Bridging sensory gap between artificial and real skin

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The prosthetic hand equipped with the proposed prosthetic skin is used just like an actual hand to cuddle a baby doll. The prosthetic skin shows soft mechanical properties, multimodal sensing capabilities, and warmth corresponding to that of human body. Credit: Kim et al.

"Smart" prosthetics still has a long road ahead. In the human, skin-based mechanoreceptors and thermoreceptors gather information streams from the environment but it is not so easy to create artificial skin for people in need of better-functioning prosthetics to experience the same. Sensory receptors in human skin transmit a wealth of tactile and thermal signals from external environments to the brain yet replication of these sensory characteristics in artificial skin and prosthetics has its challenges. Holding a cup with a prosthetic hand is one thing; being able to tell if it is scalding hot or lukewarm is another. Now a team of scientists from South Korea and the U.S are getting down to work to bring better capabilities of touch for prosthetics.

Published Tuesday in *Nature Communications*, "Stretchable silicon nanoribbon electronics for skin prosthesis" shows an advance as scientists try to bridge the gap between artificial and real skin. Scientists have met difficulties in making artificial skin capable of what the human skin can feel due to limitations in stretchability, detection range and spatiotemporal resolution. The team who authored this paper have made an advance.

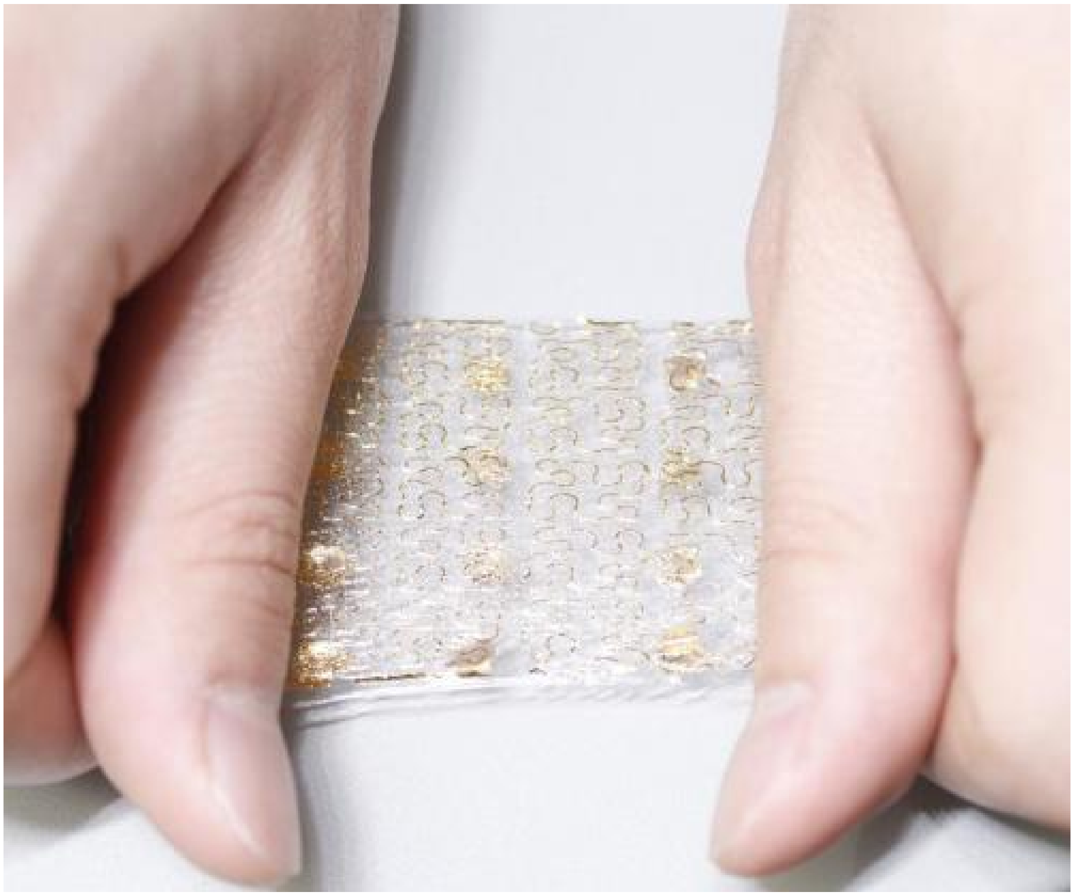
David Talbot, chief correspondent for MIT Technology Review, said Tuesday the material is a polymer designed to mimic the elastic and high-resolution sensory capabilities of real skin. The authors report a stretchable prosthetic skin equipped with ultrathin single crystalline silicon nanoribbon (SiNR) strain, pressure and temperature sensor arrays. The result is artificial skin with multi-modal sensing capability. They wrote that "SiNR mechanical and temperature sensor arrays integrated with stretchable humidity sensors and thermal actuators enable high sensitivity, wide detection ranges and mechanical durability for prosthetic systems."

