Power Walk This Way: Scientists Develop Device That Harnesses Energy from Everyday Movements

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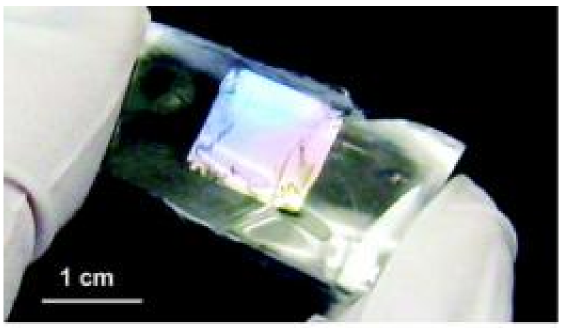

The PZT ribbons covering this minuscule rubber chip have the capacity to harness energy generated from body motions. [Credit: Nano Letters]

(PhysOrg.com) -- These boots are made for walking... and for powering up your cell phone? It could happen, say a team of Princeton and Caltech scientists. In a recent paper in the journal *Nano Letters*, they report that they have developed an innovative rubber chip that has the ability to harvest energy from motions such as walking, running, and breathing and convert it into a power source.

Score one for the body electric.

"It opens up a lot of possibilities," says Caltech graduate student Habib Ahmad, a coauthor on the paper. "We all dissipate energy as we move our bodies around, and conceivably that energy could be put to work charging small electronic devices like an iPod or a cell phone."

The key to this development is a class of materials known as piezoelectrics, which are substances—chiefly crystalline and ceramic—that respond to stress or strain by producing a charge, essentially converting mechanical energy to electrical energy. ("Piezo" derives from a Greek word, meaning to squeeze or exert pressure.)

"Piezoelectrics have been around for a while," says Ahmad. "The best-known and most widely used natural one is quartz." Ceramic ones, many of them man-made, often produce more voltage when stressed, but keeping that voltage level high generally requires that they be grown on a hard surface, or substrate. That limits how flexibly they can respond to the pressure generated by, say, a swinging arm or a treading foot.

Ahmad is currently working toward his PhD in the lab of Caltech's Gilloon Professor and Professor of Chemistry James Heath, where he is developing micro- and nanodevices—ultrasmall instruments—that can aid in detecting and diagnosing certain types of cancer. He got involved in a precursor to the piezoelectric research a couple of years ago when he collaborated with Heath postdoc Michael McAlpine in testing out a new technique that McAlpine had come up with for transferring silicon nanowires from an inflexible substrate to a plastic one.

"Basically Mike wanted to know whether these wires would still generate high voltage on a flexible surface," says Ahmad "Building electronic circuits and sensors on flexible plastics is a fairly new field, but it's one that has generated a lot of interest. So I built a chamber that allowed Mike to control which gases were exposed to the chip and in what concentrations, so that we could detect them with nanoscale sensors, and I set up all the measurement electronics and wrote data collection software."

In summer 2008, McAlpine became an assistant professor at Princeton, where he extended the techniques he had developed at Caltech to piezoelectric materials. His team became the first to fabricate minute strips, or nanoribbons, of a particularly powerful ceramic piezoelectric, lead zirconate titanate (PZT), and to transfer them successfully to a silicone rubber substrate.

"Mike asked me to help out with testing the material on a hard wafer to establish a baseline voltage," says Ahmad. He designed and produced the technical drawings for the chambers used to test the PZT wires, tested the data-collecting circuitry, and worked on the figures for the paper. Once those tests were completed and the wires transferred to the flexible surface, "Mike's team measured the voltage again and found virtually no degradation in the voltage levels."

“What made this latest result particularly exciting," says Ahmad, "is that a piezoelectric material sitting on a rubber substrate is malleable enough to be worn with relative comfort in your shoe or like a sweatband around your arm.” And because PZT generates energy nearly 100 times more effectively than quartz, “it’s got the capacity to take advantage of the body’s natural motions throughout the day.”

Beyond the appealing prospect of dancing around the house to power up your iPod, there are more serious applications on the horizon. “The military has shown a lot of interest in using piezoelectrics to harness energy,” says Ahmad, and in fact has already experimented with piezoelectric shoe implants that unfortunately proved to be too uncomfortable for soldiers to wear for any length of time. Rubber PZT chips might well resolve the comfort problem, but the researchers emphasize that there is more work to be done before their invention can be put to large-scale practical use in the armed forces or elsewhere.

“At the moment, we’ve basically got a one-centimeter chip with about

1,000 wires packed together," Ahmad says. "That's a very efficient use of space, but the energy that's produced is still relatively minimal. But there's no reason, technically speaking, why this can't be scaled up to a surface area on the order of 2 by 2 inches," at which point you can start looking at real-world applications.

Although piezoelectric materials are not Ahmad's primary field, he's enjoyed the attention that the research's bionic overtones have generated (this is the fifth paper he's coauthored and his third with McAlpine). Moreover, as a scientist concerned with applying nanotechnology to biomedicine, he's particularly interested in the work's potential there. "Since these chips are encased in silicone, which is generally recognized to be nontoxic for humans, there's the possibility for someday implanting these devices inside the body."

One possibility, say the scientists, is that the lung motion generated by breathing could potentially be "harvested into charging a pacemaker battery, thus increasing the time required between battery replacement surgeries for patients."

"Right now, we're still working on the fundamental technology," says Ahmad. "But the longer-range prospects are very exciting."

More information: Read the article in *Nano Letters*: pubs.acs.org/doi/full/10.1021/nl903377u

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