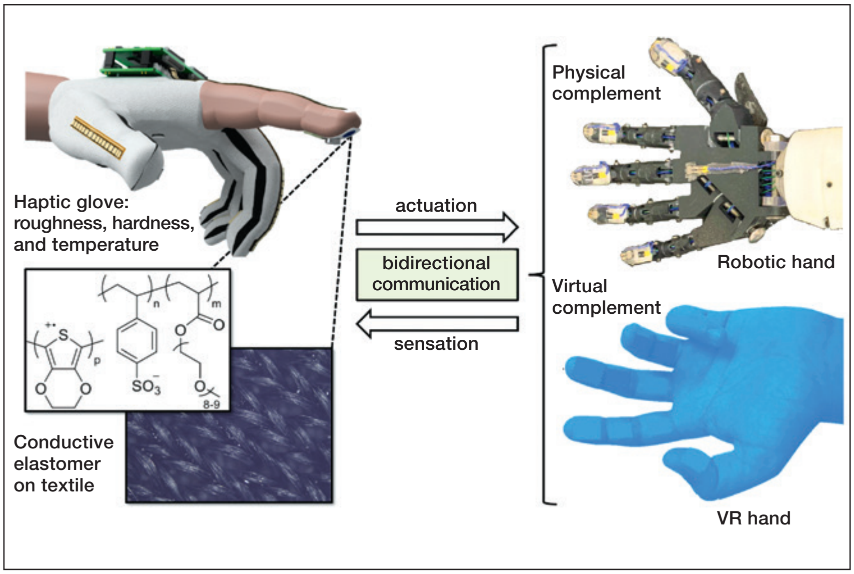
enabling risk assessment, which is difficult to achieve with the EIS analysis."

Unlike other characterization tools, acoustic sensing is noninvasive, diagnoses specific segments of battery cells, and aptly discerns between different degradation mechanisms. This approach will provide valuable fundamental insight into optimal temperature and charge/discharge regimes for novel battery designs, according to the research team. Most importantly, the required diagnostic equipment is relatively compact and simple. This allows many cells to be tested in the laboratory at once, and eventually electric transportation vehicles and grid-scale battery banks will stand to benefit from built-in sensors that will provide real-time tracking of battery health and warn about impending degradation or safety concerns.

Boris Dyatkin

Controlled radical polymerization enables sense of texture in haptics

Kinesthetic communication represents a key area of interest in perfecting user experience in virtual reality (VR) applications through creating texture sensation on fingertips. Haptic technology has been used to deliver the feeling of surface roughness, hardness, and temperature by a mixed mode of mechanical and electrical stimulation. However, nonfunctional homogeneous materials and bulky actuators pose spatial limitations on the controllability of the sensation gamut, thus deviating from the experience of real touch. Stimuli-responsive polymers synthesized by controlled free-radical polymerization over narrow molecular weight and polydispersity suggest a potential route for modifying tactile sensation at the molecular level by proper materials design and selection.



Schematic drawings of the wireless multimodal haptic glove with electrotactile sensor enabled by a synthesized conductive polymer for interfacing with a robotic hand and virtual reality (VR). Credit: *Advanced Intelligent Systems*.

In a recent issue of *Advanced Intelligent Systems* (doi:10.1002/aisy.202000018), a research team, led by Darren Lipomi at the University of California, San Diego, reported the use of aqueous reversible addition fragmentation transfer polymerization based on π-conjugated PEDOT, stretchable scaffold PSS, and an acrylic polymer, poly(ethylene glycol) methyl ether acrylate, to fabricate an elastomeric conductive block copolymer for electrotactile stimulation. "This paper represents the first time the tools of materials chemistry have been applied to a problem in haptics," says Lipomi. "We synthesized a stretchable, printable conductive polymer using controlled radical polymerization while most haptic actuators are made using commercial, off-the-shelf components." The research team developed a wireless multimodal haptic glove to recreate texture sensation when interfacing with a robotic hand or VR environment. The glove uses three types of actuators that produce electrotactile for roughness, vibrotactile for hardness, and thermoelectric effect for temperature. The synthesized conductive polymer was used for electrotactile stimulation due to its relatively high conductivity and low electrical impedance to metal electrodes.

The researchers also demonstrated the accuracy of tactile effect in psychophysical discrimination tasks in VR. Participants were asked to wear the haptic glove and evaluate the texture of test panels that appeared in the VR environment. Trained participants can achieve 98% accuracy in associating sensations while untrained participants have an accuracy of 85%. "What excites us in particular is the potential use of haptics in medicine: medical training, robot-assisted procedures, physical therapy, and other forms of remote care for 'health-care deserts,'" Lipomi says. "While we are quite far away from achieving these goals, we believe this invention is a useful contribution."

"Solving the problem of displaying realistic sensations to users is the holy grail of haptics," says Aadeel Akhtar, CEO and Founder of PSYONIC, Inc., a company developing sensorized prosthetic hands to enable amputees to feel. "The approach of using tools from organic chemistry is ingenious in developing realistic haptic interfaces that can interact at a molecular level with the skin. These methods expand the toolbox available to haptics researchers to further fine-tune the percepts users feel for more realistic sensations."

YuHao Liu

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