabricated. For single level patterns like dense pattern, mushroom shape pattern and wedge pattern (lamellar structure) were fabricated. Attempts were made to design and fabricate Multi-level hierarchical structure patterns that mimics gecko like foot structure. These micro level artificial gecko structure have large scope of applications such as climbing robots, non-sticky adhesion tapes, military surveillance and even medical applications.**

***Keywords*- LASER cutting, artificial gecko, Adhesion, Setae, Spatula.**

## I. INTRODUCTION

A number of researchers studied gecko adhesion using various theoretical and experimental techniques to understand frictional adhesion properties and mechanism of gecko feet, hairs and setae in order to mimic the gecko feet as strong, non-sticky and self-cleaning adhesion. The conventional adhesives like Pressure Sensitive Adhesives (PSAs) are soft and sticky to make continuous contact with the surface. PSAs have major effects of fouling, degrade and accidentally adhere any surface when not required. Whereas compared to PSAs artificial gecko adhesives are non-tacky, self-cleaning, easy to attach and detach. The ability of geckos to climb any rough or smooth surface at any angle inspired researchers to develop non-tacky pads for vertical climbing robots and many such applications.

The principle behind geckos extraordinary adhesion is van der waals forces of molecular attraction. Due to hierarchical fibrillar structure this weak van der waals force get converted into strong bond because of more than million number of point of contacts. The advantage of designing fibrillar adhesive structure when compared with flat structure is that each fiber deform independently, which makes sure that each fiber reaches deeper in case of rough surface to achieve clean contact [8]. The key parameter that plays important role in gecko adhesion are pattern periodicity of a synthetic setae, hierarchical structure, length, diameter, angle, size, stiffness of end tips and flexibility of a base.

Each five-toed foot of the gecko has about 500,000 foot-hairs called setae a uniformly distributed array each about 110µm in length and 4.2µm diameter. Further it is divided in to spatulae a thin stalk with triangular shape tiny end of 0.2µm length and width. [1].

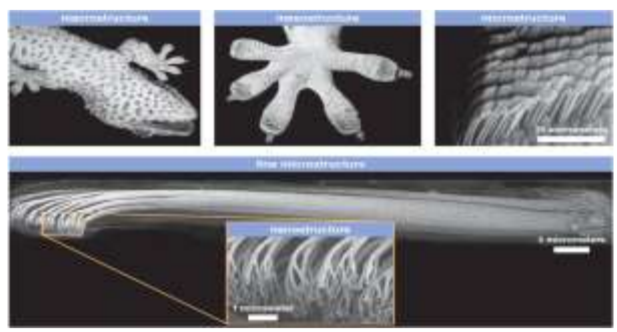


Figure 1. Gecko foot structure [1]

In the developments of synthetic setae, polymers like polyimide, polypropylene and polydimethylsiloxane (PDMS) are frequently used since they are flexible and easily fabricated. Later, as nanotechnology developed, carbon nanotubes are preferred and used in most recent projects [6]. Carbon nanotubes have both extraordinary strength and flexibility, as well as good electrical properties. Gecko adhesion widely dependent on geometry of gecko feet and adhesive material properties.

Gecko setal arrays have excellent ability of self-cleaning. Also they are non-sticky which has considerably wider application potential over pressure sensitive adhesives in several areas such as robotics for rescue and detection, chemical sensing, space position and medical application. Although Gecko adhesives are widely used in robotics application it can be also used into industry/manufacturing application where residue free and releasable tape is required. From the introduction of nanotechnology in gecko adhesion it can be directly applied to surface, which could replace screws, glues and interlocking surface like Velcros in many assembly applications such as in automotive, mobile phones etc [9]. Gecko inspired dry adhesives can be used in bio-medical application such as endoscopy and tissue adhesion. However material selected for synthetic satae for such application must be non-toxic and non-irritating. Other applications include micro mechanical and electrical systems (MEMS), wafer alignment, micro-manipulation [2].

## II. DESIGN AND FABRICATION

$CO_2$ LASER cutting machine having power of 60 W is used to manufacture moulds. The parameters which affects LASER cutting are speed and power. Cutting depth and quality are determined by a combination of power and speed. Slower speeds at higher power will produce deeper cuts. Whereas higher speeds at lower power will produce more shallow cuts. With various combinations of these parameter fabrication of different types of moulds done. The mould is fabricated from methyl methacrylate sheet of 3 mm to 8 mm thickness.

Liquid silicone polymer PDMS having tensile strength of 1.65 MPa and elongation at break is 250% is used. This method of fabrication is simple and low cost.

Taking reference from research papers various types and shapes of fibillar structures like single level, multi-level and lamellar etc. are chosen. Keeping area of contact as a preference sample size kept constant to 20mm X 20mm for all types of patterns. Fabrication of dense pattern with base diameter approximately 200 micron and height of 1mm is done shown in fig 2 (a).

Similarly considering lamellar pattern fabricated wedge pattern with base dimension as 200 micron and height up to 400 micron. The challenge in designing wedge pattern is making one edge of wedge inclined as our laser angle and bed base is fixed workpiece made inclined at 10 degree shown in fig 2 (b) [3].

While laser cutting various materials like wood, acrylic, paper etc. also trial cutting on plastic sheets were performed. So while laser cutting a plastic sheet it is found that tip like structure on end of each hair because of tar (sudden vaporization due to high temperature of LASER) is formed which can be used as a contact area for adhesion.

