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September 2007

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# Crawling Soon On a Wall Near You

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The tingly spider sense and radioactive blood will have to wait, but wall-climbing gloves and human-sized "spiderwebs" are on the near horizon, according to Nicola Pugno. In his recently-published article in the *Journal of Physics*, Pugno confirms that existing materials could be used to make a very serviceable Spiderman suit.

**Hierarchy**
Hierarchical Surface with three levels. Graphic by Nancy McGuire.
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Pugno, an engineering professor at Politecnico di Torino (Polytechnic of Turin), Italy, has done the math, which he lays out in great detail in his paper. He proposes using hierarchically structured materials to give humans the ability to mimic the wall-crawling abilities of spiders (or geckos, if you prefer). He also shows that carbon nanotube cables can be used to swing from building to building or to wrap up bad guys.

### The Gloves

To make wall-climbing gloves, one needs a material with enough adhesive strength to attach a 70-kg human securely to a wall. This material must also detach from the wall on demand, so Superglue is out of the running. The ability to self-clean is also desirable, so that the gloves don't pick up so much dirt on the way up the wall that they don't stick any more when you get to the ceiling.

Pugno dismisses suction cups, sticky fluids, or electrostatic attraction as impractical. He focuses instead on the capillary, van der Waals, and nanointerlocking forces that enable spiders and geckos to travel a room in three dimensions.

For a more gecko-like glove, hierarchically-structured hairs provide the large surface area needed for van der Waals adhesion (see picture in slide show, above). Gecko feet have rows of pads that have smaller pads branching from them—an arrangement referred to as a "hierarchical surface." The total surface area of such an arrangement is very large, so that the total of the small capillary and van der Waals attractions between the surface of the gecko foot and the surface of the wall is sufficient to support the weight of the gecko.

For our 70-kg human, Pugno proposes using carbon nanotubes, which have already demonstrated an adhesive force 200 times greater than for gecko foot hairs over small areas. Developing longer nanotubes would make it possible for the gloves to maintain their adhesion over a large enough area to support Spiderman.

Superhydrophobicity (sometimes referred to as the "lotus leaf effect") allows the sticky surface to shed water droplets, carrying dirt particles away with them and keeping the sticky surfaces clean (see picture in slide show, above).  Our carbon nanotube gloves would need hierarchical surfaces with enough levels to keep water droplets safely balanced on the surface, allowing them to roll off easily.

Spider feet use van der Waals attractions, coupled with tiny hooks that provide Velcro-like frictional adhesion. Pugno determined that a large number of very small hooks would be safer than fewer, larger hooks. Although nano-hook gloves would support less weight than their van der Waals counterparts, they would nevertheless be strong enough to support our Spiderman, even on a ceiling.

Pugno demonstrates that his adhesive gloves could be detached from a surface using a peeling action. He speculates that some training might be needed to achieve the proper wrist rotation, much like learning to use "a pair of skis, a paraglider, or a wet suit."

**The Webs**
Pugno likes his spider webs to be invisible, which is a step beyond what the comic-book Spiderman uses. Pugno calculates the requisite diameter for a single carbon nanotube that would not refract visible light, as well as the required lattice spacing for an invisible bundle of nanotubes. Meter-long cables made from multiwalled carbon nanotubes already exist, and these cables are partially transparent, so this concept is not totally outlandish. Pugno wisely admits that he would be willing to settle for less than total invisibility in order to ensure that the cables were strong enough to support his weight.

Pugno speculates that cables made from carbon nanotubes could remain invisible as long as the cables are under tension and all the individual nanotubes are pulled into parallel alignment. Such cables would re-appear when the tension is released—"this behavior could help in visualizing the cable after having trapped a victim," he states.

Pugno, N. M. **2007.** *J. Phys.: Condens. Matter 19,* 395001.