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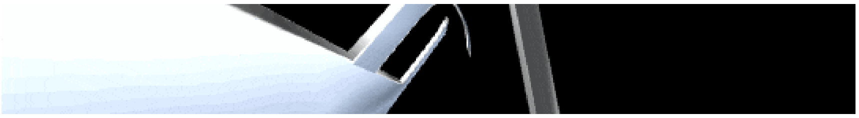


News

21 March 2018

Silicon hole injector for deep ultraviolet aluminium gallium nitride diodes

Researchers based in the USA have used p-type silicon (p-Si) nanomembranes as hole injector layers for deep ultraviolet (DUV) light-emitting diodes (LEDs) emitting at 229nm [Dong Liu et al, Appl. Phys. Lett., vol112, p081101, 2018].

The team from University of Wisconsin-Madison, HexaTech Inc, University of Texas at Arlington, and Michigan State University, hope to overcome the low hole injection efficiency of p-type III-nitride materials such as aluminium gallium nitride (AlGaN) alloys, particular those with high aluminium fractions. Apart from boosting the efficiency of LEDs, the researchers also believe that p-Si nanomembrane hole injection layers may lead to DUV laser diodes in the future.

DUV devices are desired for applications such as biological and chemical detection, decontamination, medical treatment, high-density optical recording, and lithography. AlGaN alloys allow access to bandgaps of 3.3eV-6.2eV (GaN-AlN), giving wavelengths from 376nm down to 200nm. However, high-Al-content AlGaN devices with emission wavelengths shorter than 300nm have sharply decreasing efficiency. Poor hole injection and high defect densities are leading causes of inefficiency.

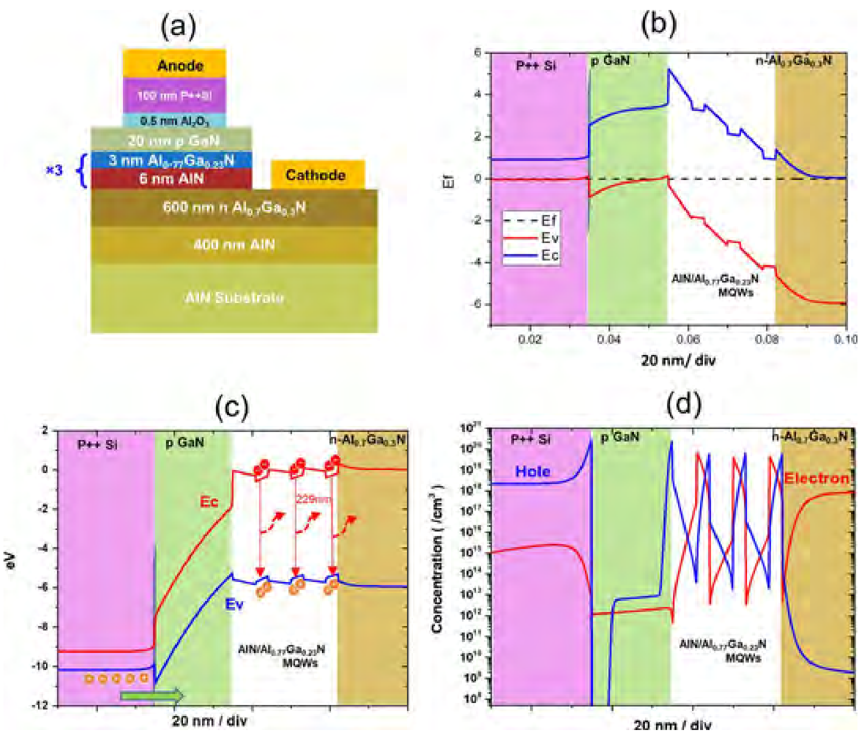


Figure 1: (a) Schematic of LED device. (b) Band diagram simulations at equilibrium and under 10V forward bias giving 300A/cm^2 current density (c). (d) Calculated barrier concentration distribution across structure under forward bias.

Bulk AlN with low dislocation density of 10^4/cm^3 was used as a substrate for low-pressure organometallic vapor phase epitaxy of the DUV structure (Figure 1). The 20nm p-GaN cap protects against rapid oxidation of the underlying Al-containing material.

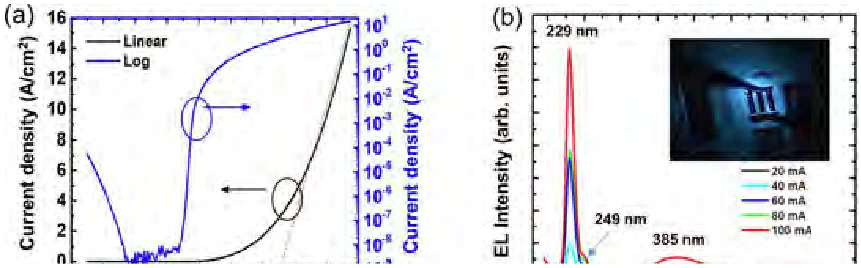
The p-GaN was covered with 0.5nm aluminium oxide (Al_2O_3) from five cycles of atomic layer deposition (ALD). The 100nm p-Si nanomembrane hole injector had a heavy doping concentration of 5x10^{19}/cm^2. The Al_2O_3 acted and passivation and quantum tunnel barrier for hole injection.

The nanomembrane was released from a silicon-on-insulator (SOI) substrate and transferred to the III-

0.547nm aided the bonding process with the transferred p-Si, which resulted in 0.677nm roughness of the total structure.

The LED fabrication consisted of mesa isolation, exposure of the n-AlGaN contact for deposition of the titanium/aluminium/nickel/gold cathode, and deposition of the titanium/gold anode. The cathode and anode geometries were interdigitated to minimize losses from lateral current spreading resistance. The effective device area was estimated at $1.31 \times 10^{-3} cm^2$.

The LED turn-on voltage was about 7V. The reverse leakage was relatively high due to wafer growth dislocation defects, it is thought. The devices were operated in continuous wave (CW) mode without thermal management or cooling. No special light extraction enhancements were applied.



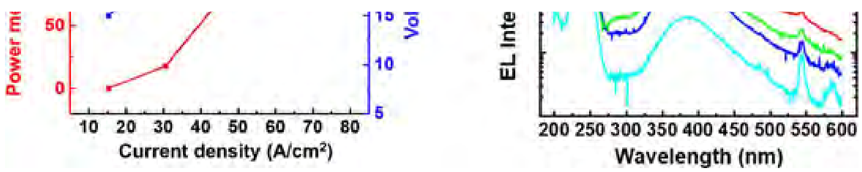


Figure 2: (a) Current density-voltage characteristics of typical LED on linear and log scales. (b) Electroluminescence (EL) spectra under different driving current densities with CW operation. Inset: optical microscopic image of forward-bias LED diode showing visible blue illumination. (c) Log-scale plot of EL spectra under currents of 40mA, 60mA, 80mA and 100mA. (d) Plot of measured light output power as a function of driving current density and associated voltages.

The peak wavelength was around 229nm. Parasitic peaks were also seen at 249nm DUV and ~380nm blue. These parasites were more than one order of magnitude less intense than the main peak. The 249nm peak is attributed to the 4.98eV bandgap of the n-AlGaN electron-injection layer. The researchers add: “The broad peak at 385nm in the visible range has multiple contributions, likely from the top p-GaN combined and with deep-levels in AlGaN, excited by 229nm photons.”

The output power reached 160μW at 24V bias and 100mA injection ($76A/cm^2$). “The light emission at 229nm showed no significant efficiency droop up to $76A/cm^2$ in CW operation and without thermal management,” the researchers claim. The external quantum efficiency was 0.03%. The team believes this could be improved by thinning the AlN substrate to reduce point-defect absorption in the 229nm wavelength range.

Tags: DUV LEDs AlGaN

Visit: https://doi.org/10.1063/1.5011180

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

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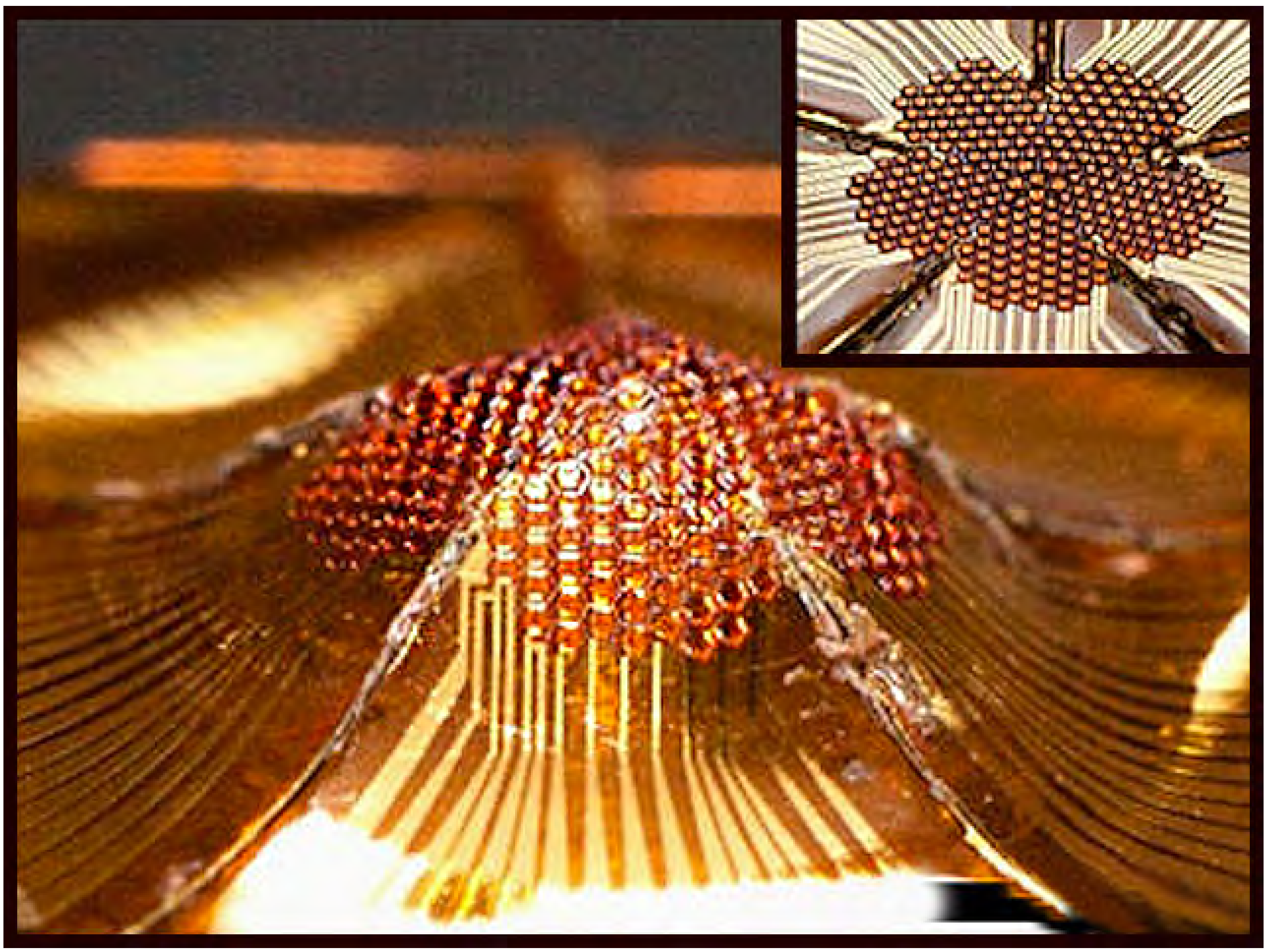

16 January 2018

Making Eyes

The curved shape of the human eye (https://en.wikipedia.org/wiki/Eye) is no mistake – it's been evolving for millions of years, possibly even from bacteria (http://bpod.mrc.ac.uk/archive/2016/7/29), to focus light from different angles, soaking up detail from the outside world. Cameras are a household example of biomimicry (https://en.wikipedia.org/wiki/Biomimetics) - imitating eyes by focussing light onto a bed of sensors. But most cameras and phones have flat sensors lacking the sensitive curve of the human eye's retina, which is challenging to reproduce with delicate materials. Taking a new approach, researchers lay overlap 'leaves' of silicon-based sensors into different moulds – concave like the human eye, or convex like an insect eye (pictured here).

The sections are folded together and cut away to leave a smooth curved sensor. This cunning mix of origami and optoelectronics (https://en.wikipedia.org/wiki/Optoelectronics) may reduce the cost of curvy artificial eyes in everything from surveillance equipment to medical cameras peering around our insides.
Written by John Ankers

- Image from work by Kan Zhang, Yei Hwan Jung and Solomon Mikael, and colleagues (https://www.wisned.com/)
- Department of Electrical and Computer Engineering, University of Wisconsin–Madison, Madison, WI, USA (https://www.engr.wisc.edu/department/electrical-computer-engineering/)
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- Published in Nature Communications, November 2017 (http://dx.doi.org/10.1038/s41467-017-01926-1)

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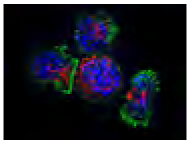
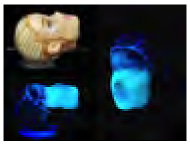
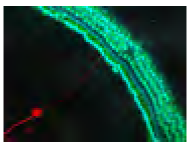
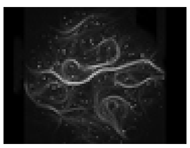
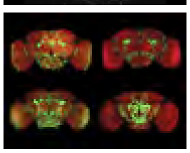
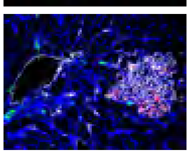
-  (http://bpod.mrc.ac.uk/archive/2018/1/15)
-  (http://bpod.mrc.ac.uk/archive/2018/1/14)
-  (http://bpod.mrc.ac.uk/archive/2018/1/13)
-  (http://bpod.mrc.ac.uk/archive/2018/1/12)
-  (http://bpod.mrc.ac.uk/archive/2018/1/11)
-  (http://bpod.mrc.ac.uk/archive/2018/1/10)
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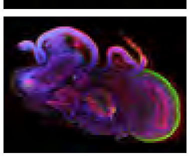
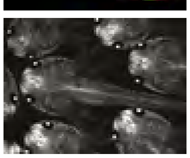
-  (http://bpod.mrc.ac.uk/archive/2018/1/8)
-  (http://bpod.mrc.ac.uk/archive/2018/1/7)

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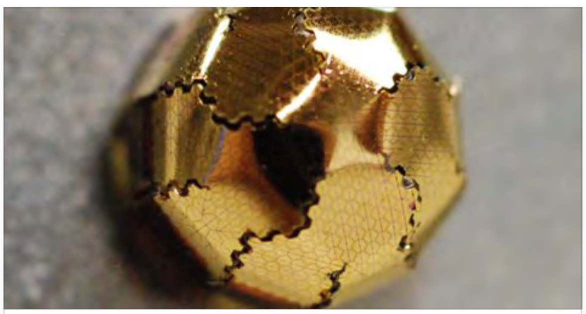
December 1, 2017 ·

Professor Zhenqiang (Jack) Ma, at the University of Wisconsin-Madison, has developed a method for making curved digital image sensors that mimic an insect's eye and a mammal's eye. According to the researchers, the #breakthrough could lead to cameras with advanced features— an infinite depth of field, wider view angle, low aberrations, and increased pixel density. #BasicResearch #ArtofScience #origami #photodetector #sensors #bioinspired



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Origami technique turns flat optical sensors into hemispherical eyes

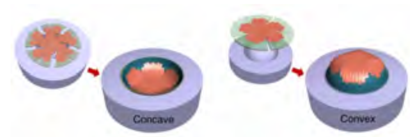
November 30, 2017 // By Julien Happich

Today's planar digital image sensors simply inherit their form factor from the substrates and semiconductor processes used in their volume manufacture. But more and more research groups are pursuing the benefits of curved hemispherical sensors, mimicking the optimized optics of biological eye systems.

While vertebrates evolved with globe-shaped eyes, with a concave retina behind a spherical lens (and the iris as a pin-hole), insects mostly sport convex multi-faceted compound eyes. Both approaches offer a wider field of view and lower aberrations than our made-made planar sensors. Yet, conforming high-resolution semiconductor-based sensors into hemispherical domes (inward or outward) presents its own challenges.

Now, a team of researchers from the University of Wisconsin Madison leveraged Japanese paper folding technique "origami" to shape silicon optoelectronic sensors into near perfect hemispherical sensor arrays.

Publishing their results in Nature Communications under the title "Origami silicon optoelectronics for hemispherical electronic eye systems", the researchers explain how they took advantage of traditional planar fabrication techniques to design an array of silicon-based lateral P–i–N photodiodes, laid out to form a large net of pentagon- and hexagon-shaped single photodetectors forming the flattened subdivisions of a half-truncated icosahedron (think of a soccer ball cut along carefully chosen seams).



The origami shaping process: a net of half truncated icosahedron based on silicon nano-membranes is pressed into hemispherical concave or convex molds.

Once lifted off their original substrate and transfer-printed to a flexible one, the thin-film array of photodiodes was cut-out along specific contours using a precision laser so the subdivisions' edges could then be jointly folded into a perfectly matching concave or convex hemispherical mould.

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Origami technique turns flat optical sensors into hemispherical eyes: Page 2 of 3

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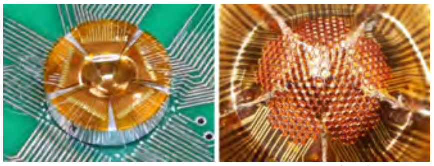
Using this approach, the researchers fabricated single-crystalline silicon-based focal plane arrays (FPA) and lens-less artificial compound eyes (both with hemisphere-like structures, but inverted).



A concave version of the digital image sensor (left) bends inward for creating a hemispherical focal plane array while the convex version (right) mimics an insect's compound eye. Yei Hwan Jung and Kan Zhang.

Interestingly, because the active layer are so thin, the same folding mechanism can be implemented for both concave and convex photodetector arrays. The paper also highlights that the origami-based fabrication eliminates the use of metal wires in-between pixels, for the connection of sparsely arrayed devices, instead the jointing folds allow for densely packed pixel arrays. For a better fit, as design resolution increases, the edges of the hemisphere-like structure can be further smoothed out by dividing large pentagonal and hexagonal faces into smaller polygon faces.

