Bio Focus

Sensors add touch and feel to prosthetic skin

The loss of any limb is devastating, especially the loss of a hand limits crucial functionalities including eating and handling objects. While prosthetic hands can mimic biological motion, an artificial "skin" must mimic the mechanoreceptors (sensing touch, pressure, and vibration) and thermoreceptors in human skin to enable real-time feedback as the person performs a task. And ideally, the patient won't be left with cold hands!

A research team based in South Korea has reported a flexible synthetic "skin" that could eventually be used with a hand prosthesis to permit the patient to feel heat, humidity, and pressure. This represents the first integration of mechanically optimized sensor array configurations within an artificial skin. As reported in the December 9, 2014, issue of *Nature Communications* (DOI:10.1038/ncomms6747), the skin is built from the biocompatible and elastic polydimethylsiloxane (PDMS) encapsulating layers of sensors. One challenge of the miniscule sensor arrays is the range of strain on the back side of the hand during flexion, leading to breakage failure of the sensors. Kim, Lee, Shim, and their colleagues overcame this challenge by first using motion-capture to study strain profiles on the hand during typical motions. They tuned the sensor geometry to the strain in various locations on the hand.

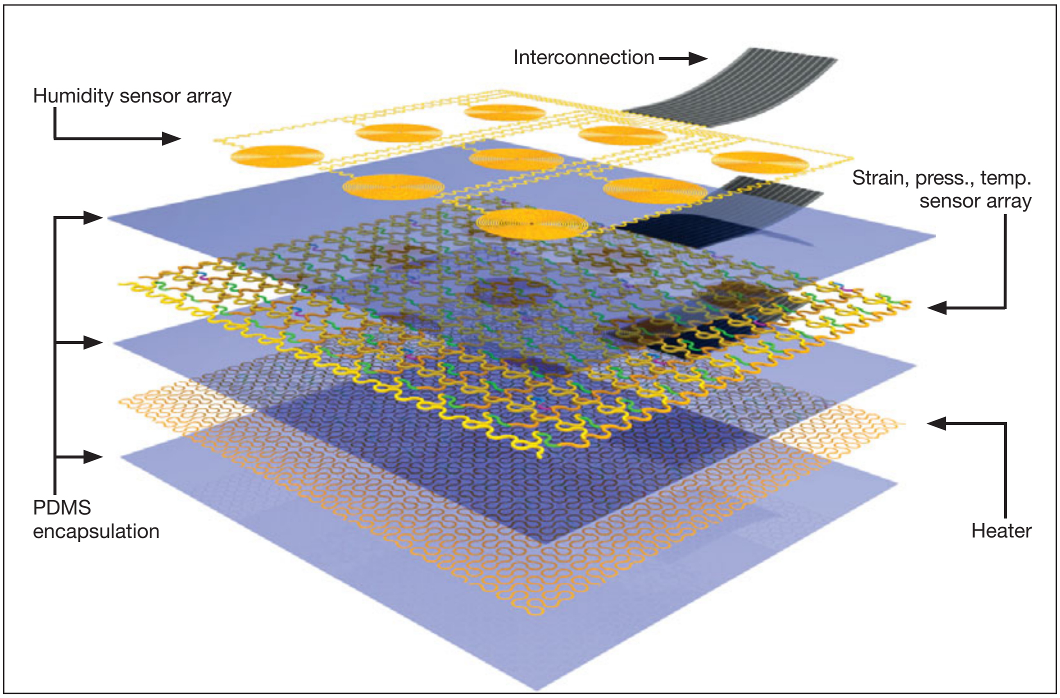
The temperature, strain, and pressure sensors themselves were ultrathin single crystalline silicon nanoribbon arrays. These exhibit linearity and fast response times with no hysteresis. The sensor arrays used geometries ranging from linear shapes, which were employed in areas of minimal stretch, to meandering curved shapes that were used in large-stretch areas of the hand to provide durability. Less-curved sensors fracture easily but are more sensitive; the sensor geometry selected for different areas of the hand is therefore a balance of requirements. The team also added coplanar capacitors and electroresistive heaters to the top and bottom layers, respectively, to enable the artificial skin to sense moisture and to enable the prosthetic skin to feel warm to the touch.

Since the ultimate goal is to connect the skin of the artificial hand to the patient's nervous system, the team decorated the multi-electrode array with ceria-coated platinum nanowires to improve biocompatibility and reduce inflammation. Connecting the electrodes to a rat sciatic nerve, the researchers demonstrated electrophysiological signal spikes in response to input signals from the pressure sensor.

"The most important driving force of this work is to accomplish an artificial skin that seems to be real skin," said Dae-Hyeong Kim. "The next step is to continue development [to] emulate the real mechano- and thermo-sensory functions of the human. Another direction is to apply the current technology to larger animals for bidirectional (from peripheral to central nervous system, and vice versa) sensing and actuating loop experiments."

Paolo Maria Rossini of the University of Rome (EPFL), who with Silvestro Micera and others announced last year a method of providing physiologically appropriate sensory information to a patient, said, "In principle, the creation of a smart prosthetic skin instrumented [as reported] could represent a remarkable step ahead in the development of a full-range prosthetic hand.... Having said that, a main problem remains to be solved: how to manage the huge amount of motor and multisensory information ... from different sensory modalities."

Jennifer Gordon



Artificial skin comprised of six stacked layers, where interconnected wires of each layer relay signals to external instruments. Reproduced with permission from *Nat. Commun.* (2014), DOI:10.1038/ncomms6747. © 2014 Macmillan Publishers Ltd.