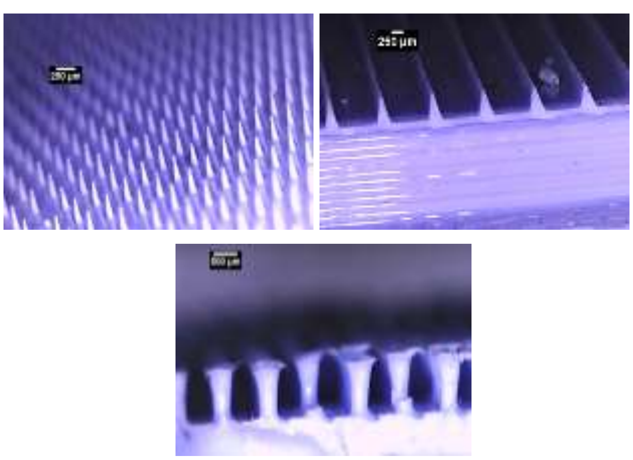


Figure 2. a) Dense pattern using various combinations of speed and power as parameters. b) Wedge shape pattern using inclined sample c) Plastic mould pattern using plastic sheet as a raw material.

Various attempts for fabrication of two level fibillar structure were performed using LASER cutting. The challenge in fabricating such multi-level structure is integrated geometry and consistent pattern over a surface. Fabrication of some multi-level fibillar structure shown in fig 2(a and b).

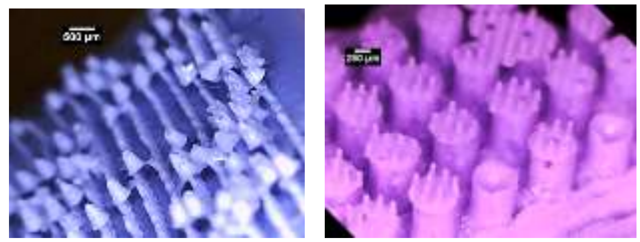


Figure 3. a) Mushroom head pattern using Laser cutting and engraving b) Multi-level pattern using multi-level moulding process

From reference to Michel P. Murphy, Seok kim "enhanced adhesion by gecko inspired hierarchical fibillar adhesives" multi-level micro scale structure results in significant decrease in adhesion [4].

## III. RESULT AND DESSCUSION

Initial tests were performed on the samples to determine coefficient of adhesion. The relationship of shear force to normal forceisa constant values stated by Amonton's first law. when setae are dragged across a surface they exhibit friction typically called Amontos friction. The coefficient of adhesion can be expressed as

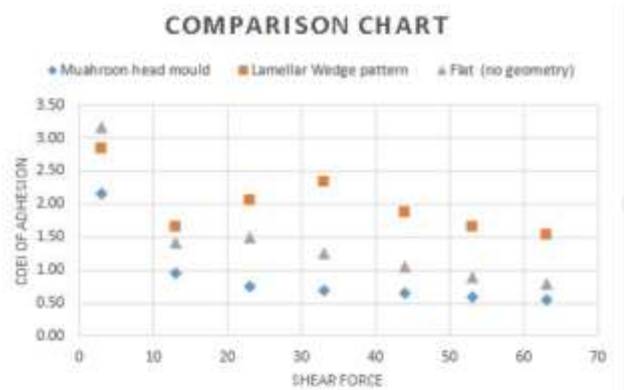
$$\mu = \frac{F_N}{F_T}$$

Where μ = Coefficient of Adhesion
$F_N$ = Normal force
$F_T$ = Tangent force

Tests were performed on three samples to determine coefficient of adhesion i.e. flat pattern (no geometry), wedge pattern and plastic mould pattern. In Dense pattern sharp tips were observed because of the manufacturing process (LASER cutting). As tip dimension is smaller it will not sustain load applied hence not considered in testing. Also multi-level pattern fabricated using LASER cutting method is not consistent over the surface.

| Preload (gms) | Coefficient of adhesion($\mu$) | | |
|---|---|---|---|
| | Flat sample | Mushroom head pattern | Wedge pattern |
| 3 | 3.17 | 2.17 | 2.87 |
| 13 | 1.42 | 0.96 | 1.65 |
| 23 | 1.50 | 0.76 | 2.07 |
| 33 | 1.25 | 0.70 | 2.34 |
| 43 | 1.05 | 0.65 | 1.87 |
| 53 | 0.90 | 0.59 | 1.65 |
| 63 | 0.80 | 0.55 | 1.54 |

Table 1. Calculations for Coefficient of adhesion




Graph 1. Graph - preload against coeificient of adhesion for wedge, flat and plastic mould pattern

From above graph and result table wedge pattern is having more consistent coefficient of adhesion over a large range when pre load is increased.

## IV. CONCLUSION

Wedge shaped lamellar pattern, dense pattern and plastic mould pattern is fabricated using laser cutting process. From above result for a micro level fibillar structure in basic testing coefficient of adhesion µ can be determined up to 2.83. Whereas the adhesion coefficient of real gecko setae is typically 8~16[7].

Further tests can be performed on wedge pattern and more geometry shapes for a better adhesion. Laser cutting is having a limitation of least dimension approx. 150 micron so it cannot be used for fabricating a multi-level structure for better and accurate results.

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