United Business Media

NXP: Can it rebound from reorg? 11

EE Times

THE NEWSWEEKLY FOR THE CREATORS OF TECHNOLOGY

ISSUE 1542 MONDAY, SEPTEMBER 22, 2008 WWW.EETIMES.COM

Broadcasters and suppliers target next-gen technologies 22

Readers choose ‘Ultimate Products’ 49

STRETCH

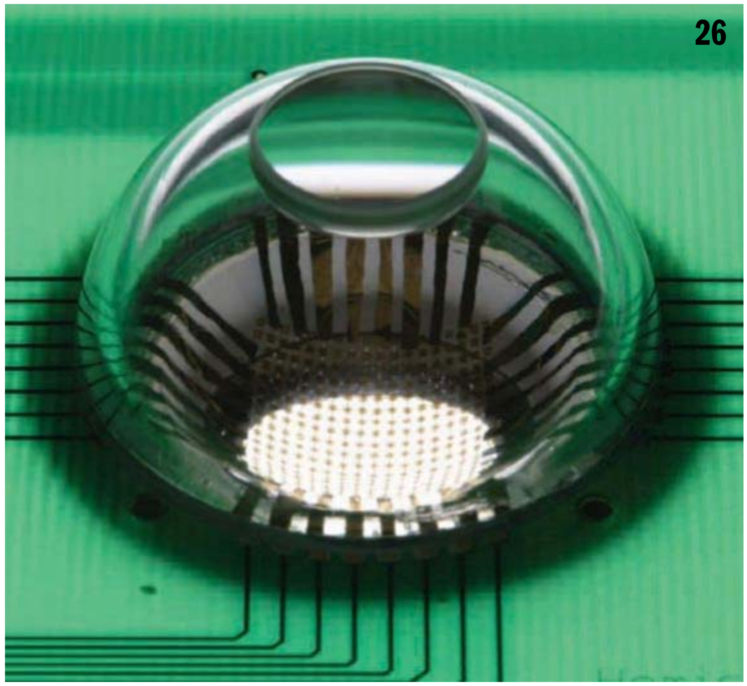
Flexible circuits could lead to bendable sensors in many apps 26

EE Times

CONTENTS SEPTEMBER 22, 2008

United Business Media LLC, 600 Community Drive,
Manhasset, N.Y. 11030

techinsights. United Business Media



OPINION

NEWS OF THE TIMES

GLOBAL WATCH

COVER STORY

INTELLIGENCE

DESIGN + PRODUCTS

[redacted]

ELECTRONIC ENGINEERING TIMES (ISSN #0192-1541) is published weekly, except 3 issues in December (51 issues) by United Business Media Ltd., 600 Community Drive, Manhasset N.Y. 11030 and is free to qualified engineers and managers involved in engineering decisions. One year subscription rates for others: United States $280; and Canada $324. Return undeliverable Canadian addresses to APC Postal Logistics, LLC, P.O. Box 503 RPO W Beaver Cre, Rich-Hill ON L4B 4R6. Registered for GST as United Business Media Ltd. GST#R13288078, Customer Number 2116057, Agreement Number 40011901. Annual air mail rates to Europe/Mexico, Central/South America, Africa $449; Asia, Australia and New Zealand $518. Mail subscription with check or money order in US Dollars to ELECTRONIC ENGINEERING TIMES, 600 Community Drive, Manhasset, NY 11030 Circulation Dept. Periodicals postage paid at Manhasset, N.Y. and additional mailing offices. POSTMASTER Send address changes to ELECTRONIC ENGINEERING TIMES, P.O. Box 2164, Skokie, IL 60076. Please address subscription, inquiries, editorial copy and advertising to ELECTRONIC ENGINEERING TIMES, 600 Community Drive, Manhasset, N.Y. 11030.

BPA WORLDWIDE NEWSPAPER

Flexible electronics

High-performance ICs learn to bend and stretch

By Sunny Bains

IN ELECTRONICS, rigid and flat is normal. In the real world, not so much.