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Origami technique turns flat optical sensors into hemispherical eyes: Page 3 of 3

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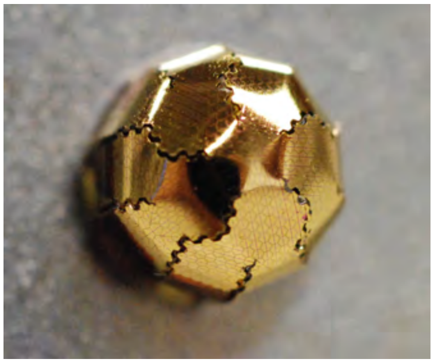
Today's planar digital image sensors simply inherit their form factor from the substrates and semiconductor processes used in their volume manufacture. But more and more research groups are pursuing the benefits of curved hemispherical sensors, mimicking the optimized optics of biological eye systems.

In their implementation, the researchers packed 281 hexagonally-shaped photodetectors (each 113 μm in diagonal) in hemispherical arrays of different radii, 2.27mm and 7.20mm, only observing a performance degradation when the photodetector was conformed to a curvature radius of 1.5mm. But they note that if made thinner (down to 20nm), a silicon nanomembrane photodetector could easily wrap around a single mode fibre (125μm in diameter).



Close up of hexagonally-shaped pixels from the origami sensor draped over a dome shape, with perfectly jointing seams. Yei Hwan Jung and Kan Zhang.

The hemispherical FPA was assembled into a simple camera system featuring a plano-convex lens (10mm diameter and 10mm focal length) while the convex version was evaluated as a compound eye mimicking camera (a photoresist microlens placed on top of each detecting unit during fabrication to maximize light intake).

The paper highlights the simplicity of the origami-shaping process and how easily the pixel density could be scaled up. The researchers hope that further optical optimizations of their compound electronic eye system (such as adding layers to mimic the pigment cells and crystalline cones) could yield truly panoramic colour vision.

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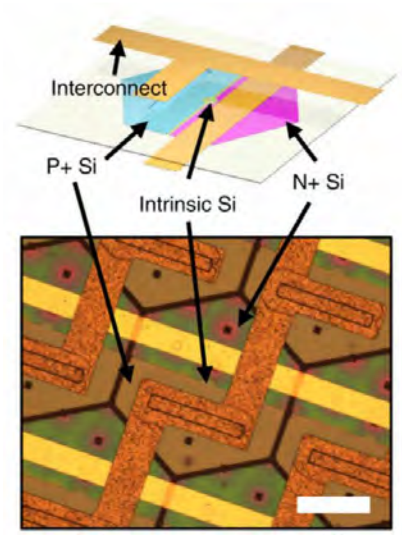


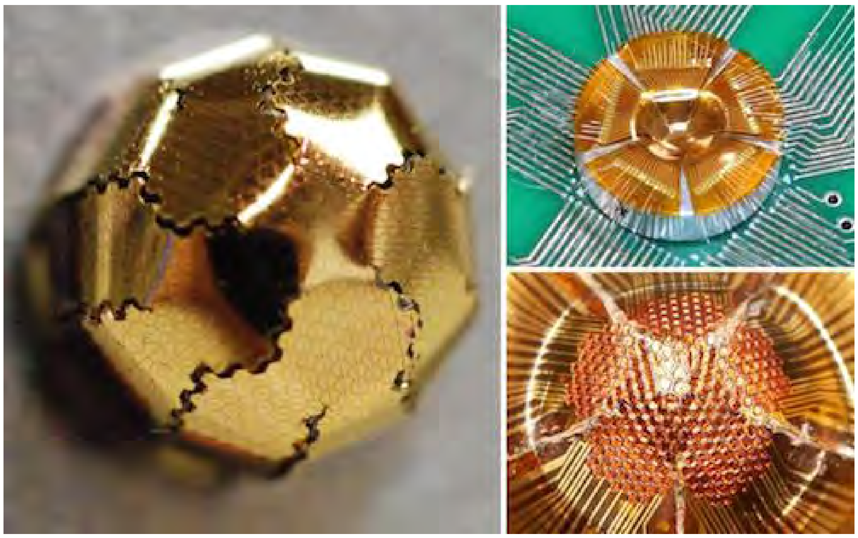
The sensor array consists of hexagon-shaped photodiodes, with a metal connector waving from one cell to the next. Scale bar in the microscope image is 50μm.

LaserFocusWorld

Bowl-shaped silicon image sensor could enable hemispherical imaging

11/27/2017

By John Wallace
Senior Editor



A flat silicon membrane carrying a hexagonal sensor array is carved up just right (left) so that it can be folded into a geodesic dome shape (actually, a truncated dodecahedron), making it into a curved image sensor. Concave (top right) and convex (bottom right) versions can be made. (Image: University of Wisconsin-Madison)

While CCD and CMOS sensors are conventionally flat, they can be curved a little bit by forcing then into a concave semispherical form, then gluing them. This method produces a sensor field that can be curved enough to, for example, enable the design of simpler imaging optics.

However, far more deeply curved concave image sensors could allow more exotic devices such as small cameras that could image almost an entire hemisphere (perhaps with a monocentric lens); highly convex sensors could lead to insect-eye type imagers. But silicon simply does not stretch enough to allow forcing it into a true bowl shape.

Now, researchers from the University of Wisconsin-Madison and the University of Texas at Arlington have created a somewhat origami-like method of creating deeply bowl- or dome-shaped silicon detectors.[1] It involves precise laser-cutting of a hexagonal sensor array on silicon so that the remaining array can be folded into the form of a geodesic dome (this is not true origami because origami doesn't allow cutting).

To create a curved photodetector, Zhenqiang (Jack) Ma, a professor at the University of Wisconsin-Madison, and his group formed pixels by mapping the repeating hexagons onto a thin, flat flexible sheet of silicon called a nanomembrane, which sits on a flexible substrate. They then used a laser to cut away some of those pixels so the remaining silicon formed perfect, gapless seams when they placed it atop a dome shape (for a convex detector) or into a bowl shape (for a concave detector).

The researchers' current prototype is approximately 7 mm in diameter. Although the pixel density is low, this could be vastly increased in future devices.

Source: https://news.wisc.edu/optoelectronics-origami-an-easy-to-make-double-duty-curved-image-sensor/

REFERENCE:

1. Kan Zhang et al., Nature Communications (2107); doi: 10.1038/s41467-017-01926-1

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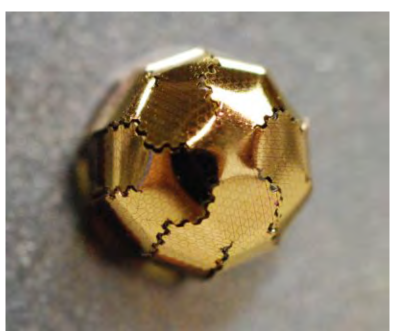
Cellphone users rest on their phone cameras to constraint probably any aspect of their lives. Far too often, however, they finish adult with photos that are a sub-par facsimile of reality.

While user blunder infrequently comes into play, a camera's digital picture sensor is a many expected culprit. A flat, silicon surface, it only can't routine images prisoner by a winding camera lens as good as a likewise winding picture sensor — differently famous as a retina — in a tellurian eye.



This picture shows how a researchers mapped pixels onto a silicon, afterwards cut some sections divided so a ensuing silicon covers over a architecture shape, with no wrinkles or gaps during a seams. Image credit: Yei Hwan Jung, Kan Zhang.

In an allege that could lead to cameras with facilities such as gigantic abyss of field, wider perspective angle, low aberrations, and vastly increasing pixel density, stretchable optoelectronics pioneer Zhenqiang (Jack) Ma has devised a process for creation winding digital picture sensors in shapes that impersonate a convex facilities of an insect's devalue eye and a mammal's concave "pinhole" eye.

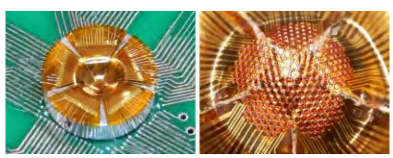
Along with his students and collaborators, Ma, a Lynn H. Matthias and Vilas Distinguished Achievement Professor of Electrical and Computer Engineering during a University of Wisconsin–Madison, described a technique in a investigate published (Nov. 24, 2017) in a journal Nature Communications.

Curved picture sensors do exist. Yet even yet they outperform their prosaic counterparts, they haven't done it into a mainstream — in part, since of a hurdles fundamental in a production process that involves dire a flat, firm square of silicon into a hemispherical figure though wrinkling or violation it or differently spiritless a quality.

Ma's technique was desirous by normal Japanese origami, a art of paper folding.

To emanate a winding photodetector, Ma and his students shaped pixels by mapping repeating geometric shapes — rather like a soccer round — onto a thin, prosaic stretchable piece of silicon called a nanomembrane, that sits on a stretchable substrate. Then, they used a laser to cut divided some of those pixels so a remaining silicon shaped perfect, gapless seams when they placed it atop a architecture figure (for a convex detector) or into a play figure (for a concave detector).

"We can initial order it into a hexagon and pentagon structure, and any of those can be serve divided," says Ma. "You can perpetually order them, in theory, so that means a pixels can be really, unequivocally dense, and there are no dull areas. This is unequivocally scalable, and we can hook it into whatever figure we want."



A concave chronicle of a digital picture sensor (left) bends central for formulating a hemispherical focal craft array. A convex chronicle (right) bends like a soccer round for mimicking an insect's devalue eye. Image credit: Yei Hwan Jung, Kan Zhang.

Pixel firmness is a bonus for photographers, as a camera's ability to take high-resolution photos is determined, in megapixels, by a volume of information a sensor can capture.

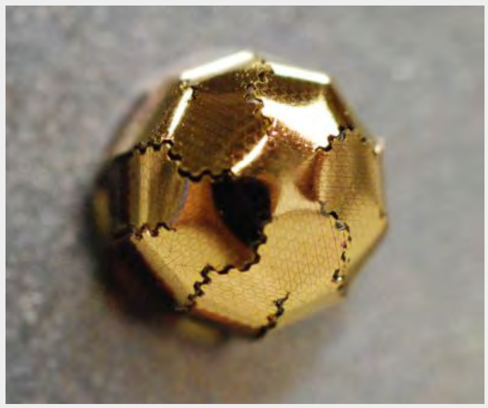
The researchers' stream antecedent is approximately 7 millimeters — roughly a quarter-inch — in diameter. That's still a bit massive for your cellphone, though Ma says he can make a sensor even smaller.

Optoelectronics origami: An easy-to-make, double-duty curved image sensor

Posted November 27, 2017

Cellphone users rely on their phone cameras to capture virtually every aspect of their lives. Far too often, however, they end up with photos that are a sub-par reproduction of reality.

While operator error sometimes comes into play, the camera's digital image sensor is the most likely culprit. A flat, silicon surface, it just can't process images captured by a curved camera lens as well as the similarly curved image sensor — otherwise known as the retina — in a human eye.



This image shows how the researchers mapped pixels onto the silicon, then cut some sections away so the resulting silicon drapes over a dome shape, with no wrinkles or gaps at the seams. Image credit: Yei Hwan Jung, Kan Zhang.

In an advance that could lead to cameras with features such as infinite depth of field, wider view angle, low aberrations, and vastly increased pixel density, flexible optoelectronics pioneer Zhenqiang (Jack) Ma has devised a method for making curved digital image sensors in shapes that mimic the convex features of an insect's compound eye and a mammal's concave "pinhole" eye.

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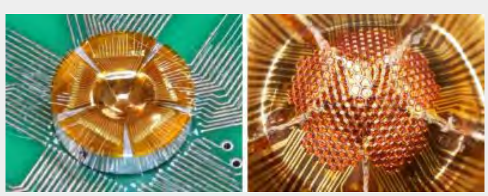
Ma's technique was inspired by traditional Japanese origami, the art of paper folding.

To create the curved photodetector, Ma and his students formed pixels by mapping repeating geometric shapes — somewhat like a soccer ball — onto a thin, flat flexible sheet of silicon called a nanomembrane, which sits on a flexible substrate. Then, they used a laser to cut away some of those pixels so the remaining silicon formed perfect, gapless seams when they placed it atop a dome shape (for a convex detector) or into a bowl shape (for a concave detector).

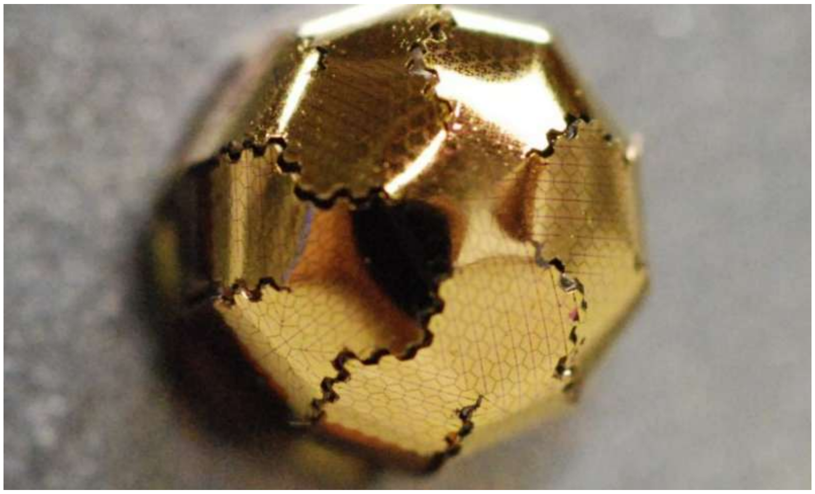
"We can first divide it into a hexagon and pentagon structure, and each of those can be further divided," says Ma. "You can forever divide them, in theory, so that means the pixels can be really, really dense, and there are no empty areas. This is really scalable, and we can bend it into whatever shape we want."



A concave version of the digital image sensor (left) bends inward for creating a hemispherical focal plane array. A convex version (right) bends like a soccer ball for mimicking an insect's compound eye. Image credit: Yei Hwan Jung, Kan Zhang.

An easy-to-make, double-duty curved image sensor

November 27, 2017 by Renee Meiller, University of Wisconsin-Madison



This image shows how the researchers mapped pixels onto the silicon, then cut some sections away so the resulting silicon drapes over a dome shape, with no wrinkles or gaps at the seams. Credit: Yei Hwan Jung and Kan Zhang.

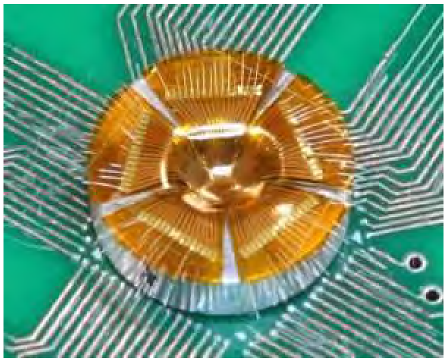
These days, we increasingly rely on our cell phone cameras to capture virtually every aspect of our lives. Far too often, however, we end up with photos that are a sub-par reproduction of reality.

And while operator error sometimes comes into play, most likely, the camera's digital image sensor is the real culprit. A flat silicon surface, it just can't process images captured by a curved camera lens as well as the similarly curved image sensors—otherwise known as the retinas—in human eyes.

In a breakthrough that could, for example, lead to cameras with beyond-the-state-of-the-art features such as infinite depth of field, wider view angle, low aberrations, and vastly increased pixel density, flexible optoelectronics pioneer Zhenqiang (Jack) Ma has devised a method for making curved digital image sensors in shapes that mimic an insect's compound eye (convex) and a mammal's "pin-hole" eye (concave).

The Lynn H. Matthias and Vilas Distinguished Achievement Professor of electrical and computer engineering at the University of Wisconsin-Madison, Ma, his students and collaborators described the technique in the Nov. 24, 2017, issue of the journal Nature Communications.

Curved image sensors do exist. Yet even though they outperform their flat counterparts, they haven't made it into the mainstream—in part, because of the challenges inherent in a manufacturing method that involves pressing a flat, rigid piece of silicon into a hemispherical shape without wrinkling it, breaking it or otherwise degrading its quality.

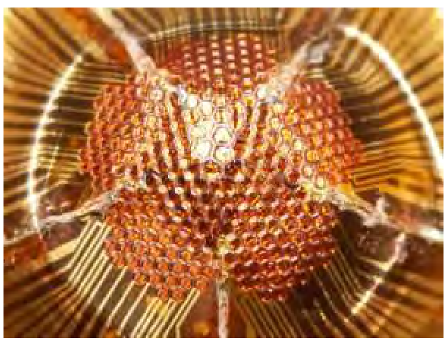


A concave version of the digital image sensor bends inward for creating a hemispherical focal plane array. Credit: Yei Hwan Jung and Kan Zhang

Ma's technique was inspired by traditional Japanese origami, or the art of paper-folding.

To create the curved photodetector, he and his students formed pixels by mapping repeating geometric shapes—somewhat like a soccer ball—onto a thin, flat flexible sheet of silicon called a nanomembrane, which sits on a flexible substrate. Then, they used a laser to cut away some of those pixels so that the remaining silicon formed perfect seams, with no gaps, when they placed it atop a dome shape (for a the convex detector) or into a bowl shape (for a concave detector).

"We can first divide it into a hexagon and pentagon structure—and each of those can be further divided," says Ma. "You can forever divide them, in theory, so that means the pixels can be really, really dense, and there are no empty areas. This is really scalable, and we can bend it into whatever shape we want."



A convex version of the digital image sensor bends like a soccer ball for mimicking an insect's compound eye. Credit: Yei Hwan Jung and Kan Zhang

That pixel density is a boon for photographers, as a camera's ability to take high-resolution photos is determined, in megapixels, by the amount of information its sensor can capture.

Currently, the researchers' prototype is approximately 7 millimeters, or roughly a quarter-inch, in diameter. That's still a bit bulky for your cell phone, but Ma says he can make the sensor even smaller. "This membrane is a very big advance in imaging," he says.

Explore further: Sony inspired by biomimicry develops curved CMOS sensors

More information: Kan Zhang et al. Origami silicon optoelectronics for hemispherical electronic eye systems, Nature Communications (2017). DOI:

Image Sensors World

News and discussions about image sensors

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Friday, November 24, 2017

Curved Origami Image Sensor

University of Wisconsin-Madison reports that its researchers were able to make a curved image sensor:

A flat silicon sensor "just can't process images captured by a curved camera lens as well as the similarly curved image sensor — otherwise known as the retina — in a human eye.

Zhenqiang (Jack) Ma has devised a method for making curved digital image sensors in shapes that mimic the convex features of an insect's compound eye and a mammal's concave "pinhole" eye.

To create the curved photodetector, Ma and his students formed pixels by mapping repeating geometric shapes — somewhat like a soccer ball — onto a thin, flat flexible sheet of silicon called a nanomembrane, which sits on a flexible substrate. Then, they used a laser to cut away some of those pixels so the remaining silicon formed perfect, gapless seams when they placed it atop a dome shape (for a convex detector) or into a bowl shape (for a concave detector).

