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Experimental Investigation of Adhesion of Synthetic Pyramid Shape Gecko-like Micro-structured Adhesive for Grippers Made of Silgard 184

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KEYWORDS

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ABSTRACT

In recent years, gecko-like dry adhesives have been used in robotic grippers and climbing robots. The adhesive has been introduced as a new approach for manipulating flat objects in production lines. The method has several advantages over other, more traditional, gripping methods such as lower power consumption compared to suction-based systems or the ability to handle non-magnetic materials. Directional Gecko-like adhesives are based on the frictional adhesion and employ asymmetric feature, mostly wedge shape, and perform only in one direction. In this paper, design and fabrication process of a new pyramid shape Gecko-like adhesive using silgard 184 has been described. The new microstructures has the ability of adhesion in several directions, and the contact surface between the adhesive and substrate increases and the possibility of self-sticking between adjacent stalks decreases. Chemical machining and microlithography were used for manufacturing molds in this research and the details were described. The performance of proposed adhesive was evaluated using an experimental set-up and adhesion force was measured on different substrate. During experiments, adhesion was controlled via applied shear force to adhesive. The experimental results showed 30% increase in adhesion using proposed adhesive in comparison with the existing similar adhesive.

1. Introduction

Automatic flat sheet transfer systems are used in production systems to transfer separate flat sheets from one machine to another or for the final packaging of products. These systems use either suction systems or the material properties of the transferred sheet to grip the sheet (for example, magnetic properties for ferromagnetic sheets). In recent years, Gecko-inspired adhesions have been used in transmission system grippers. The source of this adhesion is the van der Waals forces between the adhesive and the material [1]. This method has advantages such as low energy consumption compared to suction systems or the ability to transfer non-ferromagnetic materials compared to traditional methods of transfer [2, 3]. Directional type of this adhesive has the ability to control the adhesion force. When these adhesives are loaded vertically, only the tip of the adhesive microstructure is in contact with the material, producing little adhesive force. However, when the shear force is initially applied to these adhesives, the Gecko microstructures bend and create a larger cross-sectional area with the surface of the material being transferred, resulting in a greater adhesion force (Figure 1). In general, the higher the shear force, the greater the adhesion force created between the adhesive surface and the material (to a certain extent). Therefore, by controlling the shear force, the adhesion force can be turned on and off [4]. Recent directional artificial Gecko-like adhesives mainly use wedge microstructures made of elastomeric materials such as PDMS[1] for bonding to surfaces [5]. Various manufacturing methods such as additive polymerization have been proposed for the production of Gecko-like adhesive microstructures [6]. The main fabrication method is casting and removing the sticky microstructure from inside the mold. To fabricate these molds, various methods such as micromachining [7] and some lithographic methods were used, which include traditional ultraviolet lithography, electron lithography and layer-by-layer fabrication [8]. These adhesives are usually assembled in grippers in different ways. In directional Gecko-like grippers, the shear force required to turn on the adhesives is provided by manual excitation systems, shape memory alloy wires [9] or electric actuators (shank grippers, solenoids) [10]. The materials used in mentioned researches are commercial types of PDMS such as Silgard 170. The wedge-shaped directional adhesive microstructures have advantages such as a good level of adaptation to the material being moved. However, these microstructures turn on only in one direction and can be attached to the adhesive pads of robots and grippers in wrong direction. Also in these microstructures, there is a possibility of adhesion of adjacent stems to each other, which reduces the efficiency of adhesion.

To solve the above problems, in this paper, pyramidal microstructures of Silgard 184 have been proposed for replacement in gripper pads. In pyramidal microstructures, the possibility of adhesion of adjacent stems is minimized. Also, due to the symmetrical shape

[1] Polydimethylsiloxane

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of the pyramidal structure, it is possible to apply shear force in several directions and the problem of misalignment of the adhesive pads in robotic grippers is minimized. In this research, micro-lithography and chemical machining processes are used to make the mold of pyramidal microstructures and then using the casting process, pyramidal adhesive microstructures are produced.

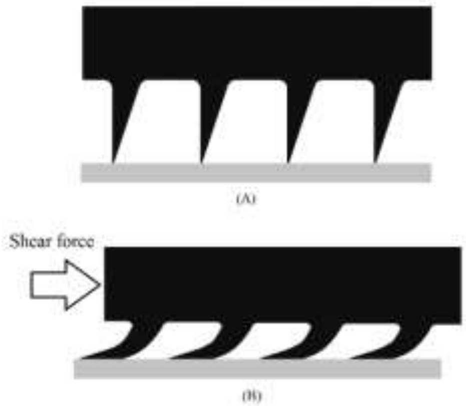

Figure 1. Principle of directional gecko-like adhesion. (A) A directional microwedge adhesive is engages its tips with the surface. (B) When loaded in shear, the contact area, and hence, the adhesion increases.