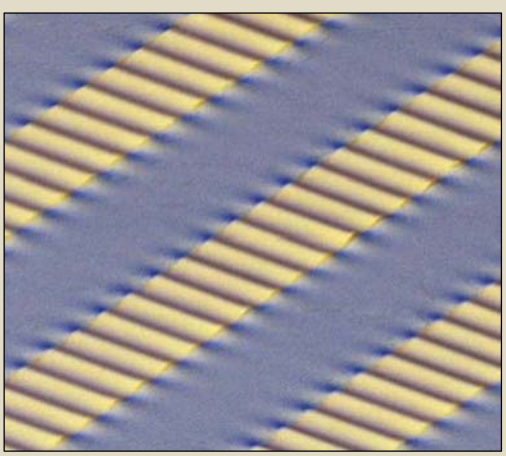
There are many applications in which it would be useful for electronics to conform to curvilinear surfaces or to deform with use, especially in sensing. A detector array could be made to encircle the heart, stretching with each beat. An artificial skin could be stretched around the wing of an aircraft, relaying detailed local information while in flight. An artificial retina could fit in the curved space at the back of the eye like the biological sensor it replaced. Thus far, however, flexible technologies have lacked the performance, manufacturability or, well ... flexibility to make such applications feasible.

But a new technology demonstrated at the University of Illinois at Urbana-Champaign (UIUC) may be able to fill this niche—one that is certain to widen once engineers are allowed to think beyond flat and rigid. The new circuits are designed to have long, thin interconnects, fabricated using standard semiconductors (silicon, gallium arsenide and so on) and conventional techniques, and then transferred onto a stretched elastic sheet (see box below). Once the substrate is relaxed, the interconnects—which are thin enough to bend without breaking—buckle under the strain. If designed correctly, they can then buckle further if compressed or flatten if stretched. Thus, an elastic circuit fabric can be created using more-or-less ordinary electronics.

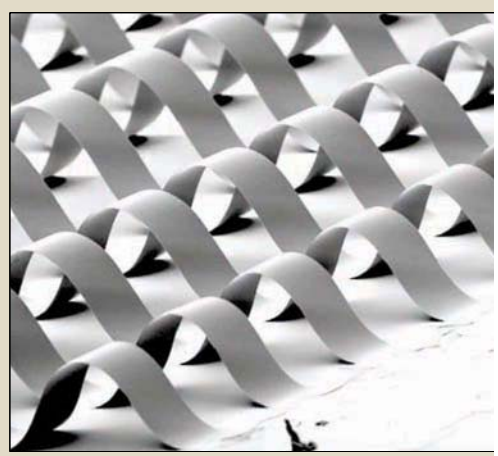
Alternatively, the elastic fabric can be used to form the electronics into 3D shapes that can be transferred onto a rigid substrate. This is how the UIUC team was able to create the first hemispherical silicon camera.

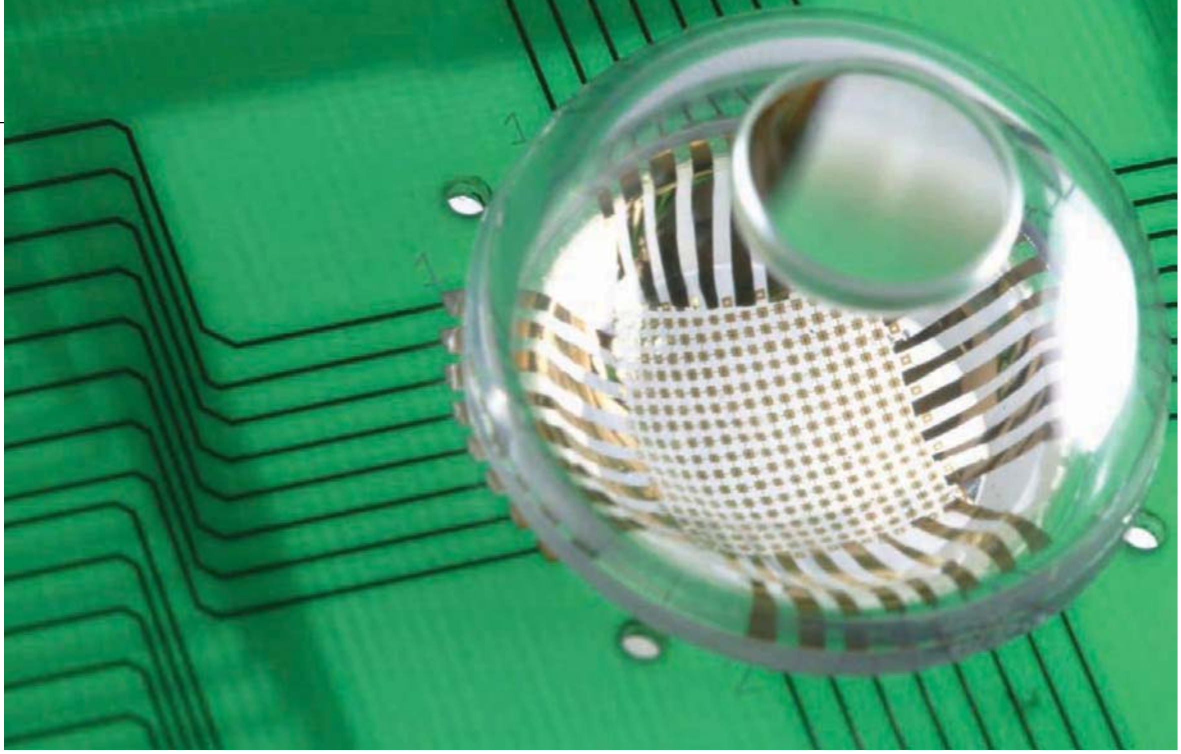
Whether flexibility or shape is the goal, the approach has the advantage of leveraging conventional microlithography and semiconductor processing. John Rogers, who led the