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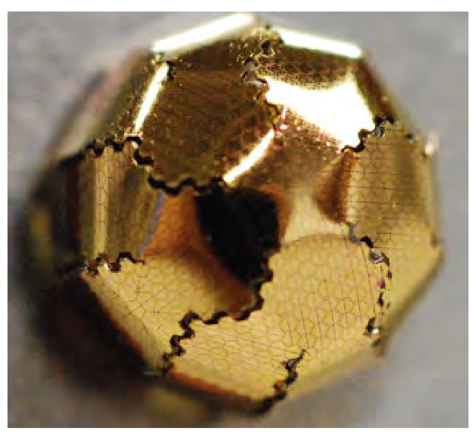
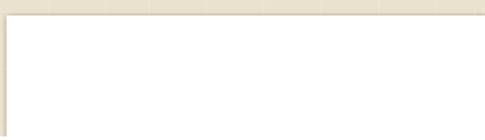


This image shows how the researchers mapped pixels onto the silicon, then cut some sections away so the resulting silicon drapes over a dome shape, with no wrinkles or gaps at the seams.

The open-access paper has been publishes in Nature Communications: "Origami silicon optoelectronics for hemispherical electronic eye systems" by Kan Zhang, Yei Hwan Jung, Solomon Mikael, Jung-Hun Seo, Munho Kim, Hongyi Mi, Han Zhou, Zhenyang Xia, Weidong Zhou, Shaoqin Gong & Zhenqiang Ma



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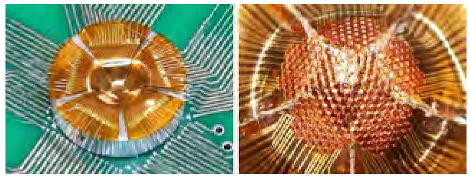

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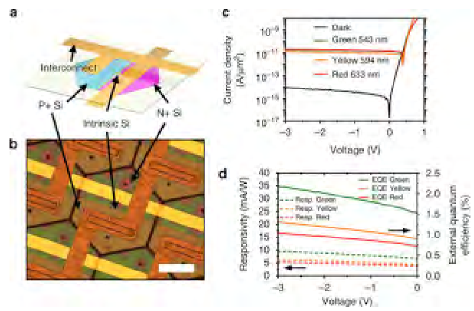


A silicon nanomembrane-based photodiode used for the electronic eyes. An array of such photodiodes were printed and fabricated on a pre-cut flexible polyimide substrate.

Posted by Vladimir Koifman at 15:57

G+

7 comments:

Eric R Fossum November 24, 2017 at 5:15 PM

i hope that someday these microfabrication techniques will find applications. They are too clever to waste!

Reply

Anonymous November 24, 2017 at 11:10 PM

fascinating techniques!

Reply

Anonymous November 25, 2017 at 1:51 PM

Amateur here: Would it be possible to have flat Si pixels, each as a separate tiny piece and they would be connected with metal "wires" only? :) Small gaps in between.. and maybe you can bend it then!

Reply

▾ Replies

Eric R Fossum November 26, 2017 at 2:41 PM

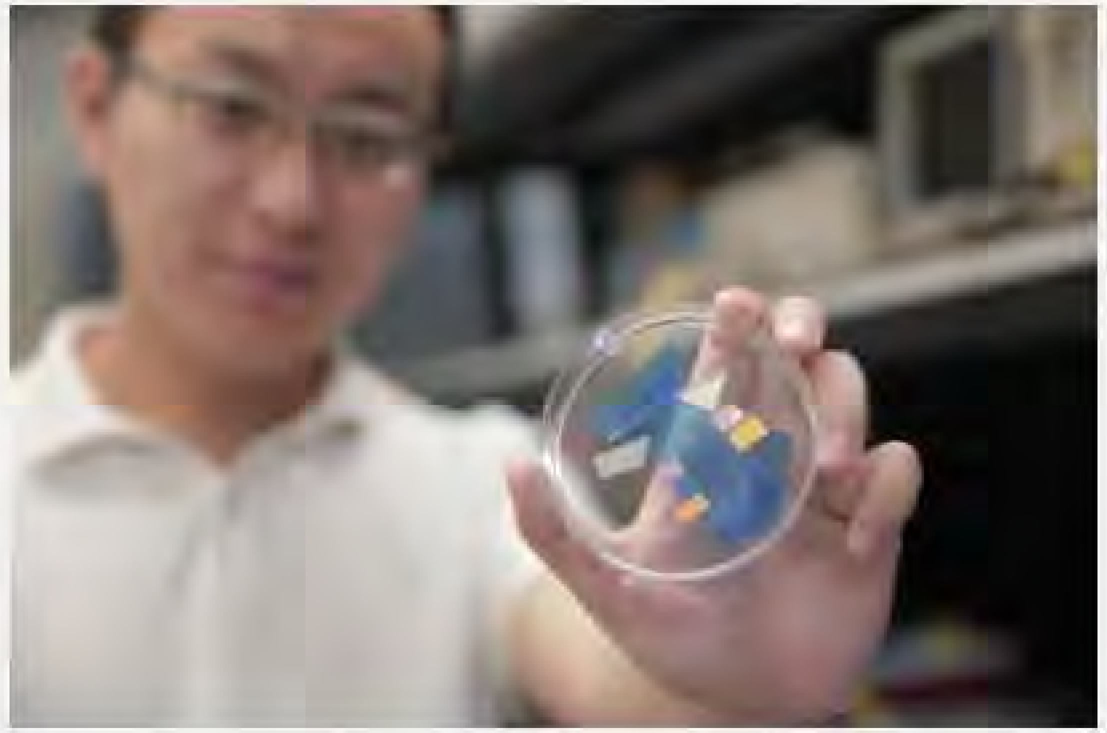
It seems the reported device is an array of PN junctions so as an image sensor it won't work too well. To move to a more classic image sensor, there should be at least a switch in each pixel, complicating the fabrication and wiring. Perhaps that is next. I am not sure what the advantage of individual pixels wired together would be but maybe it could be more flexible. Passivation of the pixel sidewalls would be important. I think a cluster-based array makes more sense for flexibility and manufacturing, assuming there was an application for this. I did see an interesting presentation from a group of college students making a flexible array of solar cells. Different approach, but similar concepts, including DRIE for etch-thru.

Stretchable Photovoltaics, University of Maryland
Team Members: Sabrina Michelle Curtis, Alexander Randolph, Gabriel Anfinrud, Haotian Wang; Advisors: Ray Phaneuf, Nathan Lazarus
Power Flex: Imagine wearing a traditional solar panel on your back. While useful for charging your smartphone, it's neither lightweight nor particularly comfortable. Now imagine a different kind of solar cell, one the thickness of a piece of paper and

PUBLIC RELEASE: 7-JUL-2017

Powerful new photodetector can enable optoelectronics advances

UNIVERSITY OF WISCONSIN-MADISON



MADISON, Wis. -- In today's increasingly powerful electronics, tiny materials are a must as manufacturers seek to increase performance without adding bulk.

Smaller also is better for optoelectronic devices -- like camera sensors or solar cells -- which collect light and convert it to electrical energy. Think, for example, about reducing the size and weight of a series of solar panels, producing a higher-quality photo in low lighting conditions, or even

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http://www.wisc.edu

More on this News Release

Powerful new photodetector can enable optoelectronics advances
UNIVERSITY OF WISCONSIN-MADISON

JOURNAL
Science Advances

FUNDER
National Science Foundation, Air Force Office of Scientific Research, US Department of

News From the Field

Powerful new photodetector can enable optoelectronics advances

July 7, 2017

In a nanoscale photodetector that combines a unique fabrication method and light-trapping structures, a team of engineers from the University of Wisconsin-Madison and the University at Buffalo has overcome obstacles to increasing performance in optoelectronic devices--like camera sensors or solar cells--without adding bulk. **Full Story**

Source
University of Wisconsin-Madison

The National Science Foundation (NSF) is an independent federal agency that supports fundamental research and education across all fields of science and engineering. In fiscal year (FY) 2017, its budget is $7.5 billion. NSF funds reach all 50 states through grants to nearly 2,000 colleges, universities and other institutions. Each year, NSF receives more than 48,000 competitive proposals for funding and makes about 12,000 new funding awards.

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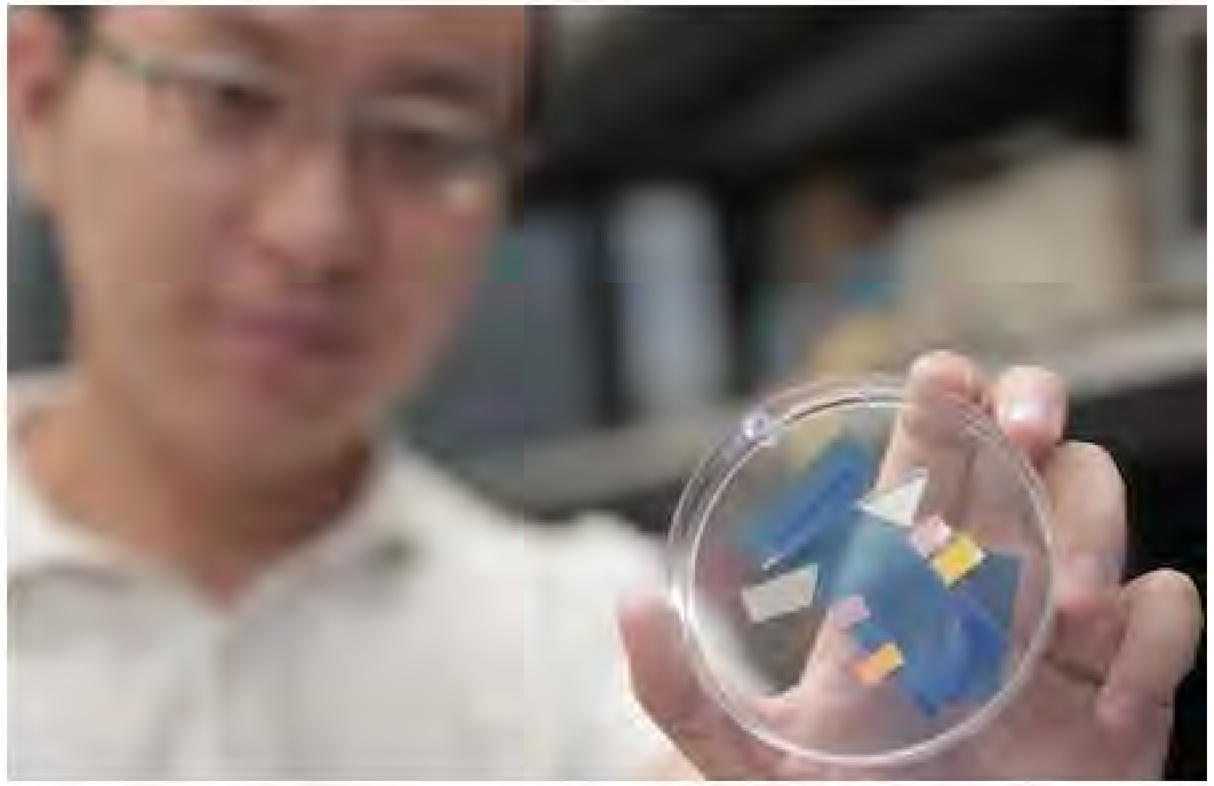
Thinner photodetector could increase performance without adding bulk

07/07/2017

By John Wallace

Senior Editor



Researcher Zhenyang Xia holds a dish containing germanium-film photodetector samples. The sample colors vary depending on what wavelength they are tuned to absorb. (Image: Stephanie Precourt/UW-Madison College of Engineering)

Smaller is often better for many photodetector applications, but two major challenges have stood in the way of making smaller thin-film semiconductor detectors. First, shrinking the size of conventionally used amorphous thin-film materials also reduces their quality. And second, when ultrathin materials become too thin, they become almost transparent and thus lose some ability to gather light.

NATURE PHOTONICS | RESEARCH HIGHLIGHTS

PHOTODETECTORS

Slim semiconductor

David Pile

Nature Photonics **11**, 532 (2017) | doi:10.1038/nphoton.2017.154

Published online 01 September 2017

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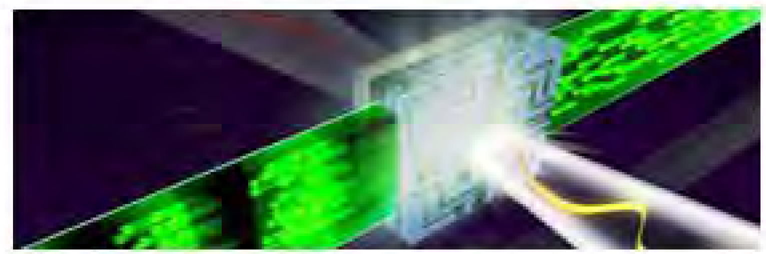
Subject terms: Imaging and sensing • Optical sensors

Sci. Adv. **3**, e1602783 (2017)

The use of ultrathin layers of semiconductor is potentially attractive for realizing fast, miniaturized optoelectronic devices; however, the absorption of light in such ultrathin layers can be very inefficient. Now, researchers in the USA have made photodetectors from nanomembranes of single-crystal Ge that are only tens of nanometres thick, yet yield good absorption and performance. The key to the advance is using a membrane transfer–printing method to put the thin crystalline Ge films directly onto optical nanocavities that enhance the light–matter interaction. The optical cavities themselves are formed by a dielectric layer of Al_2O_3 sandwiched between the Ge and a thin silver 'mirror' on silicon. The Ge is thinned down to desired thicknesses between 10 to 60 nm, confirmed by atomic force microscopy. For a 20-nm-thick Ge film photodetector, an absorption of ~16% of the light at a wavelength of 733 nm would be typical, however, the team achieved a much greater value of 81% in their cavity-enhanced design. The photodetector was fabricated with a 17-nm-thick gallium-doped (p-type) Ge film and delivered a photoresponsivity of up to 4.7 A W^{-1}. The dark current is small due to the low volume of the semiconductor used; with a normalized photocurrent to dark current of ~10^5 mW^{-1}. The approach is not limited to Ge and in principle can be applied to other semiconductors.

Editors' pick

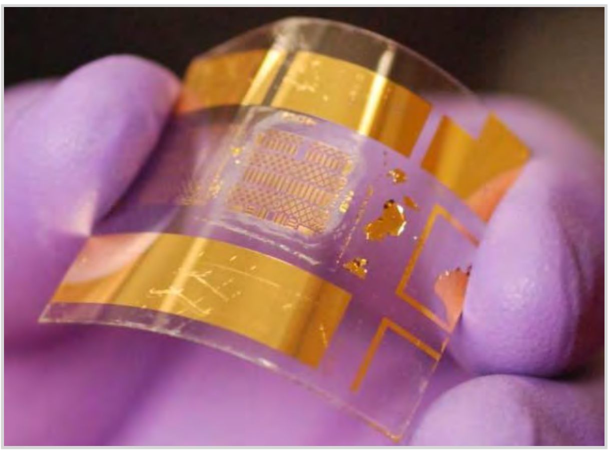


Attosecond photonics ▸

New transistor design enables flexible, high-performance wearable/mobile electronics

"Can scale to industry-level production right away"

October 2, 2017



Advanced flexible transistor developed at UW-Madison (photo credit: Jung-Hun Seo/University at Buffalo, State University of New York)

A team of University of Wisconsin–Madison (UW–Madison) engineers has created "the most functional flexible transistor in the world," along with a fast, simple, inexpensive fabrication process that's easily scalable to the commercial level.

The development promises to allow manufacturers to add advanced, smart-wireless capabilities to wearable and mobile devices that curve, bend, stretch and move.*

The UW–Madison group's advance is based on a BiCMOS (bipolar complementary metal oxide semiconductor) thin-film transistor, combining speed, high current, and low power dissipation (heat and wasted energy) on just one surface (a silicon nanomembrane, or "Si NM").**

BiCMOS transistors are the chip of choice for "mixed-signal" devices (combining analog and digital capabilities), which include many of today's portable electronic devices such as cellphones. "The [BiCMOS] industry standard is very good," says Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW–Madison. "Now we can do the same things with our transistor — but it can bend."

The research was described in the inaugural issue of Nature Publishing Group's open-access journal *Flexible Electronics*, published Sept. 27, 2017.***

Making traditional BiCMOS flexible electronics is difficult, in part because the process takes several months and requires a multitude of delicate, high-temperature steps. Even a minor variation in temperature at any point could ruin all of the previous steps.

Ma and his collaborators fabricated their flexible electronics on a single-crystal silicon nanomembrane on a single bendable piece of plastic. The secret to their success is their unique process, which eliminates many steps and slashes both the time and cost of fabricating the transistors.

"In industry, they need to finish these in three months," he says. "We finished it in a week."

He says his group's much simpler, high-temperature process can scale to industry-level production right away.

"The key is that parameters are important," he says. "One high-temperature step fixes everything — like glue. Now, we have more powerful mixed-signal tools. Basically, the idea is for [the flexible electronics platform] to expand with this."

* *Some companies (such as Samsung) have developed flexible displays, but not other flexible electronic components in their devices, Ma explained to* KurzweilAI.