2. **Materials and methods**

To make adhesive pyramidal microstructures, Silgard 184 is prepared according to the manufacturer's instructions and bubbled in a vacuum chamber for 3 minutes. After bubbling, the material is poured on the surface of the mold and rotated in a centrifuge for 30 seconds at a speed of 1200 rpm to place a thin layer of adhesive of the same thickness on the surface of the mold. The mold is then placed in the oven with the adhesive and cured at 60 ° C for 15 minutes. Finally, the cured Gecko-like adhesive is removed from the mold using a laboratory blade. Figure 2 shows the SEM image of the micro-structures made of the pyramid shape of Gecko-like adhesive and its geometrical characteristics.

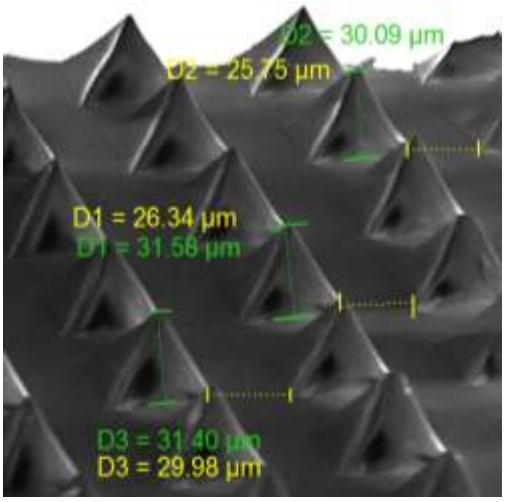

Figure 2. SEM image and geometrical characteristics of microstructures made of Gecko-like pyramid shape adhesive

After making the mold by microlithography and chemical machining process, the fabricated gecko-like adhesive samples should be tested and its performance evaluated on different surfaces and its normal adhesion diagrams should be extracted. Therefore, the adhesion of Gecko-like adhesive is tested. To perform these tests, the Geck0-like adhesive must first be attached to a flexible pad that enhances the adhesive's ability to adapt to surfaces, and then the tests must be performed.

To evaluate the performance of the adhesive, it is necessary to position the adhesive on the desired surface, then a shear force parallel to the surface on the adhesive must be applied and then the normal adhesion force (perpendicular to the surface) is measured. An innovative laboratory set-up was used to apply and measure the shear force and measure the normal adhesion force. In order for the adhesive pad to adapt well to the surface of the flat sheets being tested, a rigid backing is required, which is made of Plexiglas sheets. The layers used in this pad are a layer of Gecko-like adhesive microstructure, which is glued to a silicone foam with two layers of glue, and the silicone foam is attached to the back of Plexiglas with a two-layer adhesive, respectively. The reason for choosing silicone foam in this pad is the flexibility and good adaptability of the foam to the low and high surface of the body in micron dimensions. As the adhesive pad adapts to the surface of the object, the van der Waals force increases and the adhesion increases.

3. **Discussion and Results**

Figure 3 shows the maximum adhesion force measured for different materials using Silgard-184 at different shear stresses. This diagram shows that the highest adhesion force is obtained in acrylic.

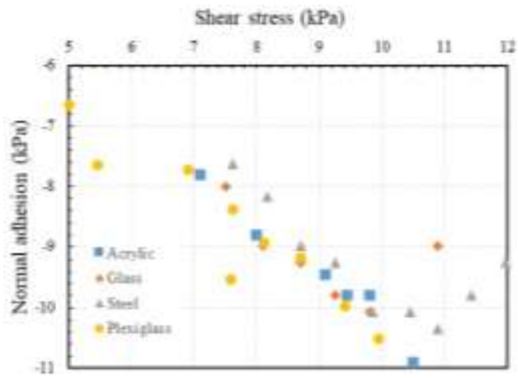

Figure 3. Maximum shear stress and normal adhesion measured in pyramidal lizard adhesive on different materials

Figure 4 compares the adhesion of a wedge microstructure with a pyramid in glass material [3]. As can be seen in this figure, the maximum adhesion of the pyramidal microstructure is measured to be 1.3 times the maximum adhesion of the wedge microstructure.

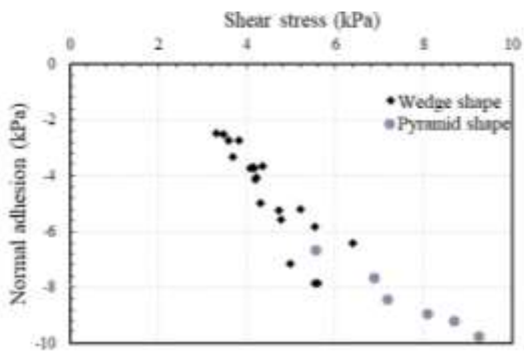

Figure 4. Comparison of the adhesion of the previous microstructure (wedge-shaped) and the proposed microstructure (pyramidal)

4. **Conclusion**

In this research, a mold was designed and fabricated to make pyramidal Gecko-like adhesive microstructures that had a successful performance in adhesion on different surfaces. In pyramidal microstructures, shear force can be applied from all four sides, which in this regard has an advantage over the existing wedge adhesive microstructures. In addition, the single structure of this microstructure allows better adaptation to the desired surfaces than the existing wedge microstructure and increases the adhesion between the adhesive pad and the desired material. This Gecko-like adhesive can be used for pads or robotic arms or wall-mounted robots.

5. **References**

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