Spiderman gloves

Theoretical van der Waals gloves could generate an adhesion force comparable to the body weight of ~500 men. Even if such a strength remains practically unrealistic (and undesired, in order to achieve an easy detachment), due to the presence of contact defects, e.g. roughness and dust particles, its huge value suggests the feasibility of Spiderman gloves. The scaling-up procedure, from a spider to a man, is expected to decrease the safety factor (body weight over adhesion force) and adhesion strength, that however could remain sufficient for supporting a man. Scientists are developing new biomimetic materials, e.g. gecko-inspired. Here we complementary face the problem of the structure rather than of the material, designing and preliminary fabricating a first prototype of Spiderman gloves, capable of supporting ~10 kilograms each on vertical walls. New Adhesive Optimization Laws are derived and applied for increasing the capability of the scaling-up.

Nicola M. Pugno

Department of Structural Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy; National Institute of Nuclear Physics; National Laboratories of Frascati; National Institute of Metrological Research (INRIM)

E-mail: nicola.pugno@polito.it

The gecko's ability to "run up and down a tree in any way", was firstly observed by Aristotle in his Historia Animalium, almost 25 centuries ago. A comparable adhesive system is found in spiders and in several insects. In general, when two solid (rough) surfaces are brought into contact with each other, physical/chemical/mechanical attraction occurs[1]. The developed force that holds the two surfaces together is known as adhesion. A simple example is suction. Suction cups operate under the principle of air evacuation, i.e., when they come into contact with a surface, air is forced out of the contact area, creating a pressure difference. The adhesive force generated is simply the pressure difference multiplied by the cup area. Thus, in our (sea level) atmosphere the achievable suction strength is coincident with the atmospheric pressure, i.e. about 0.1MPa. Such an adhesive strength is of the same order of magnitude of those observed in geckos and spiders, even if their adhesive mechanisms are different, mainly due to van der Waals attraction[2,3] and also capillarity[4]. Thus, although several insects and frogs rely on sticky fluids to adhere to surfaces, gecko and spider adhesion is fully dry.

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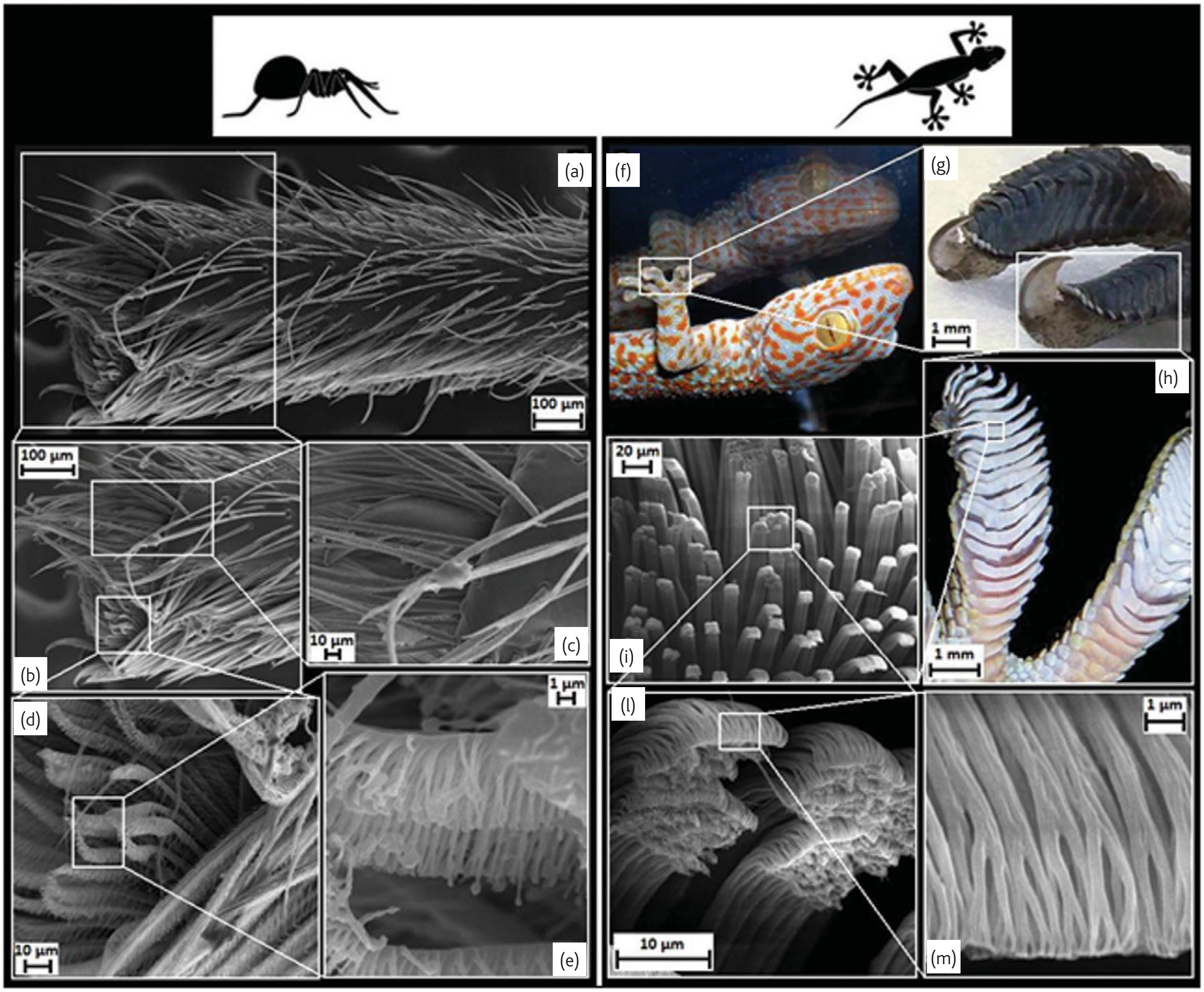