*** "Flexible electronics have mainly focused on their form factors such as bendability, lightweight, and large area with low-cost processability…. To date, all the [silicon, or Si]-based thin-film transistors (TFTs) have been realized with CMOS technology because of their simple structure and process. However, as more functions are required in future flexible electronic applications (i.e., advanced bioelectronic systems or flexible wireless power applications), an integration of functional devices in one flexible substrate is needed to handle complex signals and/or various power levels." — Jung Hun Seo et al./*Flexible Electronics*. The n-channel, p-channel metal-oxide semiconductor field-effect transistors (N-MOSFETs & P-MOSFETs), and NPN bipolar junction transistors (BJTs) were realized together on a 340-nm thick Si NM layer.*

**** Co-authors included researchers at the University at Buffalo, State University of New York, and the University of Texas at Arlington. This work was supported by the Air Force Office Of Scientific Research.*

Abstract of *High-performance flexible BiCMOS electronics based on single-crystal Si nanomembrane*

In this work, we have demonstrated for the first time integrated flexible bipolar-complementary metal-oxide-semiconductor (BiCMOS) thin-film transistors (TFTs) based on a transferable single crystalline Si nanomembrane (Si NM) on a single piece of bendable plastic substrate. The n-channel, p-channel metal-oxide semiconductor field-effect transistors (N-MOSFETs & P-MOSFETs), and NPN bipolar junction transistors (BJTs) were realized together on a 340-nm thick Si NM layer with minimized processing complexity at low cost for advanced flexible electronic applications. The fabrication process was simplified by thoughtfully arranging the sequence of necessary ion implantation steps with carefully selected energies, doses and anneal conditions, and by wisely combining some costly processing steps that are otherwise separately needed for all three types of transistors. All types of TFTs demonstrated excellent DC and radio-frequency (RF) characteristics and exhibited stable transconductance and current gain under bending conditions. Overall, Si NM-based flexible BiCMOS TFTs offer great promises for high-performance and multi-functional future flexible electronics applications and is expected to provide a much larger and more versatile platform to address a broader range of applications. Moreover, the flexible BiCMOS process proposed and demonstrated here is compatible with commercial microfabrication technology, making its adaptation to future commercial use straightforward.

references:

Jung-Hun Seo, Kan Zhang, Munho Kim, Weidong Zhou & Zhenqiang Ma. High-performance flexible BiCMOS electronics based on single-crystal Si nanomembrane. npj Flexible Electronics 1, Article number: 1 (2017); doi:10.1038/s41528-017-0001-1 (open access)

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October 8, 2017
by Alfred Schickentanz

These Transistors will be easily implantable without being noticed by the wearer and thereby allow for remote mind control. The concept of "free will" becomes less real all the time. I can see an "organic society" connected to a global brain. Something like we already have with the "global economy".

log in to reply

October 8, 2017
by Editor

All current electronic devices containing micro/nanoscale electronics are vulnerable to some level of surveillance by covert algorithms/systems and could be triggered/modified/destroyed by covert or overt signals (ultrasound, infrasound, light, coded radio waves, etc.) executed by external white/black-hat operations (and for all body and societal functions, not just thoughts).

The gatekeepers/controllers today are well-funded corporations and

Science News from research organizations

Flexible new platform for high-performance electronics

Date: September 28, 2017
Source: University of Wisconsin-Madison

Summary: A team of engineers has created the most functional flexible transistor in the world -- and with it, a fast, simple and inexpensive fabrication process that's easily scalable to the commercial level. It's an advance that could open the door to an increasingly interconnected world, enabling manufacturers to add 'smart,' wireless capabilities to any number of large or small products or objects -- like wearable sensors and computers for people and animals -- that curve, bend, stretch and move.

FULL STORY

A team of University of Wisconsin-Madison engineers has created the most functional flexible transistor in the world -- and with it, a fast, simple and inexpensive fabrication process that's easily scalable to the commercial level.

It's an advance that could open the door to an increasingly interconnected world, enabling manufacturers to add "smart," wireless capabilities to any number of large or small products or objects -- like wearable sensors and computers for people and animals -- that curve, bend, stretch and move.

Transistors are ubiquitous building blocks of modern electronics. The UW-Madison group's advance is a twist on a two-decade-old industry standard: a BiCMOS (bipolar complementary metal oxide semiconductor) thin-film transistor, which combines two very different technologies -- and speed, high current and low power dissipation in the form of heat and wasted energy -- all on one surface.

As a result, these "mixed-signal" devices (with both analog and digital capabilities) deliver both brains and brawn and are the chip of choice for many of today's portable electronic devices, including cellphones.

"The industry standard is very good," says Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW-Madison. "Now we can do the same things with our transistor -- but it can bend."

Ma is a world leader in high-frequency flexible electronics. He and his collaborators described their advance in the inaugural issue of the journal Flexible Electronics, published Sept. 27.

Making traditional BiCMOS flexible electronics is difficult, in part because the process takes several months and requires a multitude of delicate, high-temperature steps. Even a minor variation in temperature at any point could ruin all of the previous steps.

Ma and his collaborators fabricated their flexible electronics on a single-crystal silicon nanomembrane on a single bendable piece of plastic. The secret to their success is their unique process, which eliminates many steps and slashes both the time and cost of fabricating the transistors.

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Story Source:

Materials provided by University of W isconsin-Madison . Original written by Renee Meiller. Note: Content may be edited for style and length.

Cite This Page : MLA APA Chicago

University of Wisconsin-Madison. "Flexible new platform for high-performance electronics." ScienceDaily. ScienceDaily, 28 September 2017. <www.sciencedaily.com/releases/2017/09/170928142110.htm>.

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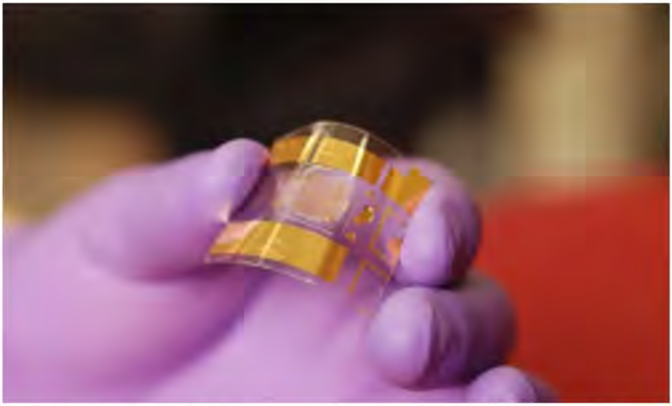
Team builds flexible new platform for high-performance electronics

September 28, 2017 by Renee Meiler, University of Wisconsin-Madison



Literal flexibility may bring the power of a new transistor developed at UW-Madison to digital devices that bend and move. Credit: Jung-Hun Seo, University at Buffalo, State University of New York

A team of University of Wisconsin-Madison engineers has created the most functional flexible transistor in the world—and with it, a fast, simple and inexpensive fabrication process that's easily scalable to the commercial level.

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PUBLIC RELEASE: 28-SEP-2017

A flexible new platform for high-performance electronics

UNIVERSITY OF WISCONSIN-MADISON

MADISON, Wis. -- A team of University of Wisconsin-Madison engineers has created the most functional flexible transistor in the world -- and with it, a fast, simple and inexpensive fabrication process that's easily scalable to the commercial level.

IMAGE: LITERAL FLEXIBILITY MAY BRING THE POWER OF A NEW TRANSISTOR DEVELOPED AT UW-MADISON TO DIGITAL DEVICES THAT BEND AND MOVE. view more >

CREDIT: PHOTO COURTESY OF JUNG-HUN SEO, UNIVERSITY AT BUFFALO, STATE UNIVERSITY OF NEW YORK

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"The industry standard is very good," says Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW-Madison. "Now we can do the same things with our transistor -- but it can bend."

Ma is a world leader in high-frequency flexible electronics. He and his collaborators described their advance in the inaugural issue of the journal *Flexible Electronics*, published Sept. 27.

Making traditional BiCMOS flexible electronics is difficult, in part because the process takes several months and requires a multitude of delicate, high-temperature steps. Even a minor variation in temperature at any point could ruin all of the previous steps.

Ma and his collaborators fabricated their flexible electronics on a single-crystal silicon nanomembrane on a single bendable piece of plastic. The secret to their success is their unique process, which eliminates many steps and slashes both the time and cost of fabricating the transistors.

"In industry, they need to finish these in three months," he says. "We finished it in a week."

He says his group's much simpler high-temperature process can scale to industry-level production right away.

"The key is that parameters are important," he says. "One high-temperature step fixes everything -- like glue. Now, we have more powerful mixed-signal tools. Basically, the idea is for flexible electronics to expand with this. The platform is getting bigger."

###

Media Contact

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More on this News Release

A flexible new platform for high-performance electronics
UNIVERSITY OF WISCONSIN-MADISON

JOURNAL
Nature Flexible Electronics

KEYWORDS

COMPUTER SCIENCE · HARDWARE · INFORMATION MANAGEMENT/TRACKING SYSTEMS · MATERIALS · TECHNOLOGY TRANSFER · TECHNOLOGY/ENGINEERING/COMPUTER SCIENCE

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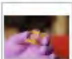


Flexible Transistor (IMAGE)

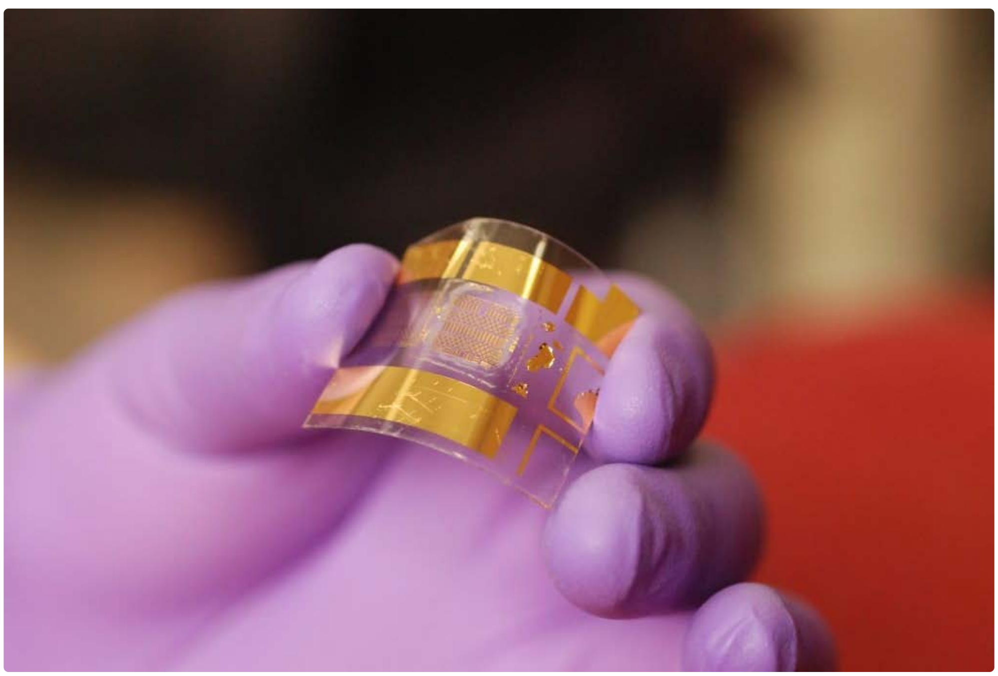
ORIGINAL SOURCE

http://news.wisc.edu/team-builds-flexible-new-platform-for-high-performance-electronics/

Team builds flexible new platform for high-performance electronics

A team of University of Wisconsin–Madison engineers has created the mos functional fexible transisor in the world — andwith it, a fas, simple and inexpensive fabrication process that's easily scalable to the commercial level.

It's an advance that could open the door to an increasingly interconnected world, enabling manufacturers to add "smart,"wireless capabilities to any number of large or small products or objects — like wearable sensors and computers for people and animals — that curve, bend, sretch and move.



Literalfexibility may bring the power of a new transisor developed at UW–Madison to digital devices that bend and move. PHOTO COURTESY OF JUNG-HUN SEO, UNIVERSITY AT BUFFALO, STATE UNIVERSITY OF NEW YORK

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His collaborators include Jung-Hun Seo of the University at Bufalo, State University of New York; Kan Zhang of UW–Madison; and WeidongZhou of the University of Texas at Arlington.

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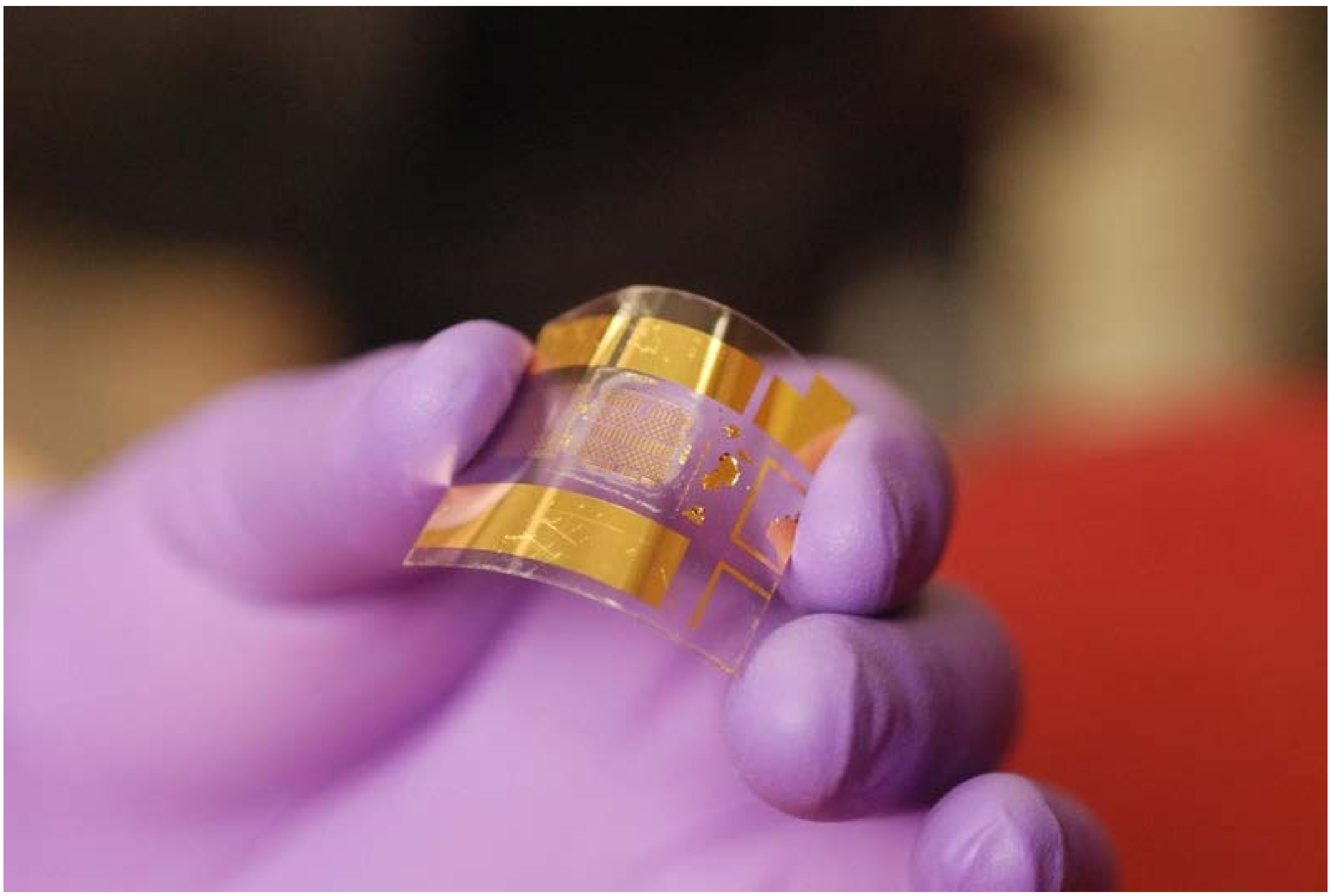
Posted on October 02, 2017

A flexible new platform for high-performance electronics



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Source and top image: University of Wisconsin-Madison

Learn more at the next leading event on the topic: Printed Electronics USA 2017 on 15 - 16 Nov 2017 in Santa Clara Convention Center, CA, USA hosted by IDTechEx.

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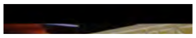

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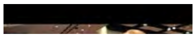

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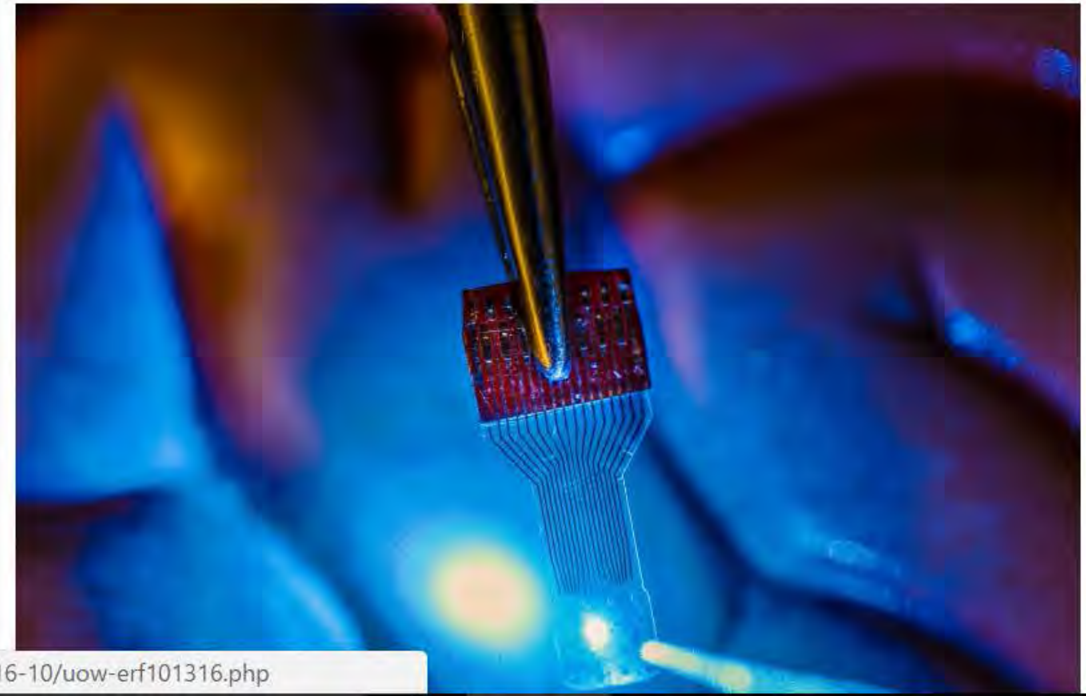

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Engineers reveal fabrication process for revolutionary transparent sensors

UNIVERSITY OF WISCONSIN-MADISON

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Science News from research organizations

Engineers reveal fabrication process for revolutionary transparent sensors

Date: October 13, 2016
Source: University of Wisconsin-Madison

Summary: Researchers have described in great detail how to fabricate and use transparent graphene neural electrode arrays in applications in electrophysiology, fluorescent microscopy, optical coherence tomography, and optogenetics.

