Gecko-inspired dry adhesive for robotic applications

Jing Yu¹, Saurabh Das¹, Sathya Charry², John Tamelier², Kimberly Turner², and Jacob N. Israelachvili¹

Department of Chemical Engineering, Department of Mechanical Engineering
University of California at Santa Barbara, Santa Barbara, CA 93106-5080
Tel: 805-893-8358 E-mail: jacob@engineering.ucsb.edu

Abstract: The gecko can rapidly attach and detach from almost any kind of surface. This ability is attributed to the hierarchical structures of their toe pads, which generate both strong adhesion and friction forces. In this study, large arrays of micron-scale rectangular flaps composed of polydimethylsiloxane (PDMS) have been fabricated using massively parallel microelectromechanical systems (MEMS) fabrication techniques with the intention of creating a responsive, high friction, high adhesion, anisotropic material similar to that found in geckos. Friction and adhesion tests demonstrate that the tilted angle and specialized structure allow us to optimize both friction and adhesion forces along different directions during movement. These properties, when coupled with suitable articulation mechanisms, can have important implications for designing reversible adhesion systems for climbing robotic applications.

Geckos have a remarkable climbing ability by using a vast array of multi-scale hierarchical structures (Fig. 1a). These structures, by conforming to both micro- and nano-scale asperities, achieve a large true area of contact, so that the geckos can adhere to different surfaces via the weak van der Waals force together with other types of noncovalent forces such as capillary forces. In this study, large arrays of both vertical and angled micro-flap structures have been fabricated using microfabrication techniques. Vertical and two types of pre-angled PDMS micro-flap structures, and angled long flaps (Fig. 1b), mimicking the angled setae structure of the gecko feet were manufactured using micro-fabrication techniques.

In order to quantify the adhesion and friction properties of the fabricated structures, a 3D displacement and force sensing probe attachment for the surface forces apparatus (SFA) 2000 was developed. The new attachment can generate both normal and lateral movement of surfaces, and measure the resulting normal and lateral forces independently. It was designed to let us do both load/pull and load/drag/pull tests of the fabricated structures on a small scale with a contact area of around 0.1~1 mm².

Our experimental results demonstrate that by using surfaces with directional oriented or tilted structures, we can generate anisotropic adhesion and friction: the tilted micro flaps on the fabricated surfaces gave rise to both strong friction and adhesion forces while sliding forward along the tilted direction, and low adhesion when sliding backwards against the direction of tilt. Mimicking the frictional adhesion mechanism employed by the gecko, the tilted flaps are capable of providing strong adhesion for attachment (in the shear gripping motion) and weak adhesion for detachment (in the shear releasing motion). The anisotropy built into the design allows for controllability and switchability based on shearing length and direction. Therefore, these results are very important for designing responsive adhesives for climbing robotics applications.