Fig. 1 Spider and gecko feet showed by SEM. In the Tokay gecko (Fig. 1f) the attachment system is characterized by a hierarchical hairy structures, which starts with macroscopic lamellae (soft ridges ~1mm in length, Fig. 1h), composed by setae(30-130µm in length and 5-10µm in diameter, Fig. 1i,l). Each setae branches in (Fig. 1m) 100-1000 substructures called spatulae, the contact tips (0.1-0.2µm wide and 15-20nm thick) responsible for the gecko's adhesion[5]. Terminal claws are located at the top of each singular toe (Fig. 1g). Van der Waals and capillary forces are responsible for the generated adhesive forces[3], whereas claws guarantee an efficient attachment system on surfaces with very large roughness. Similarly, in spiders an analogous ultrastructure is found[2]. Thus, in addition to the tarsal claws, which are present on the tarsus of all spiders (Fig. 1c), adhesive hairs can be distinguished in many species (Fig. 1d,e). Like for insects, these adhesive hairs are specialised structures that are not restricted only to one particular area of the leg, but may be found either distributed over the entire tarsus, as for lycosid spiders, or concentrated on the pretarsus as a tuft (scopula) situated ventral to the claws (Fig. 1a,b). In jumping spider Evarcha arcuata, in addition to the tarsal claws (hooks with radius of ~50µm), a scopula (with surface area of 37000μm^2) is found at the tip of the foot[2]; the scopula is differentiated in setae, each of them covered with numerous setules (with an average density of ~2.1μm^{-2}), terminating in a triangular contact (with surface area of ~0.17μm^2).

Hierarchical miniaturized hairs (without adhesive secretions) are characteristic features of both spiders[2] and geckos[5,6], see Figure 1. In jumping spider *Evarcha arcuata*, the total number of setules per foot can be calculated at 78000 and thus all 8 feet are provided with a total of ~0.6 million points of contact. The average adhesion force per setule was measured to be ~41nN, corresponding for the 8 feet or scopulae to $\sigma_{spider} \approx 0.24$MPa and to a safety factor (that is the adhesive force over the body weight, ~15.1mg) of $\lambda_{spider} \approx 173$. Similarly, for a tokay gecko (Gekko gecko), the adhesive force of a single seta and even of a single spatula has recently been measured to be respectively ~194µN[7] or ~11nN[8]. This corresponds to an adhesive strength of $\sigma_{gecko} \approx 0.58$MPa[7] and a safety factor of $\lambda_{gecko} \approx 102$[9], comparable only with those of spiders[2] (~173), cocktail ants[10] (>100) or knotgrass leaf beetles[11] (~50). Note that, according to the previous values, we have estimated[9] for a gecko a total number of points of contact of ~3 billions, thus