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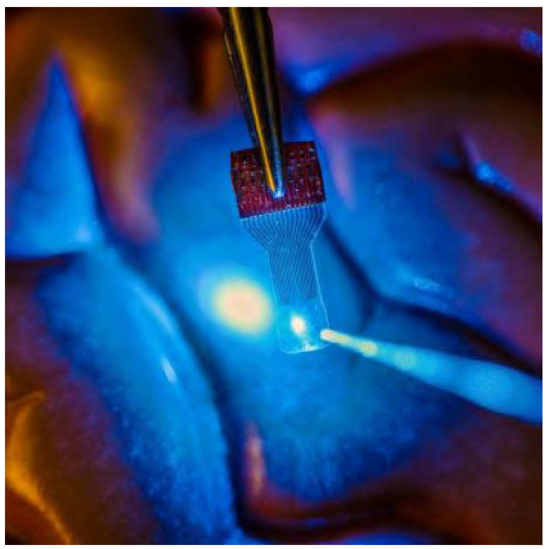
FULL STORY



A blue light shines through a clear, implantable medical sensor onto a brain model. See-through sensors, which have been developed by a team of UW–Madison engineers, should help neural researchers better view brain activity.

Credit: Justin Williams research group

when University of Wisconsin-Madison engineers announced in the journal Nature Communications that they had developed transparent sensors for use in imaging the brain, researchers around the world took notice.

Then the requests came flooding in. "So many research groups started asking us for these devices that we couldn't keep up," says Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW-Madison.

Ma's group is a world leader in developing revolutionary flexible electronic devices. The see-through, implantable micro-electrode arrays were light years beyond anything ever created.

Although he and collaborator Justin Williams, the Vilas Distinguished Achievement Professor in biomedical engineering and neurological surgery at UW-Madison, patented the technology through the Wisconsin Alumni Research Foundation, they saw its potential for advancements in research. "That little step has already resulted in an explosion of research in this field," says Williams. "We didn't want to keep this technology in our lab. We wanted to share it and expand the boundaries of its applications."

As a result, in a paper published in the journal Nature Protocols, the researchers have described in great detail how to fabricate and use transparent graphene neural electrode arrays in applications in electrophysiology, fluorescent microscopy, optical coherence tomography, and optogenetics. "We described how to do these things so we can start working on the next generation," says Ma.

Now, not only are the UW-Madison researchers looking at ways to improve and build upon the technology, they also are seeking to expand its applications from neuroscience into areas such as research of stroke, epilepsy, Parkinson's disease, cardiac conditions, and many others. And they hope other researchers do the same.

"This paper is a gateway for other groups to explore the huge potential from here," says Ma. "Our technology demonstrates one of the key in vivo applications of graphene. We expect more revolutionary research will follow in this interdisciplinary field."

Story Source:

Materials provided by University of Wisconsin-Madison. Original written by Renee Meiller. Note: Content may be edited for style and length.

Journal Reference:

1. Dong-Wook Park, Sarah K Brodnick, Jared P Ness, Farid Atry, Lisa Krugner-Higby, Amelia Sandberg, Solomon Mikael, Thomas J Richner, Joseph Novello, Hyungsoo Kim, Dong-Hyun Baek, Jihye Bong, Seth T Frye, Sanitta Thongpang, Kyle I Swanson, Wendell Lake, Ramin Pashaie, Justin C Williams, Zhenqiang Ma. Fabrication and utility of a transparent graphene neural electrode array for electrophysiology, in vivo imaging, and optogenetics. Nature Protocols, 2016; 11 (11): 2201 DOI: 10.1038/nprot.2016.127

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University of Wisconsin-Madison. "Engineers reveal fabrication process for revolutionary transparent sensors." ScienceDaily. ScienceDaily, 13 October 2016. <www.sciencedaily.com/releases/2016/10/161013220643.htm>.

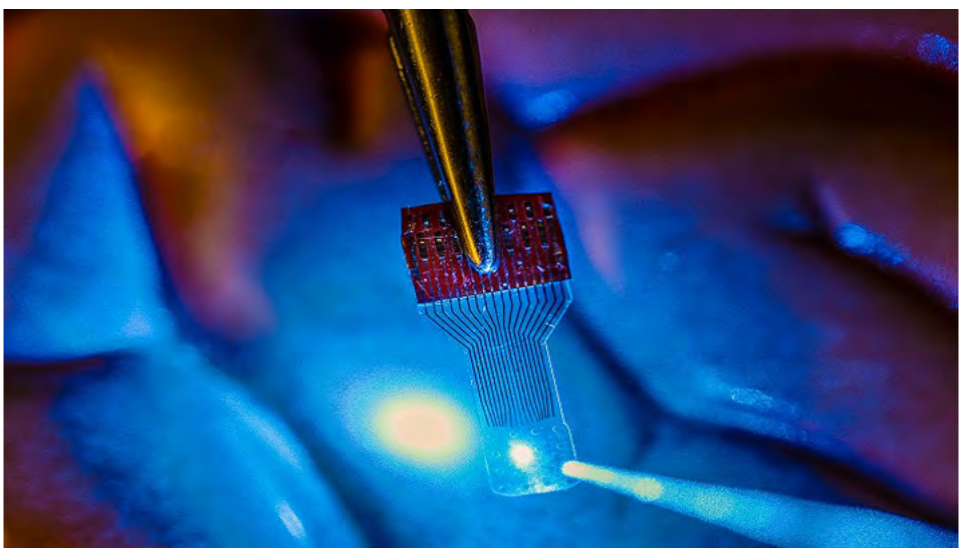
Medical Devices and Healthcare IT

Researchers Reveal How to Make Transparent Sensors

14 October 2016

Two years ago a team of engineers from the University of Wisconsin-Madison engineers announced it had developed transparent sensors that could be used in brain imaging.

At the time, Zhenqiang (Jack) Ma and collaborator Justin Williams received a plethora of requests from research groups asking for more information on the devices.



A blue light shines through a clear, implantable medical sensor onto a brain model. See-through sensors, which have been developed by a team of UW-Madison engineers, should help neural researchers better view brain activity. (Image Credit: Justin Williams)

The duo patented the technology through the Wisconsin Alumni Research Foundation, and saw the growing interest as an advancement in research.

"That little step has already resulted in an explosion of research in this field," said Williams, the Vilas Distinguished Achievement Professor in biomedical engineering and neurological surgery at UW-Madison, . "We didn't want to keep this technology in our lab. We wanted to share it and expand the boundaries of its applications."

That's what prompted the recent paper published this week in the journal Nature Protocols. Here the researchers describe in great detail how to fabricate and use transparent graphene neural electrode arrays in applications in electrophysiology, fluorescent microscopy, optical coherence tomography, and optogenetics.

"We described how to do these things so we can start working on the next generation," said Ma, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW-Madison

CALENDAR OF EVENTS

Date	Event	Location
21-23 Apr 2017	E-Fest East	Tennessee Tech University, Cookeville, TN
30 May-	IEEE Electronic	Lake Buena ..., Florida

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Now, the UW-Madison researchers are looking at ways to improve and build upon the technology, as \ expand its applications from neuroscience into areas such as research of stroke, epilepsy, Parkinson's disease, cardiac conditions, and many others.

With the release of the work, they are encouraging other research groups to do the same.

"This paper is a gateway for other groups to explore the huge potential from here," said Ma. "Our tech demonstrates one of the key in vivo applications of graphene. We expect more revolutionary research follow in this interdisciplinary field."

An excerpt from the paper:

"Transparent neural electrode arrays with ultraflexibility and biocompatibility have the potential to prov optimal platform for various applications, including optogenetics and neural imaging. Neural electrode with broad-wavelength transparency from the UV to the IR spectra are especially desirable, and they | unique opportunities to advance techniques that would otherwise be impeded or impossible with conv opaque metal electrodes. Transparent neural electrodes allow simultaneous observation of cells imme beneath electrode sites during optical or electrical stimulation. Graphene, a novel 2D carbon-based m one of the most promising candidates for transparent neural electrodes, because the material has a UV to IR transparency of over 90%, in addition to its high electrical and thermal conductivity, flexibility, and biocompatibility. Here we present a protocol for the fabrication of the transparent graphene neural electrode array and its operation for electrophysiology, fluorescence microscopy, OCT, and optogenetics. The fabrication methods and the surgical protocols described herein are based on the graphene μECoG electrode array, which can be implanted on the surface of the cerebral cortex. However, this protocol may be amenable to fabrication and testing of a multitude of other electrode arrays used in biological research, such as penetrating neural electrode arrays to study deep brain, nerve cuffs that are used to interface with the peripheral nervous system (PNS), or devices that interface with the muscular system."

To contact the author of this article, email Nicolette.Emmino@ieeeglobalspec.com

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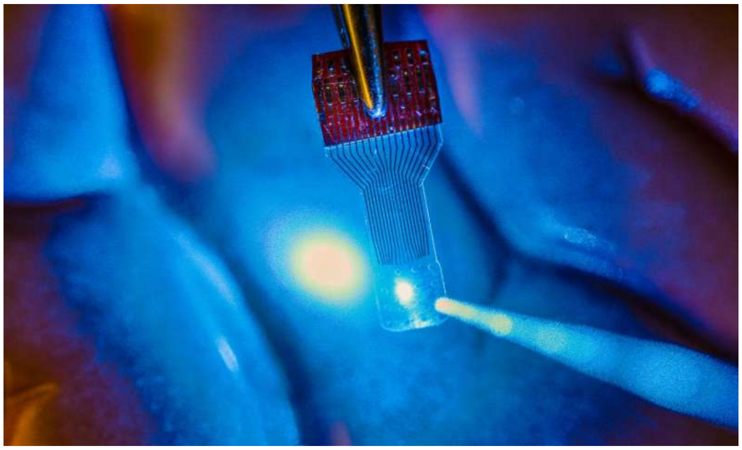
Engineers reveal fabrication process for revolutionary transparent sensors

October 13, 2016 by Renee Meiller



A blue light shines through a clear, implantable medical sensor onto a brain model. See-through sensors, which have been developed by a team of UW-Madison engineers, should help neural researchers better view brain activity. Credit: Justin Williams research group

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As a result, in a paper published Thursday (Oct. 13, 2016) in the journal Nature Protocols, the researchers have described in great detail how to fabricate and use transparent graphene neural electrode arrays in applications in electrophysiology, fluorescent microscopy, optical coherence tomography, and optogenetics. "We described how to do these things so we can start working on the next generation," says Ma.

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Explore further: See-through sensors open new window into the brain

More information: Dong-Wook Park et al, Fabrication and utility of a transparent graphene neural electrode array for electrophysiology, in vivo imaging, and optogenetics, Nature Protocols (2016). DOI: 10.1038/nprot.2016.127

Dong-Wook Park et al. Graphene-based carbon-layered electrode array technology for neural imaging and optogenetic applications, Nature Communications (2014). DOI: 10.1038/ncomms6258

Journal reference: Nature Communications Nature Protocols

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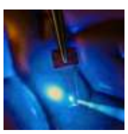

See-through sensors open new window into the brain
October 21, 2014

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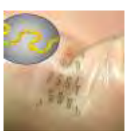

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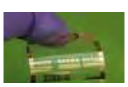

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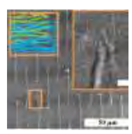

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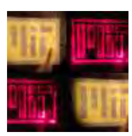
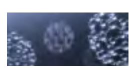


Graphene 'copy machine' may produce cheap semiconductor wafers
April 19, 2017

In 2016, annual global semiconductor sales reached their highest-ever point, at $339 billion worldwide. In that same year, the semiconductor industry spent about $7.2 billion worldwide on wafers that serve as the substrates ...



Nanoparticles remain unpredictable
April 19, 2017

The way that nanoparticles behave in the environment is extremely complex.

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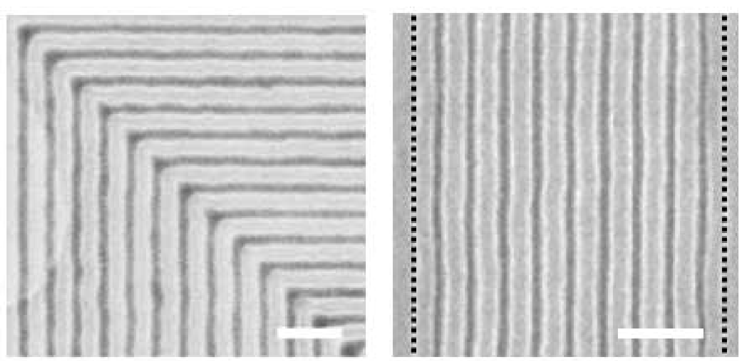
Posted: Sep 09, 2016

New computer chip manufacturing method with graphene squeezes more onto limited wafer space

(Nanowerk News) Computer chip makers con. nuously strive to pack more transistors in less space, yet as the size of those transistors approaches the atomic scale, there are physical limits on how small they are able to make the pa erns for the circuitry.

Now, taking advantage of a germanium wafer coated with a layer of virtually pris ne graphene — a sheet of carbon arranged just one atom thick — a team of engineers from the University of Wisconsin–Madison and the University of Chicago has devised a simpler, reproducible and less expensive manufacturing approach using directed self-assembly.



Scanning electron micrographs of block copolymer films assembled on graphene/germanium chemical pa erns with 90 degree bends (le side) and with density mul plica on by a factor of 10 (right side). The black do ed lines (right side) indicate the period of the graphene/germanium chemical pa ern, in which the period of the assembled block copolymer is reduced by a factor of 10 due to density mul plica on. The scale bars are 200 nm.

Directed self-assembly is a large-scale, nano-pa erning technique that can increase the density of circuit pa erns and circumvent some limita ons of conven onal lithographic processes for prin ng circuits on wafers of semiconductors such as silicon.

Electrical engineer Zhenqiang "Jack" Ma and materials engineer Michael Arnold of UW–Madison, chemical engineer Paul Nealey of the University of Chicago, and their students published details of the advance in the Aug. 16 edi on of the journal Scien fic Reports ("Directed self-assembly of block copolymer films on atomically-thin graphene chemical pa erns").

Their work could mean a boost in func onality for semiconductor electronics and in capacity for data storage.

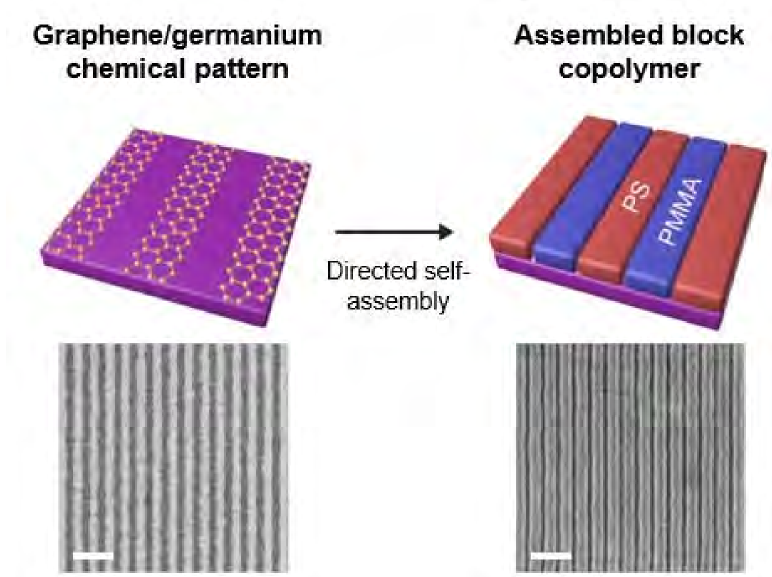
To achieve the incredibly ny size required for the circuitry in future semiconductor electronics, manufacturers are developing directed self-assembly, which enables the fabrica on of intricate, perfectly ordered polymer pa erns for circuitry.

For directed self-assembly, the researchers use conven onal chemical techniques to define a pre-pa ern. When chains of molecules known as block copolymers self-assemble on the pre-pa ern, they follow the pa ern to form well-ordered features.

The researchers' new method is much faster, and reduces the number of steps in the process to just two: lithography and plasma etching.

In the first demonstra on of their technique, the researchers used electron beam lithography and a mild plasma etching technique to pa ern one-atom-thick graphene stripes on a germanium wafer. Then they spin-coated the wafer with a common block copolymer called polystyrene-block-poly(methyl methacrylate).

When heated, the block copolymer self-assembled completely in just 10 minutes — compared to 30 minutes using conven onal chemical pa erns — and with fewer defects. The researchers a ribute this rapid assembly to the smooth, rigid, crystalline surfaces of germanium and graphene.



Chemical pa erns consis ng of alterna ng graphene and germanium stripes (le side) are used to direct the self-assembly of block copolymers into well-ordered pa erns (right side). The top images are schema cs and the bo om images are scanning electron micrographs. The scale bars are 200 nm.

Their new method takes advantage of a phenomenon called density mul plica on. The researchers used electron beam lithography to first create a larger master template with sparse pa erns that guide the orienta on of their block copolymers.

When they directed the block copolymer to self-assemble, it did so in a way that enhanced the resolu on of the original template — in this case, by a factor of 10. The best previous enhancement by density mul plica on was a factor of four.

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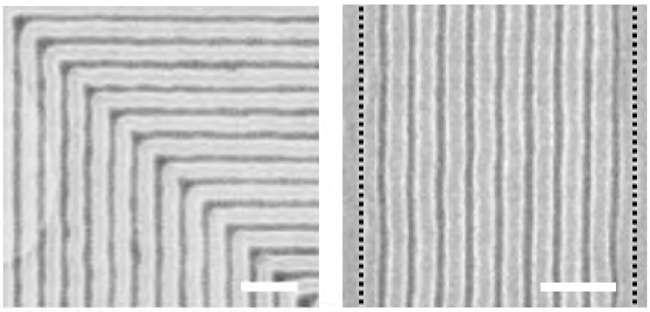
The technique enables them to combine the uniformity and simpler processing of tradi onal “top-down” lithographic methods with the advantages of “bo om-up” assembly and greater density mul plica on, and offers a promising route for large-scale produc on at significantly reduced cost.

“Using this one-atom-thick graphene template has never been done before. It’s a new template to guide the self-assembly of the polymers,” says Ma. “This is mass-produc on-compa ble. We opened the door to even smaller features.”

Source: By Renee Meiller, University of Wisconsin–Madison

New computer chip manufacturing method squeezes more onto limited wafer space

9 September 2016, by Renee Meiller



Scanning electron micrographs of block copolymer films assembled on graphene/germanium chemical patterns with 90 degree bends (left side) and with density multiplication by a factor of 10 (right side). The black dotted lines (right side) indicate the period of the graphene/germanium chemical pattern, in which the period of the assembled block copolymer is reduced by a factor of 10 due to density multiplication. The scale bars are 200 nm. Credit: University of Wisconsin-Madison

Computer chip makers continuously strive to pack more transistors in less space, yet as the size of those transistors approaches the atomic scale, there are physical limits on how small they are able to make the patterns for the circuitry.

Now, taking advantage of a germanium wafer coated with a layer of virtually pristine graphene—a sheet of carbon arranged just one atom thick—a team of engineers from the University of Wisconsin–Madison and the University of Chicago has devised a simpler, reproducible and less expensive manufacturing approach using directed self-assembly.