Michelle Starr, a CNET associate editor, commented on the significance of the study: "Under the leadership of biomedical engineer Dae-Hyeong Kim, the team has developed a skin that can stretch over the entire prosthesis; and its applications aren't just limited to pressure. It's embedded with ultrathin, single crystalline silicone nanoribbon, which enables an array of sensors." Alongside pressure arrays, she said, were temperature arrays and associated humidity sensors, strain sensors, electroresistive heaters and stretchable multi-electrode arrays for nerve stimulation. Talbot said that while stretchable sensing materials have been under development for a while, this is "the most sensitive material yet, with as many as 400 sensors per square millimeter." An accompanying caption in MIT Technology Review showed an electronics-laden glove made up of layers of materials with stretchable gold and silicon sensors.

The proposed prosthetic skin conformally attached to the prosthetic hand. The embedded sensor array probides multimodal sensing capabilities corresponding to the actual human skin. Credit: Kim et al.

Talbot described how the team worked: "They used motion-capture cameras to study how a real hand moves and stretches, and then applied varying silicon shapes to different spots on the prosthetic skin to accommodate that stretchability." Also, he said, "they added a layer of actuators that warm it up to roughly the same temperature as human skin ."

In the study, the authors showed a photograph of a representative smart artificial skin with integrated stretchable sensors and actuators covering the entire surface area of a prosthetic hand. They also showed representative hand movements, such as clenching the fist, bending and tilting wrist movements. The prosthetic hand and laminated electronic skin could take on complex operations such as hand shaking, keyboard tapping, ball grasping, holding a cup of hot/cold drink, touching dry/wet surfaces and human to human contact.



The proposed prosthetic skin is can be stretched freely up to 50%. The embedded sensor arrays are also designed to be stretchable. Credit: Kim et al.

More information: Stretchable silicon nanoribbon electronics for skin prosthesis, *Nature Communications* 5, Article number: 5747, www.nature.com/ncomms/2014/141 … full/ncomms6747.html

Abstract
Sensory receptors in human skin transmit a wealth of tactile and thermal signals from external environments to the brain. Despite advances in our understanding of mechano- and thermosensation, replication of these unique sensory characteristics in artificial skin and prosthetics remains

challenging. Recent efforts to develop smart prosthetics, which exploit rigid and/or semi-flexible pressure, strain and temperature sensors, provide promising routes for sensor-laden bionic systems, but with limited stretchability, detection range and spatio-temporal resolution. Here we demonstrate smart prosthetic skin instrumented with ultrathin, single crystalline silicon nanoribbon strain, pressure and temperature sensor arrays as well as associated humidity sensors, electroresistive heaters and stretchable multi-electrode arrays for nerve stimulation. This collection of stretchable sensors and actuators facilitate highly localized mechanical and thermal skin-like perception in response to external stimuli, thus providing unique opportunities for emerging classes of prostheses and peripheral nervous system interface technologies.

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