NanoEngineers Print and Test Chemical Sensors on Underwear (w/ Video)

June 17 2010

Chemical-sensing electrodes printed directly on the inside elastic waistband of underwear. Photo credit: UC San Diego / Daniel Kane

(PhysOrg.com) -- Chemical sensors printed directly on elastic underwear waistbands retained their sensing abilities even after engineers stretched, folded and pulled at the chemical-sensing printable electrodes - sensors that could one day be incorporated into intelligent “hospital-on-a-chip” systems. This work, funded by the U.S. Office of Naval Research, is led by professor Joseph Wang, from the Department of NanoEngineering at the University of California, San Diego Jacobs School of Engineering.

The primary goal of the new peer-reviewed study, published in the journal *Analyst*, was to aggressively test the performance of electrodes printed directly on textiles, something the researchers say has not been done before. The textile of choice - elastic waistbands of underwear -

highlights one potential application of the “hospital-on-a-chip” systems the electrodes will be part of: “smart underwear.”

The “smart” in “smart underwear” refers to the fact that the printed sensors will be incorporated into logic-based biocomputing systems that will monitor biomarkers found in human sweat and tears, make autonomous diagnoses, and administer drugs.

Based on specific combinations of biomarkers such as lactate, oxygen, norepinephrine and glucose, the textile-based smart systems will autonomously diagnose battlefield injuries or changes in patients’ health status. According to the diagnosis, the smart system will automatically trigger the release of drugs held in reservoirs, in order to begin treatment before help arrives. All sensors, power, electronics, and logic systems will be embedded in the clothing - such as the elastic waistband of underwear.

“The elastic waistband of common underwear has been selected as model clothing owing to its tight contact and direct exposure with the skin, and hence for its potential for direct sweat monitoring,” wrote the authors of the *Analyst* paper entitled, “Thick-film textile-based amperometric sensors and biosensors”. The authors are affiliated with UC San Diego and Chung Yuan Christian University.

Based on their experiments, the engineers concluded that bending, stretching and pulling on sensors printed directly on elastic waistbands had minimal detrimental effects on their ability to detect hydrogen peroxide and NADH, two compounds that sensors in these types of systems will need to recognize.

Sensor performance, nevertheless, can be optimized by tailoring sensor printing protocols, as well as the ink formulation and ink viscosity for specific textile substrates.

Reflecting on the considerable interest the research on sensors embedded onto underwear has received, Wang said "…putting the electrodes on the underwear, we didn't plan to make it so sexy. Our approach is scientific. The waistband of the underwear gives you the best contact with the skin where you expect to get a good sampling of the sweat."

From Biomarkers to 1s and 0s and Treatment

The UC San Diego NanoEngineers and their collaborators at Clarkson University continue to make progress on the system's "smarts" - enzyme logic gates that will process the sensed biomarker information and tease out accurate, automated diagnoses that will in some cases trigger the release of drugs, explained Wang, who has been working on sensor technologies for more than two decades.

A 2008 ONR grant announcement from UC San Diego introduced this project. In the announcement, professor Wang explained that lactate, oxygen, norepinephrine and glucose are examples as the kinds of injury biomarkers that will serve as biological input signals for the prototype logic system. Electrodes containing a combination of enzymes will serve as sensors and provide the logic necessary to convert the biomarkers to products which may then be picked up by another enzyme on the electrode for further logic operations. The electrodes will also act as transducers that produce strings of 1s and 0s that will activate smart materials that release medication based on pre-determined treatment plans.

"We just want the ones and zeros. The digital pattern of ones and zeros will reveal the type of injury and automatically trigger the proper treatment," said Wang.

For example, if an injured soldier were to enter a state of shock,

enzymes on the electrode would sense rising levels of the biomarkers lactate, glucose and norepinephrine. In turn, the concentrations of products generated by the enzymes would change - higher hydrogen peroxide, lower norepi-quinone, higher NADH and lower NAD+. This will cause the built-in logic structure to output the signal “1,0,1,0” which points to shock and will trigger a pre-determined treatment response.

“This is biocomputing in action,” said Wang.

More information: “Thick-film textile-based amperometric sensors and biosensors,” by Yang-Li Yang, Min-Chieh Chuang, Shyh-Liang Lou and Joseph Wang, from the University of California, San Diego and Chung Yuan Christian University.

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https://phys.org/news/2010-06-nanoengineers-chemical-sensors-underwear-video.html

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