Directed self-assembly is a large-scale, nano-patterning technique that can increase the density of circuit patterns and circumvent some limitations of conventional lithographic processes for printing circuits on wafers of semiconductors such as silicon.

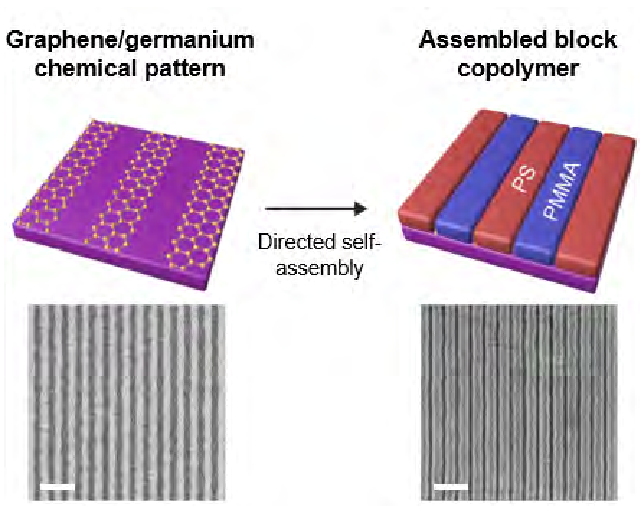
Electrical engineer Zhenqiang "Jack" Ma and materials engineer Michael Arnold of UW–Madison, chemical engineer Paul Nealey of the University of Chicago, and their students published details of the advance in the Aug. 16 edition of the journal *Scientific Reports*.

Their work could mean a boost in functionality for semiconductor electronics and in capacity for data storage.

To achieve the incredibly tiny size required for the circuitry in future semiconductor electronics, manufacturers are developing directed self-assembly, which enables the fabrication of intricate, perfectly ordered polymer patterns for circuitry.

For directed self-assembly, the researchers use conventional chemical techniques to define a pre-pattern. When chains of molecules known as block copolymers self-assemble on the pre-pattern, they follow the pattern to form well-ordered features.

The researchers' new method is much faster, and reduces the number of steps in the process to just two: lithography and plasma etching.



Chemical patterns consisting of alternating graphene and germanium stripes (left side) are used to direct the self-assembly of block copolymers into well-ordered patterns (right side). The top images are schematics and the bottom images are scanning electron micrographs. The scale bars are 200 nm. Credit: University of Wisconsin-Madison

In the first demonstration of their technique, the researchers used electron beam lithography and a mild plasma etching technique to pattern one-atom-thick graphene stripes on a germanium wafer. Then they spin-coated the wafer with a common block copolymer called polystyrene-block-poly(methyl methacrylate).

When heated, the block copolymer self-assembled completely in just 10 minutes—compared to 30 minutes using conventional chemical patterns—and with fewer defects. The researchers attribute this rapid assembly to the smooth, rigid, crystalline surfaces of germanium and graphene.

Their new method takes advantage of a phenomenon called density multiplication. The researchers used electron beam lithography to first create a larger master template with sparse patterns that guide the orientation of their block copolymers.

When they directed the block copolymer to self-assemble, it did so in a way that enhanced the resolution of the original template—in this case, by a factor of 10. The best previous enhancement by density multiplication was a factor of four.

While the stripe pattern was a simple demonstration of their technique, the researchers also showed it works with more architecturally complex or irregular patterns, including those with abrupt 90-degree bends.

"These templates offer an exciting alternative to traditional chemical patterns composed of polymer mats and brushes, as they provide faster assembly kinetics and broaden the processing window, while also offering an inert, mechanically and chemically robust, and uniform template with well defined and sharp material interfaces," says Nealey.

The technique enables them to combine the uniformity and simpler processing of traditional "top-down" lithographic methods with the advantages of "bottom-up" assembly and greater density multiplication, and offers a promising route for large-scale production at significantly reduced cost.

"Using this one-atom-thick graphene template has never been done before. It's a new template to guide the self-assembly of the polymers," says Ma. "This is mass-production-compatible. We opened the door to even smaller features."

Provided by University of Wisconsin-Madison

Consumer Electronics

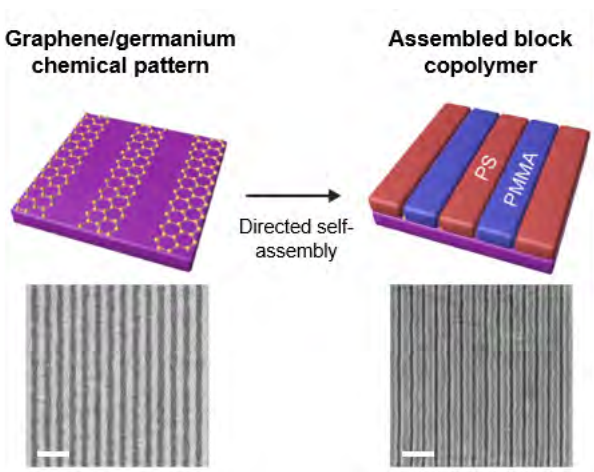
Chip-Making Process Packs More onto Wafer Space

Chuck Heschmeyer

15 September 2016

Computer chip makers constantly strive to pack more transistors into less space, but the barrier is always the size of the wafer itself and the physical limitations of the transistors.

Now, taking advantage of a germanium wafer coated with a layer of graphene, a team of engineers from the University of Wisconsin–Madison and the University of Chicago has devised a simpler, reproducible and less expensive manufacturing approach using directed self-assembly.



Chemical patterns consisting of alternating graphene and germanium stripes (left side) are used to direct the self-assembly of block co-polymers into well-ordered patterns (right side). The top images are schematics, and the bottom images are scanning electron micrographs. The scale bars are 200 nm. Source: University of Wisconsin-Madison

Directed self-assembly is a large-scale, nano-patterning technique that can increase the density of circuit patterns and circumvent some limitations of conventional lithographic processes for printing circuits on wafers of semiconductors such as silicon. The technique, which enables the fabrication of intricate, precisely ordered polymer patterns for circuitry, is being adopted and developed by electronics manufacturers to address the ever-smaller requirements of future devices.

The researchers' new method is fast and requires only two steps: lithography and plasma etching.

As explained by researchers, in the first demonstration of their technique, they used electron beam lithography and a mild plasma etching technique to pattern one-atom-thick graphene stripes on a germanium wafer. Then they spin-coated the wafer with a common block co-polymer called polystyrene-block-poly(methyl methacrylate).

When heated, the block co-polymer completely self-assembled in just 10 minutes compared to 30 minutes using conventional chemical patterns, and had fewer defects. The researchers attribute this rapid assembly to the smooth, rigid and crystalline surfaces of germanium and graphene.

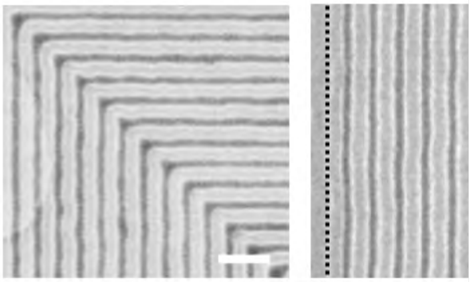
While the stripe pattern was a simple demonstration of the technique, researchers also showed it works with more architecturally complex or irregular patterns, including those with 90° bends.

"These templates offer an exciting alternative to traditional chemical patterns composed of polymer mats and brushes, as they provide faster assembly kinetics and broaden the processing window, while also offering an inert, mechanically and chemically robust, and uniform template with well-defined and sharp material interfaces," said Paul Nealey, a University of Chicago chemical engineer.

Their technique combines the uniformity and simpler processing of traditional "top-down" lithographic methods with the advantages of "bottom-up" assembly and greater density multiplication, and offers a promising route for large-scale production at significantly reduced cost, the researchers said.

CALENDAR OF EVENTS

Date	Event	Location
02-06 Oct 2016	The IEEE Photonics Conference 2016 (IPC-2016)	Waikoloa, HI, USA
15-16 Nov 2016	Minds + Machines	San Francisco, CA USA



Scanning electron micrographs of block co-polymer films as graphene/germanium chemical patterns with 90° bends (left side) multiplication by a factor of 10 (right side). The black dotted lin indicate the period of the graphene/germanium chemical pattern period of the assembled block co-polymer is reduced by a facto density multiplication. The scale bars are 200 nm. Source: Univers Madison

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Thomas2156 Sep 16, 2016

I wish this article had more detail. What kind of plasma etching are they performing, all they indicate is "mild" plasma etch. I would like to know if I could experiment with this in an isotropic plasma etcher, or if it require the directional nature of reactive ion etching as most other etching applications similar to this require. I have a pretty standard, small etcher from PlasmaEtch. Does anyone know if this will work, for experimental purposes only?

Here is a link to my etcher: Plasmaetch PE-50

Thanks!

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New computer chip manufacturing method squeezes more onto limited wafer space

Posted September 8, 2016

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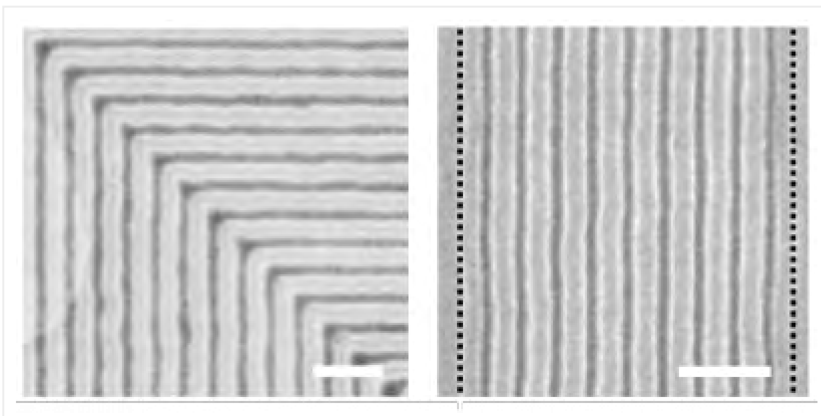

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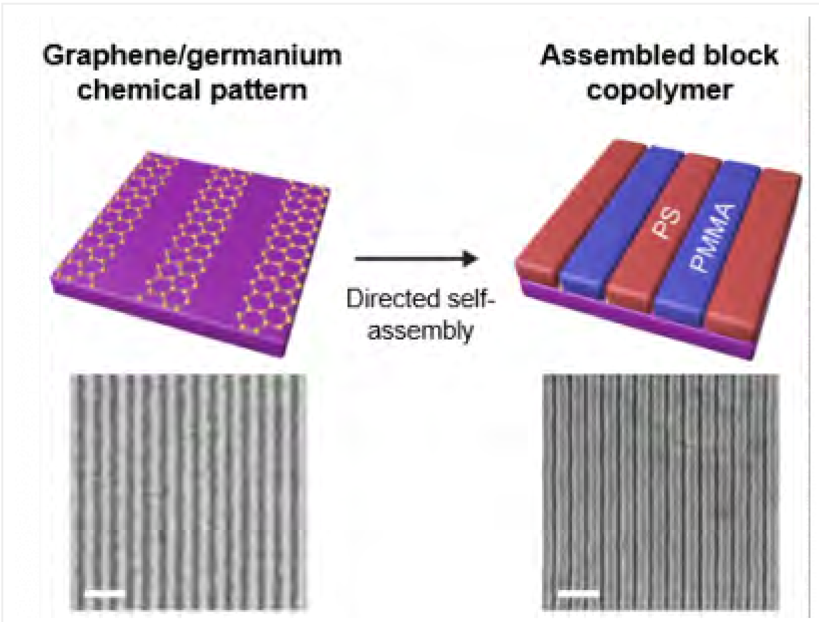

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The researchers are patenting their method through the Wisconsin Alumni Research Foundation. Funding from the U.S. departments of Energy and Defense, UW–Madison and the University of Chicago supported their work.

Other authors on the paper include Tzu-Hsuan Chang, Robert M. Jacobberger, Solomon Mikael, Dalong Geng and Xudong Wang of UW–Madison, and Shisheng Xiong, Hyo Seon Suh and Chi-Chun Liu of the University of Chicago.

Source: University of Wisconsin-Madison

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PUBLIC RELEASE: 24-MAY-2016

Diamonds closer to becoming ideal semiconductors

Researchers find new method for doping single crystals of diamond

AMERICAN INSTITUTE OF PHYSICS

WASHINGTON, D.C, May 24, 2016 - Along with being a "girl's best friend," diamonds also have remarkable properties that could make them ideal semiconductors. This is welcome news for electronics; semiconductors are needed to meet the rising demand for more efficient electronics that deliver and convert power.

The thirst for electronics is unlikely to cease and almost every appliance or device requires a suite of electronics that transfer, convert and control power. Now, researchers have taken an important step toward that technology with a new way to dope single crystals of diamonds, a crucial process for building electronic devices.

"We need the devices to manipulate the power in the way that we want," said Zhengqiang (Jack) Ma, an electrical and computer engineering professor at the University of Wisconsin-Madison. He and his colleagues describe their new method in the *Journal of Applied Physics*, from AIP Publishing.

For power electronics, diamonds could serve as the perfect material. They are thermally conductive, which means diamond-based devices would dissipate heat quickly and easily, foregoing the need for bulky and expensive methods for cooling. Diamond can also handle high voltages and power. Electrical currents also flow through diamonds quickly, meaning the material would make for energy efficient devices.

But among the biggest challenges to making diamond-based devices is doping, a process in which other elements are integrated into the semiconductor to change its properties. Because of diamond's rigid crystalline structure, doping is difficult.

Currently, you can dope diamond by coating the crystal with boron and heating it to 1450 degrees Celsius. But it's difficult to remove the boron coating at the end. This method only works on diamonds consisting of multiple crystals stuck together. Because such polydiamonds have irregularities between the crystals, single-crystals would be superior semiconductors.

You can dope single crystals by injecting boron atoms while growing the crystals artificially. The problem is the process requires powerful microwaves that can degrade the quality of the crystal.

Now, Ma and his colleagues have found a way to dope single-crystal diamonds with boron at relatively low temperatures and without any degradation. The researchers discovered if you bond a single-crystal diamond with a piece of silicon doped with boron, and heat it to 800 degrees Celsius, which is low compared to the conventional techniques, the boron atoms will migrate from the silicon to the diamond. It turns out that the boron-doped silicon has defects such as vacancies, where an atom is missing in the lattice structure. Carbon atoms from the diamond will fill those vacancies, leaving empty spots for boron atoms.

This technique also allows for selective doping, which means more control when making devices. You can choose where to dope a single-crystal diamond simply by bonding the silicon to that spot.

The new method only works for P-type doping, where the semiconductor is doped with an element that provides positive charge carriers (in this case, the absence of electrons, called holes).

"We feel like we found a very easy, inexpensive, and effective way to do it," Ma said. The researchers are already working on a simple device using P-type single-crystal diamond semiconductors.

But to make electronic devices like transistors, you need N-type doping that gives the semiconductor negative charge carriers (electrons). And other barriers remain. Diamond is expensive and single crystals are very small.

Still, Ma says, achieving P-type doping is an important step, and might inspire others to find solutions for the remaining challenges. Eventually, he said, single-crystal diamond could be useful everywhere -- perfect, for instance, for delivering power through the grid.

###

The article, "Thermal diffusion boron doping of single-crystal natural diamond," is authored by Jung-Hun Seo, Henry Wu, Solomon Mikael, Hongyi Mi, James P. Blanchard, Giri Venkataramanan, Weidong Zhou, Shaoqin Gong, Dane Morgan and Zhenqiang Ma. The article will appear in the *Journal of Applied Physics* on May 24, 2016 [DOI:10.1063/1.4949327]. After that date, it can be accessed at: http://scitation.aip.org/content/aip/journal/jap/119/20/10.1063/1.4949327.

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PUBLIC RELEASE: 27-MAY-2016

Fast, stretchy circuits could yield new wave of wearable electronics

UNIVERSITY OF WISCONSIN-MADISON

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More on this News Release

Fast, stretchy circuits could yield new wave of wearable electronics
UNIVERSITY OF WISCONSIN-MADISON

JOURNAL
Advanced Functional Materials

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Science News *from research organizations*

Fast, stretchy circuits could yield new wave of wearable electronics

Date: May 27, 2016

Source: University of Wisconsin-Madison

Summary: A team of engineers has created the world's fastest stretchable, wearable integrated circuits, an advance that could drive the Internet of Things and a much more connected, high-speed wireless world.

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FULL STORY

Fabricated in interlocking segments like a 3-D puzzle, the new integrated circuits could be used in wearable electronics that adhere to the skin like temporary tattoos. Because the circuits increase wireless speed, these systems could allow health care staff to monitor patients remotely, without the use of cables and cords.

Credit: Image courtesy of Yei Hwan Jung and Juhwan Lee/University of Wisconsin-Madison

The consumer marketplace is flooded with a lively assortment of smart wearable electronics that do everything from monitor vital signs, fitness or sun exposure to play music, charge other electronics or even purify the air around you -- all wirelessly.

Now, a team of University of Wisconsin-Madison engineers has created the world's fastest stretchable, wearable integrated circuits, an advance that could drive the Internet of Things and a much more connected, high-speed wireless world.

Led by Zhenqiang "Jack" Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW-Madison, the researchers published details of these powerful, highly efficient integrated circuits today, May 27, 2016, in the journal *Advanced Functional Materials*.

The advance is a platform for manufacturers seeking to expand the capabilities and applications of wearable electronics -- including those with biomedical applications -- particularly as they strive to develop devices that take advantage of a new generation of wireless broadband technologies referred to as 5G.

With wavelength sizes between a millimeter and a meter, microwave radio frequencies are electromagnetic waves that use frequencies in the .3 gigahertz to 300 gigahertz range. That falls directly in the 5G range.

In mobile communications, the wide microwave radio frequencies of 5G networks will accommodate a growing number of cellphone users and notable increases in data speeds and coverage areas.

In an intensive care unit, epidermal electronic systems (electronics that adhere to the skin like temporary tattoos) could allow health care staff to monitor patients remotely and wirelessly, increasing patient comfort by decreasing the customary tangle of cables and wires.

What makes the new, stretchable integrated circuits so powerful is their unique structure, inspired by twisted-pair telephone cables. They contain, essentially, two ultra-tiny intertwining power transmission lines in repeating S-curves.

