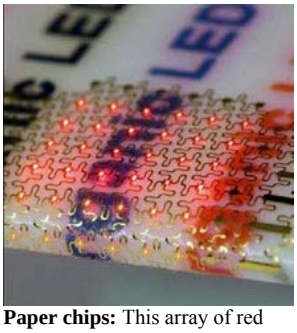
Cheap Electronics on Paper Diagnostic Chips

High-performance disposable electronics could improve the quality of inexpensive tests.

By Katherine Bourzac Tuesday, October 19, 2010

Disposable diagnostic tests currently under development could offer medical workers and patients in rural areas more detailed health information, such as viral counts in the blood of HIV patients, without the need for expensive equipment such as cameras, computers, or even cell phones. Researchers at two startup companies and the University of Illinois are building all the capabilities of expensive lab-bench tests onto a piece of paper, without adding significant weight or other cost to the tests. The group behind these flexible arrays of LEDs, light detectors, and transistors is also working with medical-device companies to incorporate them into surgical tools and bedside monitors for hospitals.



Paper chips: This array of red LEDs built on a piece of paper can be folded without damaging the electronics.
Credit: NPG/*Nature Materials*

"The only way many people will get medical care at all is if [a medical worker] can walk or ride a bike to a rural area carrying all the medical equipment they need," says Una Ryan, CEO of Diagnostics For All, a company that's developing single-use paper diagnostic tests. Paper is cheap, lightweight, and easy to dispose of by burning. The company has patterned postage-stamp-sized pieces of paper with channels that wick blood and other fluids into an area treated with chemicals that change color to indicate, for example, elevated liver enzymes that reveal an AIDS patient is on the wrong drugs. The simple color-change reaction can provide critical information that lets doctors know whether a patient is in danger. "We don't need water or electricity," says Ryan.

Diagnostics For All will begin field trials of this liver-enzyme test, which costs a few cents per test, in Kenya next year. But many patients would benefit from health information that's more quantitative than can be obtained from a color-change-based test. Ryan says the company would like to provide HIV/AIDS patients and their medical providers with information about viral loads, for example, without any additional equipment. Tests that provide quantitative information also promise to be more sensitive, which is critical when, for example, trying to diagnose HIV/AIDS in a newborn who can only afford to give a drop of blood rather than a whole vial.

The company is now collaborating with MC10, an electronics startup in Cambridge, Massachusetts, and researchers at the University of Illinois at Urbana-Champaign to build sophisticated electronics including light sensors, transistors, and microscale LEDs on the surface of the paper tests. Rooz Ghaffari, who heads product development at MC10, says LEDs on the devices under development send light through the region of the paper where reaction wells are located; if certain disease markers are present, the light that's detected on the other side by an array of photodetectors will have shifted in a measurable way. This information can be processed by on-board transistor arrays to produce a readout that could be displayed by another set of LEDs. MC10 and Diagnostics For All have a $100,000 pilot grant from the Gates Foundation to develop a disposable device for monitoring viral load in HIV/AIDS patients.

"We want to have all these components built onto a piece of paper, but it has to be low cost, high performance, so thin you can bend it, and not sacrifice the ruggedness of the [paper] devices," says Ghaffari. Diagnostics For All's Ryan believes the cost added by these on-board electronics will not be significant. That's because the flexible electronics, though they work as well as their rigid counterparts, use very little of the semiconducting materials that make conventional electronics so expensive. The flexible versions are made using a combination chemical-etching-and-stamping technique developed by John Rogers, professor of materials science and engineering at the University of Illinois. Instead of building just one set of electronics on a relatively thick semiconductor wafer, as is done in the chip industry, Rogers uses etching to shape and release multiple thin layers from the

surface of a wafer, enabling him to produce many more transistors, solar cells, or other devices from the same amount of material. A robotically controlled rubber stamping machine can then pick up the individual devices and place them on flexible, even stretchable, substrates, including paper, rubber, and fabric.

In a paper published online this week in the journal Nature Materials, Rogers describes using flexible electronics to make several prototype devices, including the photodetector and LED arrays on paper that are being developed by his lab with MC10 and Diagnostics For All. "We've shown that the way we're using materials in these systems can lead to a lot of new capabilities for medicine," says Rogers.

Story continues below

Rogers is also working with medical supplier Baxter on intravenous tubing that incorporates flexible electronics to monitor what dose of a drug the patient is actually getting. In addition, flexible chemical sensors inside IV tubing could give a warning signal if a bag of IV drugs or nutrients were mislabeled. In the Nature Materials paper, Rogers's lab has made a similar demonstration device, a flexible IV tube that can monitor levels of glucose, which is commonly given intravenously in hospitals.

Ryan and Ghaffari say that early work on the electronic paper diagnostics is going well and that the group will apply for a second-phase, $1 million grant from the Gates Foundation to fund further development and commercialization in the coming months. A remaining hurdle to releasing these tests into the field is powering them, but they only need to run for a few minutes and will not require a full battery. Ghaffari says the next phase of research will focus on incorporating a disposable thin-film battery into the tests.

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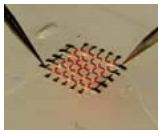

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