THE TECHNOLOGY EVOLVES



← **UNIVERSITY OF ILLINOIS researchers first demonstrated a kind of elastic silicon in which thin ribbons of the material were directly attached to polydimethylsiloxane (PDMS) while it was being stretched. Once allowed to relax, the incorporated ribbons formed sine waves that varied in wavelength and amplitude when the elastic material was subsequently deformed. With this system, stretch and compression of a few percent each could be accommodated. The ribbons shown here are 20-μm wide and 100-nm thick.**





ARTIFICIAL EYEBALL: Thanks to the design of circuits with bendable interconnects and an elastic transfer step, this hemispherical detector array was fabricated using conventional 2D lithography.

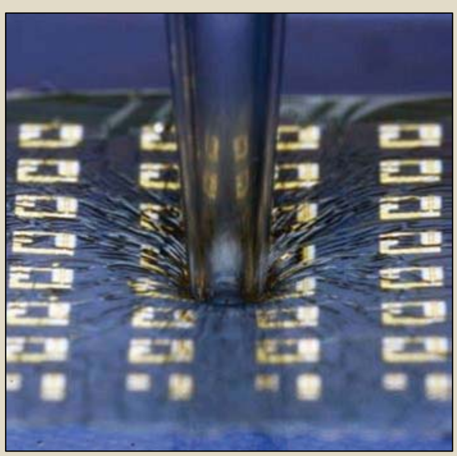
SOURCE: BECKMAN INSTITUTE, UNIV. OF ILLINOIS

UIUC research, has set up a company—Semprius—to commercialize the technology. "The most important advantage," Rogers said, "is that we use known, established materials and processing techniques to achieve levels of performance in the circuits as high as comparably designed wafer-based systems, but with levels of stretchability approaching that of a rubber band [up to 100 percent strains and even larger]. An associated advantage is that we can fully exploit all existing electronics knowledge and fabrication facilities."

Bob Reuss—an independent consultant and former DARPA program manager and Motorola senior technologist—also suggests the technology will, at the very least, find a niche. "To achieve conformal and/or flexible electronics with at least moderate functionality, I believe the technology will be valuable, if not essential. So success will mean creation of a new market segment," he said.

Further, he added, "Elastic S is in my opinion an example of 'more than Moore.' It is not on the International Technology Roadmap for Semiconductors and perhaps never will be. Rather, it is one of a variety of technologies being created either to more effectively utilize IC technology for applications beyond computing and communications, or to actually

← HOWEVER, RESEARCHERS found they could get a more predictable ribbon shape, and more flexibility, by patterning the adhesive on the elastic substrate so the semiconductor ribbons could buckle without constraint by the PDMS. This produced patterns with free-standing sine waves and a greater ability to stretch and compress. The ribbons shown here, 50-μm wide and 290-nm thick, were deposited on a substrate with an initial strain of 50 percent. Using these techniques, the team achieved stretchability of 100 percent and compressibility of 25 percent.



