Bioinspired material mimics squid beak

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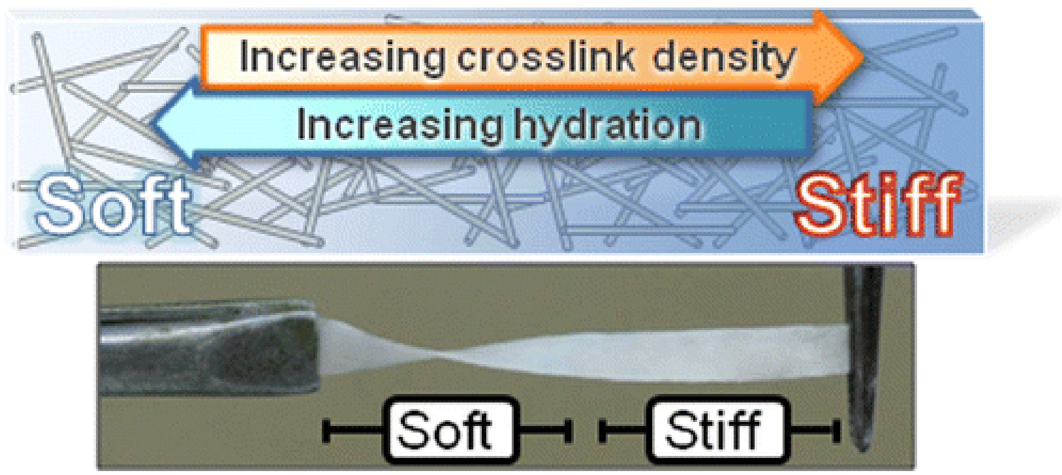

(Phys.org) —Researchers led by scientists at Case Western Reserve University have turned to an unlikely model to make medical devices safer and more comfortable—a squid's beak.

Many medical implants require hard materials that have to connect to or pass through soft body tissue. This mechanical mismatch leads to problems such as skin breakdown at abdominal feeding tubes in stroke patients and where wires pass through the chest to power assistive heart pumps. Enter the squid.

The tip of a squid's beak is harder than human teeth, but the base is as soft as the animal's Jello-like body. In order to connect these two mechanically dissimilar parts of the squid a major part of the beak has a mechanical gradient that acts as a shock absorber so the animal can bite a fish with bone-crushing force yet suffer no wear and tear on its fleshy mouth.

Nature's technology could make a range of medical devices more comfortable and safer for patients, from glucose sensors for diabetics to prosthetic arms and legs that attach to amputees' bones, the researchers say. Their work is published today in the *Journal of the American Chemical Society*.

"We're mimicking the architecture and the water-enhanced properties of the squid to generate these materials," said Stuart J. Rowan, the Kent H. Smith professor of macromolecular science and engineering at Case Western Reserve, and senior author.

Rowan worked with PhD student Justin D. Fox and assistant professor of biomedical engineering Jeffrey R. Capadona at CWRU, and Paul D. Marasco, who, like Capadona, is a principal investigator at the Advanced Platform Technology Center at the Louis Stokes Cleveland Department of Veterans Affairs Medical Center.

Other researchers have shown the structure of the beak is a nanocomposite comprised of a network of chitin fibers embedded within increasingly cross-linked structural proteins from mouth to tip. The gradient is present when the beak material is dry, but is dramatically enhanced when in water, the squid's natural environment.

Rowan and Capadona were among a team of researchers who had previously reported a material that mimics the sea cucumber's skin, which is soft and pliable when wet and stiff and hard when dry.

They thought that material, in the form of a film, could be cross-linked with nanofibers to maintain stiffness when wet. They filled the film with functionalized cellulose nanocrystals that, when exposed to light, form cross-links.

To ramp up stiffness across the film, one end was exposed to no light and subsequent sections to increasingly more light. The longer the exposure, the more cross-links that formed.

Just like the beak, the grade from soft to hard was steeper when wet. Water switches off the weaker non-covalent bonds that form when the material is dry.

The wet environment inside the body will enhance the gradient just as well, which makes this technology especially attractive for implants, the researchers say.

"There are all sorts of places in medicine where we're using hard materials but we're mostly soft," Marasco said. The contrast is a recipe for sores and infection, poor performance and implant failure.

Needles in diabetics' insulin pumps, metal stents inserted in blood vessels and electrodes inserted in muscles or brains could be safer and more effective if materials would remain hard where they need to be but buffer surrounding soft tissues.

"Prosthetic limbs are connected to the arm or leg with a socket of hard plastic that fits over the residual limb," Marasco continued. "But bone moves around under the socket and can damage the soft tissue inside, while the socket can be hard on the skin where it makes contact."

A better solution, he said, would be to run a metal insert into the bone inside the body and attach a prosthesis directly outside the body using this kind of mechanical buffer where the hard metal passes through the soft skin.

The researchers are already working on the next generation of materials and cross-linking strategies to make the buffer gradient steeper. The tip of a squid's beak is 100 times harder than it's softest portion, while this first mimic's hard tip is five times harder than its soft end.

"This is a proof of concept," Rowan said. "Now that we have shown the concept works we're now getting a wee bit more complicated and targeting materials that will allow us to move closer to applications."

More information: Bioinspired Water-Enhanced Mechanical Gradient Nanocomposite Films That Mimic the Architecture and Properties of the Squid Beak, J. Am. Chem. Soc., 2013, 135 (13), pp 5167–5174. DOI: 10.1021/ja4002713

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