SPECIAL REPORT

THE NEXT WAVE OF WEARABLES

WHILE WEARING FITNESS TRACKERS *has become a popular trend, many people believe their real value lies in the devices' ability to monitor not just steps taken but vital signs as well. For that application, the gadgets have a long way to go. The devices and their apps are not that accurate and don't monitor enough fitness metrics. Most trackers contain relatively few sensors and are limited as far as where they can be worn on the body. And their batteries must be constantly recharged.*

This special report describes efforts to make wearables work better by building a platform with sensors that accurately measure blood pressure, heart rate, and even the sort of airborne pollutants that can cause breathing problems [this page]. These units are built on flexible materials, so they can be worn just about anywhere on the body. What's more, they don't need batteries but instead run on energy harvested from the wearer's movements.

One article tackles another problem with today's wearable trackers: They not only do too little but also fall short in motivating their users to do more [p. 6]. Once the goals for the day are reached, there's not much to motivate users to take charge of other aspects of their health. But one specialist with a background in experimental psychology shows how games and social media can help inspire users on a subconscious level to be more health conscious.

With all the effort directed to develop new and improved medical devices, engineers are needed more than ever. The IEEE Life Sciences Technical Community predicts that the number of jobs in the life sciences will expand dramatically over the coming years. In this issue, we highlight the skills needed for engineers to enter this interdisciplinary field [p. 7]. We've also rounded up some of the resources and conferences that IEEE offers on electronic health, or e-health [p. 15].

And we profile IEEE Senior Member Joel Rodrigues, who is developing the networking technologies that will make e-health applications possible [p. 17]. His work involves wireless and body sensor networks, mobile and cloud computing, and information management.

And speaking of the future, we also includes a Q&A with the two 2016 IEEE president-elect candidates, Senior Member Karen Bartleson and Life Fellow Frederick "Fred" Mintzer, about their plans to take the organization to the next level [p. 8].

—Kathy Pretz, editor in chief

Health Monitors Get More Personal

Self-powered sensors are being integrated into fabric BY **KATHY PRETZ**

WEARABLE HEALTH and fitness trackers are among the most popular gadgets around. More than 13 million of them were sold globally last year, according to GfK, a German market research firm. And these numbers are only expected to grow as more sophisticated versions hit the market, with claims that they can monitor vital signs such as blood pressure, heart rate, and even hydration levels.

But a few problems with activity trackers must be addressed before they can be used as medical monitors. Trackers tend to contain too few sensors, must be charged frequently, and can only be worn on the wrist or clipped to clothing. And perhaps most troubling, they aren't accurate enough.

"Their level of accuracy is low because as a consumer product they haven't gone through the rigorous regulatory approval of medical devices," says IEEE Fellow Veena Misra. "But users want this type of technology."

Misra is director of the U.S. National Science Foundation Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies, better known as ASSIST. The center is located at North Carolina State University, in Raleigh, where she is also a professor of electrical and computer engineering. She is the lead author of "Flexible Technologies for Self-Powered Wearable Health and Environmental Sensing," published in April in *Proceedings of the IEEE*.

ASSIST, led by NC State, is a joint effort with Florida International University, Pennsylvania State University, and the University of Virginia. The center is using nanotechnology to build clinically accurate health-monitoring platforms and technologies that are self-powered and can be used on different areas of the body. ASSIST is working with several partners, including hospitals and medical device makers. According to Misra, the center will create the platform, and the partners will develop the products.

"The center's vision is to develop and integrate the technology in the direction of accurate, data-driven health management," she says. "We believe this is the requirement for improving global health care and quality of life."

ELECTRONIC TEXTILES

Most of today's wearables fit the electronics in wristbands, which rely on batteries that require periodic charging. ASSIST is developing novel flexible materials that conform to the body and can include a variety of sensors that can perform tasks such as checking vital signs and detecting particulates in the environment. And they can be worn on different parts of the body. What's more, the devices can be powered by energy harvested from the movement of the wearer's body. Batteries are no longer needed.

For example, ASSIST has developed a piezoelectric-coated film on nickel foil encapsulated in kapton tape that can scavenge energy from the movement of a person's elbow. Piezoelectric-coated fibers or nanowires woven into an athletic compression shirt, for instance, could generate power every time the wearer moves, according to ASSIST researcher Jesse Jur. An assistant professor of textile engineering, chemistry, and science at NC State, Jur is also one of the authors of the *Proceedings* article.

When the elbow bends, the device stretches, generating a current. Another wearable monitoring system uses inexpensive and highly stretchable and recoverable polymer films

CHAD HAGEN

ASSIST/NC STATE UNIVERSITY

ASSIST researchers are working on ways to weave electronics into garments, like this armband worn on the elbow, that can harvest thermal and mechanical energy generated by body heat and motion. This energy can be used to power wearable medical devices.

woven into compression fabrics that integrate microelectronic devices and printed circuits.

"It's important to have a material that is flexible and stretchable over the skin so it's comfortable but at the same time provides good electronic access to the skin," says Misra.

Adds Jur, "We're also working on durable ways to interconnect hard electronics placed at different locations on garments so they can communicate with each other. Textiles are typically inexpensive, and printed electronics technologies are getting a lot cheaper, so we are trying to integrate the two in a seamless manner."

HARVESTING POWER

ASSIST is focused on harnessing renewable sources of power for the tiny devices from body heat (which creates thermal energy) and body motion (which creates mechanical energy), says Misra.

For local transfer of thermal energy to usable power, ASSIST researchers have been exploring thermoelectric energy generators (TEGs). These devices rely on the Seebeck effect, in which a temperature gradient across a material causes diffusion of charge carriers from the hot to the cold side. This creates a separation of charge within the material and, as a result, a voltage.

When a thermoelectric material is placed between hot and cold surfaces, power is generated. Where the TEG is placed on the body is important. The transfer of heat to electrical energy requires efficient heat collection from the body at one point and efficient heat rejection to the outside environment at another, with some kind of thermal insulation between the two. Today's body heat–harvesting devices are limited because they are made of rigid ceramic plates, unable to maintain good skin contact in curved areas of the body.

"To harvest heat from the body, you must make intimate contact with the skin, and for that you need very good heat spreaders in the form of thermal electric material and a good heat sink on the other end to provide the 'cold' side of the generator," Misra says. "This approach will basically get us away from using a battery."

For their wearables, the researchers are targeting power levels as high as 500 microwatts to power multiple sensors and their electronics.

The ideal place for a TEG is on a person's pulse points, where blood vessels are close to the skin's surface. That's why textiles play a critical role: They conform to the body and provide the thermal insulation to maintain a temperature difference.

PROTOTYPES

The center has created a flexible wristband made of polymers integrated with components that include a TEG, low-power chips, and a low-power radio. It has also built a wireless, wrist-worn platform that includes sensors for measuring vital signs such as arterial blood pressure and blood oxygen saturation as well as tracking airborne pollutants. "Innovation lies in making these things truly wearable all the time," Misra adds. ◆

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