← NEXT, THE RESEARCHERS demonstrated that the technique could be used with working devices. Ultrathin circuits were fabricated on a sacrificial layer and then removed using chemical etching, as shown here. They were subsequently transferred to the stretched PDMS with the thin interconnects between circuits free to buckle to accommodate deformation of the substrate. The performance of the circuitry, encapsulated with polyimide for protection, was found largely unaffected by imposed strains within design limits. →

replace the existing IC infrastructure where cost and form factor are not competitive for the intended application."

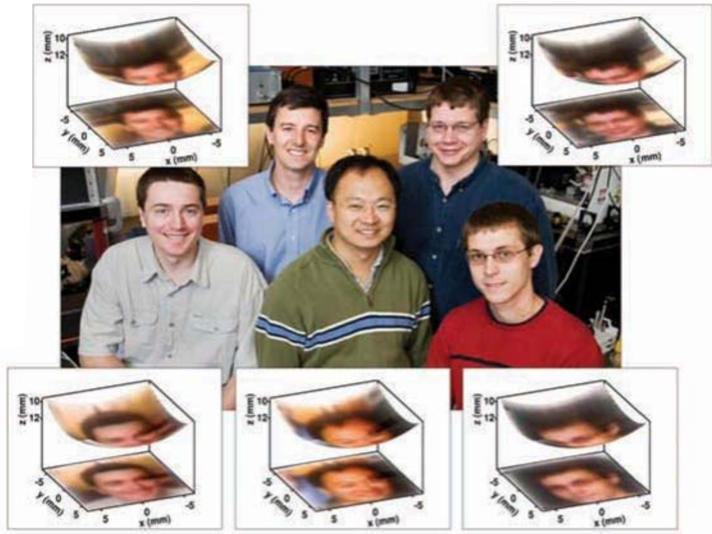
Elastic, not plastic

The best-known way to create flexible electronics is to print circuits directly onto carbon-based plastics. One target application for this technology is the electronic newspaper, which is in the process of being realized commercially. Though the technology is maturing, it has inherent problems: It relies on organic materials that have much poorer electronic performance than semiconductors. Worse, the development of these materials does not come free as a byproduct of progress in the electronics industry. Finally, although these materials are flexible, they are not elastic: They bend, but they don't stretch.

Another approach is to fabricate conventional chips and then thin the wafers to make them lighter and less rigid. Again, stretching is not an option, and even bending ability is limited. Yet another option is to attach small chips to an elastic surface and create wires to connect them after the fact. Though this offers both performance and mechanical flexibility, there are many non-conventional (and, therefore, expensive) fabrication steps involved.

The UIUC approach depends on the fact that silicon, gallium arsenide and other semiconductors—all basically brittle—become flexible when deposited in very thin layers. Max Lagally, a materials science and engineering professor at the University of Wisconsin-Madison, works in the area of nanostructures for electronics, among other things. "Thin, flexible Si [and other semiconductors, including Ge] has tremendous potential," he says. "There is the flexibility, the ability to take advantage of the third dimension. One can also strain them and thus take advantage of better electronic properties—one can stack them, etc."

The UIUC approach, in fact, "takes little advantage of these properties, as the carrier is what is flexible," Lagally said. This is in contrast to researchers creating far more sophisticated micro- and nano-mechanical devices by engineering the strain in fabricated layers so, when released, they form complex three-dimensional structures. Rather, he explained, the group's most important achievement, is the transfer technology—the ability to transfer the silicon pieces and connect them in such a way that they end up in the hemispherical pattern. It is really the first example of a hemispherical photodetector in silicon."

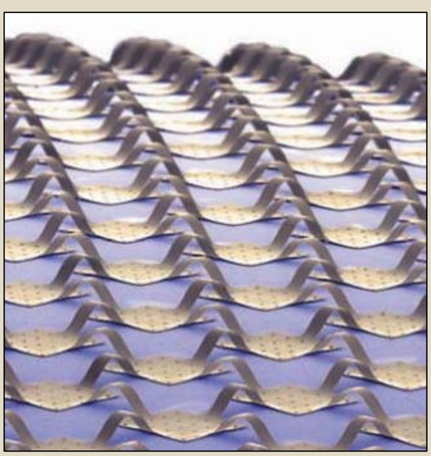


SEEING IS BELIEVING: Though the new camera has low resolution, it was able to take recognizable pictures of the University of Illinois team, using color and spatial multiplexing and very simple optics.