This serpentine shape -- formed in two layers with segmented metal blocks, like a 3-D puzzle -- gives the transmission lines the ability to stretch without affecting their performance. It also helps shield the lines from outside interference and, at the same time, confine the electromagnetic waves flowing through them, almost completely eliminating current loss. Currently, the researchers' stretchable integrated circuits can operate at radio frequency levels up to 40 gigahertz.

And, unlike other stretchable transmission lines, whose widths can approach 640 micrometers (or .64 millimeters), the researchers' new stretchable integrated circuits are just 25 micrometers (or .025 millimeters) thick. That's tiny enough to be highly effective in epidermal electronic systems, among many other applications.

Ma's group has been developing what are known as transistor active devices for the past decade. This latest advance marries the researchers' expertise in both high-frequency and flexible electronics.

"We've found a way to integrate high-frequency active transistors into a useful circuit that can be wireless," says Ma, whose work was supported by the Air Force Office of Scientific Research. "This is a platform. This opens the door to lots of new capabilities."

Story Source:

The above post is reprinted from materials provided by **University of Wisconsin-Madison**. The original item was written by Renee Meiller. *Note: Materials may be edited for content and length.*

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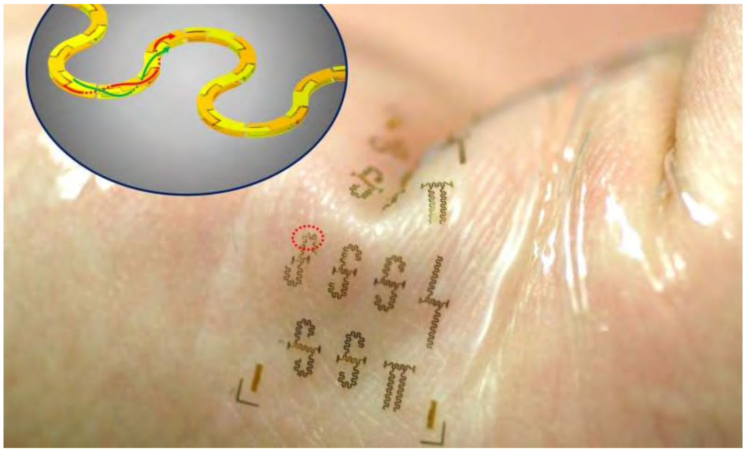
Fast, stretchy circuits could yield new wave of wearable electronics

May 27, 2016



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Explore further: DARPA circuit achieves speeds of 1 trillion cycles per second, earns Guinness world record

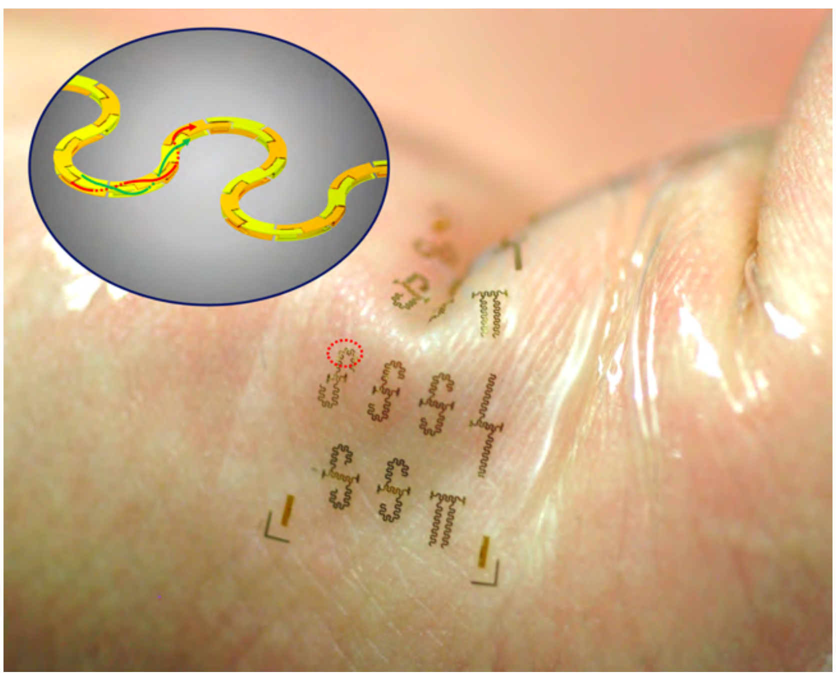
Journal reference: Advanced Functional Materials

Provided by: University of Wisconsin-Madison

SCIENCE & HEALTH

New Wearable Tech Can Make Hospital Visits More Comfortable

CARLI VELOCCI 31 MAY 2016 8:00 PM



In the age of the internet, you can do almost anything wirelessly. This is especially intriguing in the health care field where professionals can monitor the data of patients without having to be in the room.

Image courtesy Yei Hwan Jung and Juhwan Lee/University of Wisconsin — Madison.

A new paper published by a team at the University of Wisconsin-Madison can have huge implications for the medical industry because it will only make the above scenario easier. This is thanks to new advances in wearable integrated circuits that claim to be the fastest, thinnest and stretchiest to date.

According to the university, the circuits are structured with transmission lines in repeating S-curves, which gives the transmission lines more flexibility. "It also helps shield the lines from outside interference" and confines "the electromagnetic waves flowing through them".

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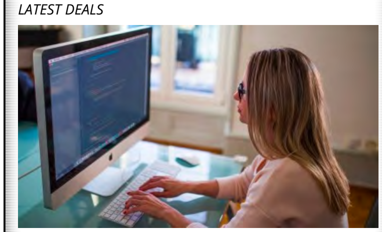

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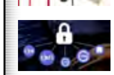

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Fast, Stretchy Circuits Could Yield New Wave of Wearable Electronics

Released: 27-May-2016 4:05 PM EDT

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Citations

Advanced Functional Materials May 27, 2016

Newswise — MADISON, Wis. — The consumer marketplace is flooded with a lively assortment of smart wearable electronics that do everything from monitor vital signs, fitness or sun exposure to play music, charge other electronics or even purify the air around you — all wirelessly.

Now, a team of University of Wisconsin-Madison engineers has created the world's fastest stretchable, wearable integrated circuits, an advance that could drive the Internet of Things and a much more connected, high-speed wireless world.

Led by Zhenqiang “Jack” Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering at UW–Madison, the researchers published details of these powerful, highly efficient integrated circuits today, May 27, 2016, in the journal Advanced Functional Materials.

The advance is a platform for manufacturers seeking to expand the capabilities an including those with biomedical applications — particularly as they strive to develop devices that take advantage of a new generation of wireless broadband technologies referred to as 5G.

With wavelength sizes between a millimeter and a meter, microwave radio frequencies are electromagnetic waves that use frequencies in the .3 gigahertz to 300 gigahertz range. That falls directly in the 5G range.

In mobile communications, the wide microwave radio frequencies of 5G networks will accommodate a growing number of cellphone users and notable increases in data speeds and coverage areas.

In an intensive care unit, epidermal electronic systems (electronics that adhere to the skin like temporary tattoos) could allow health care staff to monitor patients remotely and wirelessly, increasing patient comfort by decreasing the customary tangle of cables and wires.

What makes the new, stretchable integrated circuits so powerful is their unique structure, inspired by twisted-pair telephone cables. They contain, essentially, two ultra-tiny intertwining power transmission lines in repeating S-curves.

This serpentine shape — formed in two layers with segmented metal blocks, like a 3-D puzzle — gives the transmission lines the ability to stretch without affecting their performance. It also helps shield the lines from outside interference and, at the same time, confine the electromagnetic waves flowing through them, almost completely eliminating current loss. Currently, the researchers' stretchable integrated circuits can operate at radio frequency levels up to 40 gigahertz.

And, unlike other stretchable transmission lines, whose widths can approach 640 micrometers (or .64 millimeters), the researchers' new stretchable integrated circuits are just 25 micrometers (or .025 millimeters) thick. That's tiny enough to be highly effective in epidermal electronic systems, among many other applications.

Ma's group has been developing what are known as transistor active devices for the past decade. This latest advance marries the researchers' expertise in both high-frequency and flexible electronics.

“We've found a way to integrate high-frequency active transistors into a useful circuit that can be wireless,” says Ma, whose work was supported by the Air Force Office of Scientific Research. “This is a platform. This opens the door to lots of new capabilities.”

Other authors on the paper include Yei Hwan Jung, Juhwan Lee, Namki Cho, Sang June Cho, Huilong Zhang, Subin Lee, Tong June Kim and Shaoqin Gong of UW–Madison and Yijie Qiu of the University of Electronic Science and Technology of China.

—*Renee Meiller*

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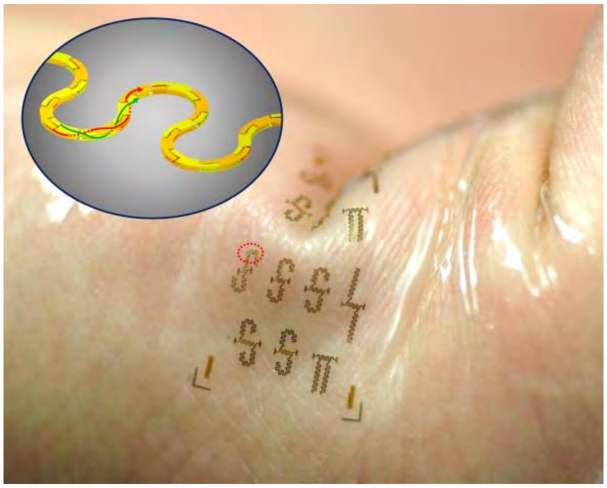
Skin-tight circuits could drive IoT to healthcare

May 30, 2016 // By Jean-Pierre Joosting



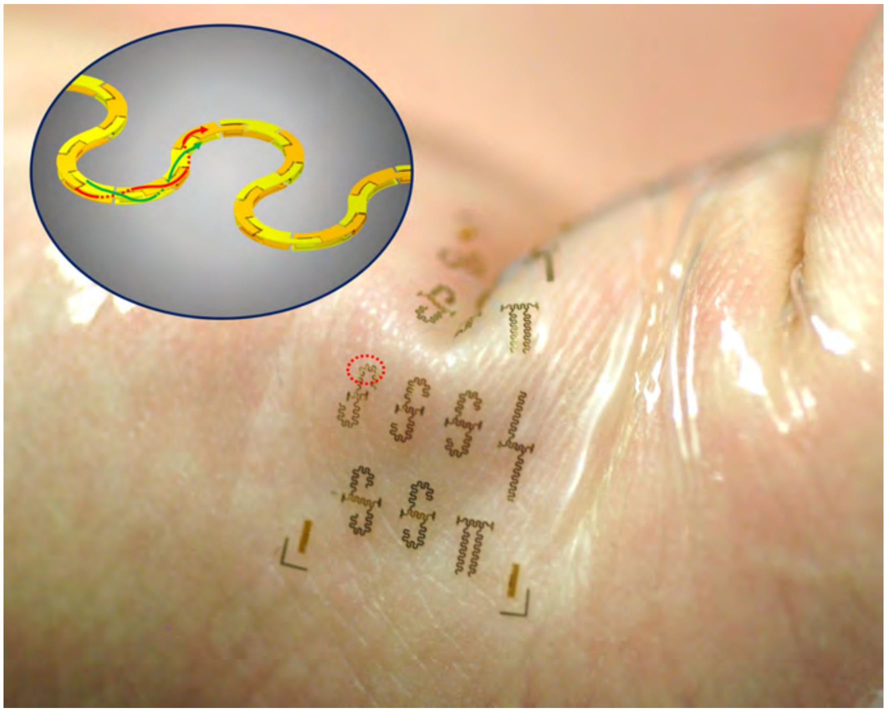
A team of University of Wisconsin-Madison engineers claim to have created the fastest stretchable, wearable integrated circuits, an advance that could drive the Internet of Things and a much more connected, high-speed wireless world.

The engineers have created a platform for manufacturers seeking to expand the capabilities and applications of wearable electronics particularly as they strive to develop devices that take advantage of a new generation of wireless broadband technologies referred to as 5G.

The stretchable integrated circuits feature a unique structure, inspired by twisted-pair telephone cables. They contain, essentially, two ultra-tiny intertwining power transmission lines in repeating S-curves.

This serpentine shape – formed in two layers with segmented metal blocks, like a 3-D puzzle – gives the transmission lines the ability to stretch without affecting their performance. It also helps shield the lines from outside interference and, at the same time, confine the electromagnetic waves flowing through them, almost completely eliminating current loss. Currently, these stretchable integrated circuits can operate at radio frequency levels up to 40 GHz.

Further, unlike other stretchable transmission lines, whose widths can approach 640 micrometers (or 0.64 millimeters), the these new stretchable integrated circuits are just 25 micrometers (or 0.025 millimeters) thick. That's tiny enough to be highly effective in epidermal electronic systems, among many other applications.



Fabricated in interlocking segments like a 3-D puzzle, the new integrated circuits could be used in wearable electronics that adhere to the skin like temporary tattoos. Because the circuits increase wireless speed, these systems could allow health care staff to monitor patients remotely, without the use of cables and cords. Image courtesy of Yei Hwan Jung and Juhwan Lee/University of Wisconsin-Madison.

1 2 next

Daily Mail .com

The smart stick-on tattoo that could save your life: Air Force funds wireless medical sensors set to revolutionise medicine

- New circuits can transmit high speed data about patient's health
- Could allow health care staff to monitor patients remotely and wirelessly

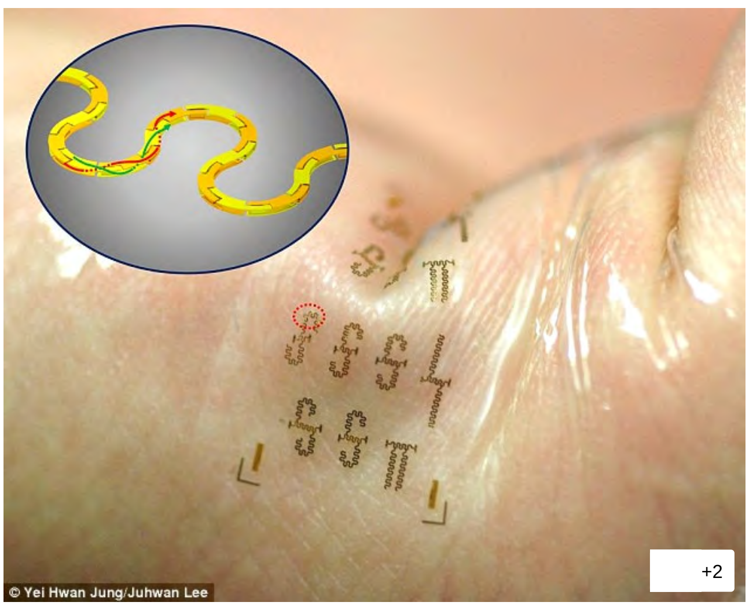
By Mark Prigg For Dailymail.com

PUBLISHED: 15:43 EST, 30 May 2016 | **UPDATED:** 16:17 EST, 30 May 2016

A radical new smart tattoo could allow medical sensors to become wireless - radically changing everything from ER rooms to warfare.

The Air Force funded research has created a new way to wirelessly transmit data with a flexible, stretchable circuit.

It could change everything from smart watches to operating theatre systems



The radical new smart tattoo could allow medical sensors to become wireless - changing everything from ER rooms to warfare.

'We've found a way to integrate high-frequency active transistors into a useful circuit that can be wireless,' said Zhenqiang 'Jack' Ma of the University of Wisconsin—Madison.

'This is a platform.

'This opens the door to lots of new capabilities.'

HOW THEY WORK

The tattoos contain two ultra-tiny intertwining power transmission lines in repeating S-curves.

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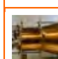
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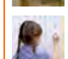
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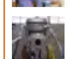
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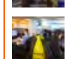
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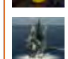
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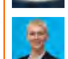
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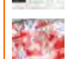
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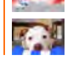
The smart bone that can keep your dog occupied all day (and let you play with it

Ma, whose work was supported by the Air Force Office of Scientific Research.

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What makes the new, stretchable integrated circuits so powerful is their unique structure, inspired by twisted-pair telephone cables.

The new system would allow wireless medical to transmit data to nearby computers, rather than having wires attached to patients.

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This serpentine shape — formed in two layers with segmented metal blocks, like a 3-D puzzle — gives the transmission lines the ability to stretch without affecting their

Northern California News

UW-Madison researchers develop extremely efficient wearable integrated circuits

Submitted by VICTOR BROWN *on* TUE, 05/31/2016 - 09:42

A team of researchers at the University of Wisconsin-Madison (UW-Madison) has revealed in a recently published paper that it has developed extremely efficient wearable integrated circuits, which apparently mark the world's fastest, thinnest and most flexible integrated circuits.

The details about the new advancement in wearable integrated circuit technology have been shared by the researchers -- led by UW-Madison professor Zhenqiang ‘Jack’ Ma -- in a paper published in the May 27 edition of the Advanced Functional Materials journal.

According to the researchers, the new technology has the potential to give the users of wearable devices the ability to keep track of their health wirelessly, without the need for cables; thereby underscoring significant implications for the medical industry.

Highlighting the fact that the wearable integrated circuits are structured with transmission lines in repeating S-curves, to pave the way for increased flexibility of transmission lines, the researchers said that the integrated circuits would be potentially deployable on wearable devices by placing them on human skin, similar to temporary tattoos.

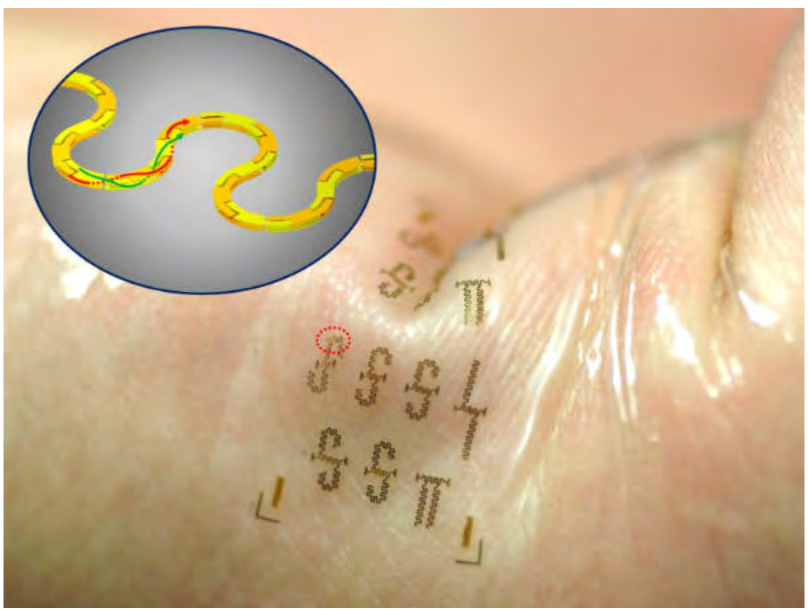
In reference to the new integrated circuits technology, Ma said: "We've found a way to integrate high-frequency active transistors into a useful circuit that can be wireless. This is a platform. This opens the door to lots of new capabilities."

