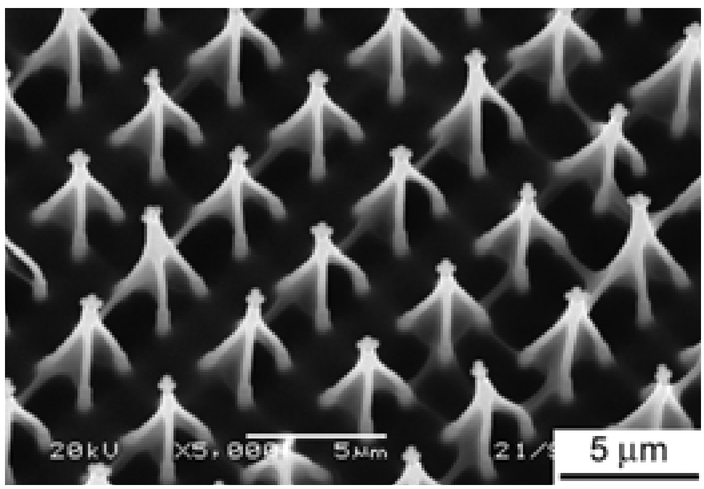
MATERIALS SCIENCE

Strength through Gel

For athletes, gelatinous muscles are certainly not something to be pleased about – but they are for materials scientists at the Max Planck Institute of Colloids and Interfaces in Potsdam and Bell Laboratories in the US: scientists there have developed a substance made from a gel and silicon needles that works like a muscle. Furthermore, they've constructed a nanometer-sized grip arm out of this active material by exploiting a simple but extremely effective natural principle. They exploit the ability of gels to perform mechanical work by absorbing and releasing water – just as plants do. (SCIENCE, January 26, 2007)



As if grabbing on command, the four-armed grippers stand out in the active hybrid substance HAIRS-2. Scientists anticipate using the new substance to generate movement that is controlled by changing the air humidity.

Some flowers open up during the day as if by magic, and close again as soon as it gets dark – almost as if they had muscles. In fact, the flower petals are moved by gel-like substances that swell or contract depending on the air humidity. In nature, not only flowers use this hydraulic mechanism, but also pine cones and carnivorous plants, like sundew.

Scientists have now used this mechanism for innovative compounds, called HAIRS (hydrogel high-aspect-ratio rigid structures) – hybrid systems composed of nanometer-sized silicon needles and a hydrogel. "What's special about the hybrid compounds is the combination of stiff, inflexible bodies, the silicon needles, with elastic and soft connecting elements, the gel," says Peter Fratzl, Director at the Max Planck Institute of Colloids and Interfaces. This results in an active substance – that is, a material that can perform work. Depending on the air humidity, the gel changes its surface – contracting or swelling up and thus changing the orientation of the silicon needles. Using this simple principle, scientists have produced two different substances: HAIRS-1 and HAIRS-2.

In HAIRS-1, the silicon needles are distributed in parallel throughout the gel. When the gel contracts, this pulls on the silicon needles and tips them sideways. The material behaves like an artificial muscle. The silicon needles in HAIRS-1 are simply embedded in the gel, but in HAIRS-2, the needles are also anchored firmly to a silicon surface. "In contrast to HAIRS-1, the silicon needles in HAIRS-2 cannot tip sideways when the gel contracts," explains Fratzl. In HAIRS-2, the needles must bend – groups of four neighboring needles bend toward each other and form a four-pronged grip arm.

This specific arrangement occurs because capillary forces come into play when the gel contracts. The gel behaves like water on a surface – it tries to reduce its surface tension, resulting in one gel droplet sitting between four needles, forming a kind of four-cornered pillar. When the gel contracts, it pulls the needles at the corners inward, creating a four-pronged grip arm. The gripping movement of the needles is completely reversible – if the gel is rehydrated, it expands and the needles move back to their upright position.

The new hybrid substance is the first active material that works based on the principle of flower petals and pinecones. Even before biologists found it in plants, American architect and engineer Buckminster Fuller discovered it and built houses following this principle. "We let ourselves be inspired by biology to create this active substance," says Fratzl: "And it could find applications as microactuators or in microfluidics."

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