SOURCE: BECKMAN INSTITUTE, UNIV. OF ILLINOIS

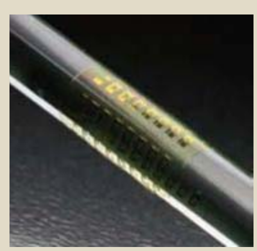
However, according to Rogers, the UIUC team—with colleagues at Northwestern University (Evanston, Ill.) and elsewhere—have also made an important contribution to the understanding of mechanics in silicon. "The buckling mechanics and the modes of deformation push into the forefront of theoretical mechanics," Rogers said. "In fact, our very careful experimental studies of elastic silicon revealed a flawed assumption in every previous known theoretical treatment of buckling in stiff materials on compliant substrates."

Further, he sees the future of electronics as taking mechanics into account. "I think these kinds of systems bring mechanical design to the forefront of system definition, at a level that might be as important as circuit design," he said. "We envision, in fact, a kind of mechanics equivalent to PSPICE that could aid in the layout of a circuit for optimal performance in an elastic configuration. A combined mechanics/electronics design tool might be the ultimate. We



← TO DEMONSTRATE that the technology could be used in a real-world application, the team built a hemispherical detector array, or electronic eye, using circuits like those shown here. To achieve the curvature, the team took a hemisphere of PDMS and stretched it radially to produce a flat membrane, like a drumhead. The circuits were transferred onto this substrate, then deformed with it as it relaxed to its normal shape. Finally, they were transferred onto its permanent substrate: an inverted hemisphere on a glass lens.

← RESEARCHERS ARE NOW working to develop real applications, particularly biomedical and bio-inspired sensors. They will have to address issues of device density, ensuring that the thermal properties of the elastic substrates used do not impede the performance of the final systems, and bio-compatibility.



← ELASTIC substrate-mounted silicon circuits can conform to objects with a relatively small radii of curvature—in this case, 2mm.

—S.B.

SOURCE: BECKMAN INSTITUTE, UNIV. OF ILLINOIS work closely with theoretical mechanicians and analog circuit designers to pursue this type of outcome."

Potential applications

There is "an entire, untapped world of applications for electronics that demand properties unachievable with conventional technologies based on semiconductor wafers," Rogers said. "The most prominent examples fall into two categories: bio-inspired devices and biomedical devices. Both rely on systems that have the layouts of biological systems, none of which have the rigid, planar nature of a semiconductor wafer."

In the biomedical area, Rogers said, "We are working on electronic sensor patches that conformally integrate with the complex, curvilinear surface of the human brain. Our goal, in collaborations with a professor [Brian Litt] in the medical school at University of Pennsylvania, is to provide a system that can detect the onset of a seizure in a person who suffers from epilepsy, before the seizure actually occurs."

The technology has a good chance of succeeding in these areas, concurs Reuss, who believes it will prove lucrative for investors. "Whether to augment, replace or monitor biological function, flexible/stretchable electronics will be needed to effectively and comfortably achieve human interface," he said. "Given the aging population, as well as the desire to medicate [for] a variety of debilitating diseases, there seems to be a huge available market for the right technical solutions." Structural health monitoring and portable electronics, he added, will also be attractive applications.

However, Reuss is not convinced that commercial success can be taken for granted: Industry inertia may be a problem. "There is a well used expression: 'If it *can* be done in Si, it *will* be done in Si,'" he said. "So conventional ICs, perhaps thinned to less than 50μm, should never be ruled out."

Further, he added, the advantages of the new technology may be offset by the higher cost associated with a process flow more complex than simply printing inks onto a substrate such as plastic. If inks become available that provide performance closer to conventional ICs, cost-vs.-performance trade analysis may become more difficult."

Carmichael Roberts of North Bridge Venture Partners is a lead investor in Rogers' new technology. Not surprisingly, he has high hopes for it. "Conventional silicon has produced products worth billions of dollars," he said. "In 10 years or less, this new silicon technology has the potential to be worth billions of dollars as well." ∎

↗ MORE See *rogers.mse.uiuc.edu* and *www.semprius.com*

Sunny Bains (*www.sunnybains.com*) is a London-based scientist and freelance technology journalist.