Home | Wearables | News

World's fastest New wearable circuits to revolutionise Internet of Things

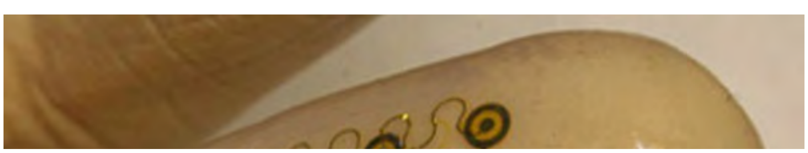
By: GizBot Bureau Updated: Monday, May 30, 2016, 14:16 [IST]

A team of US engineers has created the world's fastest stretchable, wearable integrated circuits -- a technological feat that can revolutionise the Internet of Things (IoT) and high-speed wireless world in the future.



SEE ALSO: **Here Are 5 Amazing Features Of Google's Project Jacquard You Probably Didn't Know About**

Led by Zhenqiang "Jack" Ma from University of Wisconsin-Madison, the team developed the new stretchable integrated circuits taking inspiration from twisted-pair telephone cables. They contain, essentially, two ultra-tiny intertwining power transmission lines in repeating S-curves.



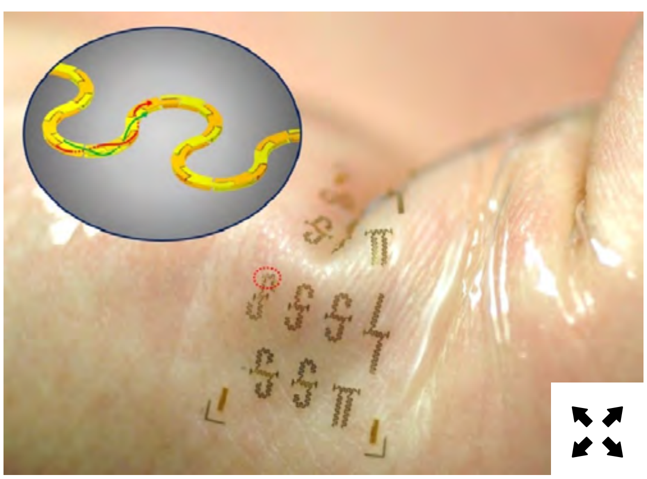
MENU

TECH SC

TAG wearable technology , circuits

Fast, 'Stretchy Circuits' May Redefine Inter Things: Wearable Tech For Your Skin Comi Soon?

30 May 2016, 10:57 am EDT **By Anu Passary Tech Times**



Fabricated in interlocking segments like a 3D puzzle, the new integrated circuits could be used in wearable electronics that adheres to the skin like temporary tattoos. The circuits increase wireless speed and could allow health care staff to monitor patients remotely, minus cables and cord. (Yei Hwan Jung and Juhwan Lee | University of Wisconsin-Madison)

Even as the popularity of fitness trackers and sm continues to grow, researchers are devising new redefine the wearable market and potentially the Things (IoT).

A team of engineers at the University of Wiscons now developed the world's fastest flexible weara integrated circuits to boot! Thanks to the techno will soon be able to keep track of one's health wi the need for cables.

The team of researchers led by UW-Madison pro Jack Ma published the details of the extremely e circuits in the *Advanced Functional Materials* jou

"We've found a way to integrate high-frequency into a useful circuit that can be wireless. This is a

opens the door to lots of new capabilities," says

The integrated circuits could potentially be deployed on wearables by placing them on human skir temporary tattoos.

While traditional transmission lines measure nearly 0.64 millimeter, the solution from the engineers only 0.25-millimeter thick. This makes it small enough to be extremely effective in the epidermal ele

The platform also has a serpentine shape and supports frequencies that range between 0.3 GHz to range is basically what will be the 5G standard in the near future.

What makes the stretchable integrated circuit so powerful is its novel structure, which is inspired b telephone cables that get twisted together. The intertwining transmission lines basically repeat an snake-like shape is what endows it with the ability to stretch while the performance does not get

Additionally, the shape not only aids in safeguarding the transmission lines from any interference, I containing the electromagnetic waves that flow through. In this manner, it is effective in successfu loss of current.

Currently, these new circuits are able to operate at frequency levels of a maximum 40 GHz. The res supported by the Air Force Office of Scientific Research, which hints that the potential wearable te

Most Advanced Wearable Device In The World Created Amid Predicted $40B Market

Tuesday, May 31, 2016 8:41 AM UTC

Fitbit Force Wearable Technology.Before You Buy/YouTube

Engineers at the University of Wisconsin-Madison created what could right now be the most advanced wearable device in the world, which could have a major impact in the medical field in particular. According to an SNS Research report, the wearable electronic device market could be worth $40 billion by 2020, but this

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Diamonds closer to becoming ideal semiconductors

Researchers find new method for doping single crystals of diamond

Date: May 24, 2016

Source: American Institute of Physics

Summary: The thirst for electronics is unlikely to cease and almost every appliance or device requires a suite of electronics that transfer, convert and control power. Now, researchers have taken an important step toward that technology with a new way to dope single crystals of diamonds, a crucial process for building electronic devices.

Share:

FULL STORY

Along with being a "girl's best friend," diamonds also have remarkable properties that could make them ideal semiconductors. This is welcome news for electronics; semiconductors are needed to meet the rising demand for more efficient electronics that deliver and convert power.

The thirst for electronics is unlikely to cease and almost every appliance or device requires a suite of electronics that transfer, convert and control power. Now, researchers have taken an important step toward that technology with a new way to dope single crystals of diamonds, a crucial process for building electronic devices.

"We need the devices to manipulate the power in the way that we want," said Zhengqiang (Jack) Ma, an electrical and computer engineering professor at the University of Wisconsin-Madison. He and his colleagues describe their new method in the Journal of Applied Physics, from AIP Publishing.

For power electronics, diamonds could serve as the perfect material. They are thermally conductive, which means diamond-based devices would dissipate heat quickly and easily, foregoing the need for bulky and expensive methods for cooling. Diamond can also handle high voltages and power. Electrical currents also flow through diamonds quickly, meaning the material would make for energy efficient devices.

But among the biggest challenges to making diamond-based devices is doping, a process in which other elements are integrated into the semiconductor to change its properties. Because of diamond's rigid crystalline structure, doping is difficult.

Currently, you can dope diamond by coating the crystal with boron and heating it to 1450 degrees Celsius. But it's difficult to remove the boron coating at the end. This method only works on diamonds consisting of multiple crystals stuck together. Because such polydiamonds have irregularities between the crystals, single-crystals would be superior semiconductors.

You can dope single crystals by injecting boron atoms while growing the crystals artificially. The problem is the process requires powerful microwaves that can degrade the quality of the crystal.

Now, Ma and his colleagues have found a way to dope single-crystal diamonds with boron at relatively low temperatures and without any degradation. The researchers discovered if you bond a single-crystal diamond with a piece of silicon doped with boron, and heat it to 800 degrees Celsius, which is low compared to the conventional techniques, the boron atoms will migrate from the silicon to the diamond. It turns out that the boron-doped silicon has defects such as vacancies, where an atom is missing in the lattice structure. Carbon atoms from the diamond will fill those vacancies, leaving empty spots for boron atoms.

This technique also allows for selective doping, which means more control when making devices. You can choose where to dope a single-crystal diamond simply by bonding the silicon to that spot.

The new method only works for P-type doping, where the semiconductor is doped with an element that provides positive charge carriers (in this case, the absence of electrons, called holes).

"We feel like we found a very easy, inexpensive, and effective way to do it," Ma said. The researchers are already working on a simple device using P-type single-crystal diamond semiconductors.

But to make electronic devices like transistors, you need N-type doping that gives the semiconductor negative charge carriers (electrons). And other barriers remain. Diamond is expensive and single crystals are very small.

Still, Ma says, achieving P-type doping is an important step, and might inspire others to find solutions for the remaining challenges. Eventually, he said, single-crystal diamond could be useful everywhere -- perfect, for instance, for delivering power through the grid.

Story Source:

The above post is reprinted from materials provided by American Institute of Physics. Note: Materials may be edited for content and length.

Journal Reference:

1. Jung-Hun Seo, Henry Wu, Solomon Mikael, Hongyi Mi, James P. Blanchard, Giri Venkataramanan, Weidong Zhou, Shaoqin Gong, Dane Morgan and Zhenqiang Ma. Thermal diffusion boron doping of single-crystal natural diamond. Journal of Applied Physics, May 24, 2016 DOI: 10.1063/1.4949327

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PUBLIC RELEASE: 20-APR-2016

With simple process, UW-Madison engineers fabricate fastest flexible silicon transistor

UNIVERSITY OF WISCONSIN-MADISON

MADISON, Wis. -- One secret to creating the world's fastest silicon-based flexible transistors: a very, very tiny knife.

Working in collaboration with colleagues around the country, University of Wisconsin-Madison engineers have pioneered a unique method that could allow manufacturers to easily and cheaply fabricate high-performance transistors with wireless capabilities on huge rolls of flexible plastic.

The researchers -- led by Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering, and

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More on this News Release

With simple process, UW-Madison engineers fabricate fastest flexible silicon transistor
UNIVERSITY OF WISCONSIN-MADISON

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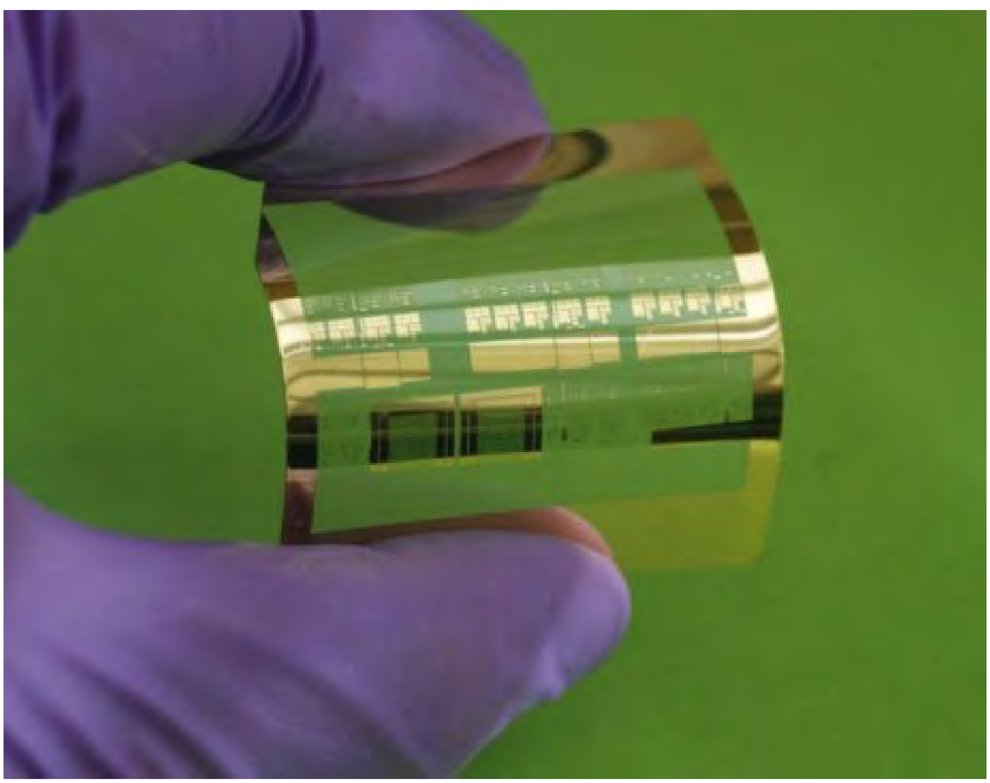
With simple process, engineers fabricate fastest flexible silicon transistor

Date: April 20, 2016
Source: University of Wisconsin-Madison

Summary: One secret to creating the world's fastest silicon-based flexible transistors: a very, very tiny knife. Engineers have now pioneered a unique method that could allow manufacturers to easily and cheaply fabricate high-performance transistors with wireless capabilities on huge rolls of flexible plastic.

FULL STORY



Using a unique method they developed, a team of UW--Madison engineers has fabricated the world's fastest silicon-based flexible transistors, shown here on a plastic *substrate.*

Credit: Image courtesy Jung-Hun Seo/UW–Madison

One secret to creating the world's fastest silicon-based flexible transistors: a very, very tiny knife.

Working in collaboration with colleagues around the country, University of Wisconsin-Madison engineers have pioneered a unique method that could allow manufacturers to easily and cheaply fabricate high-performance transistors with wireless capabilities on huge rolls of flexible plastic.

The researchers -- led by Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering, and research scientist Jung-Hun Seo -- fabricated a transistor that operates at a record 38 gigahertz, though their simulations show it could be capable of operating at a mind-boggling 110 gigahertz. In computing, that translates to lightning-fast processor speeds.

It's also very useful in wireless applications. The transistor can transmit data or transfer power wirelessly, a capability that could unlock advances in a whole host of applications ranging from wearable electronics to sensors.

The team published details of its advance April 20 in the journal Scientific Reports.

The researchers' nanoscale fabrication method upends conventional lithographic approaches -- which use light and chemicals to pattern flexible transistors -- overcoming such limitations as light diffraction, imprecision that leads to short circuits of different contacts, and the need to fabricate the circuitry in multiple passes.

Using low-temperature processes, Ma, Seo and their colleagues patterned the circuitry on their flexible transistor -- single-crystalline silicon ultimately placed on a polyethylene terephthalate (more commonly known as PET) substrate -- drawing on a simple, low-cost process called nanoimprint lithography.

In a method called selective doping, researchers introduce impurities into materials in precise locations to enhance their properties -- in this case, electrical conductivity. But sometimes the dopant merges into areas of the material it shouldn't, causing what is known as the short channel effect. However, the UW-Madison researchers took an unconventional approach: They blanketed their single crystalline silicon with a dopant, rather than selectively doping it.

Then, they added a light-sensitive material, or photoresist layer, and used a technique called electron-beam lithography -- which uses a focused beam of electrons to create shapes as narrow as 10 nanometers wide -- on the photoresist to create a reusable mold of the nanoscale patterns they desired. They applied the mold to an ultrathin, very flexible silicon membrane to create a photoresist pattern. Then they finished with a dry-etching

process -- essentially, a nanoscale knife -- that cut precise, nanometer-scale trenches in the silicon following the patterns in the mold, and added wide gates, which function as switches, atop the trenches.

With a unique, three-dimensional current-flow pattern, the high performance transistor consumes less energy and operates more efficiently. And because the researchers' method enables them to slice much narrower trenches than conventional fabrication processes can, it also could enable semiconductor manufacturers to squeeze an even greater number of transistors onto an electronic device.

Ultimately, says Ma, because the mold can be reused, the method could easily scale for use in a technology called roll-to-roll processing (think of a giant, patterned rolling pin moving across sheets of plastic the size of a tabletop), and that would allow semiconductor manufacturers to repeat their pattern and mass-fabricate many devices on a roll of flexible plastic.

"Nanoimprint lithography addresses future applications for flexible electronics," says Ma, whose work was supported by the Air Force Office of Scientific Research. "We don't want to make them the way the semiconductor industry does now. Our step, which is most critical for roll-to-roll printing, is ready."

Story Source:

The above post is reprinted from materials provided by University of Wisconsin-Madison. Note: Materials may be edited for content and length.

Journal Reference:

1. *Jung-Hun Seo, Tao Ling, Shaoqin Gong, Weidong Zhou, Alice L. Ma, L. Jay Guo, Zhenqiang Ma. Fast Flexible Transistors with a Nanotrench Structure. Scientific Reports, 2016; 6: 24771 DOI: 10.1038/srep24771*

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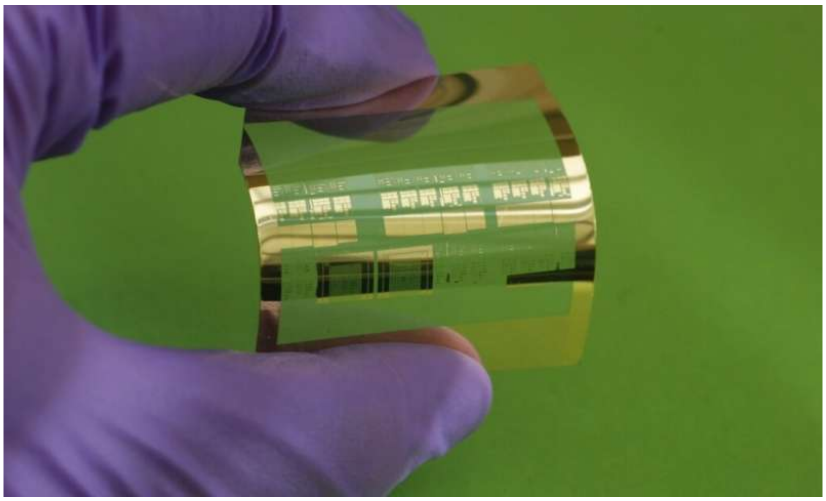
University of Wisconsin-Madison. "With simple process, engineers fabricate fastest flexible silicon transistor." ScienceDaily. ScienceDaily, 20 April 2016. <www.sciencedaily.com/releases/2016/04/160420120550.htm>.

With simple process, engineers fabricate fastest flexible silicon transistor

April 20, 2016 by Renee Meiller



Using a unique method they developed, a team of UW–Madison engineers has fabricated the world's fastest silicon-based flexible transistors, shown here on a plastic substrate. Credit: Jung-Hun Seo

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Then, they added a light-sensitive material, or photoresist layer, and used a technique called electron-beam lithography—which uses a focused beam of electrons to create shapes as narrow as 10 nanometers wide—on the photoresist to create a reusable mold of the nanoscale patterns they desired. They applied the mold to an ultrathin, very flexible silicon membrane to create a photoresist pattern. Then they finished with a dry-etching process—essentially, a nanoscale knife—that cut precise, nanometer-scale trenches in the silicon following the patterns in the mold, and added wide gates, which function as switches, atop the trenches.

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More information: Jung-Hun Seo et al, Fast Flexible Transistors with a Nanotrench Structure, Scientific Reports (2016). DOI: 10.1038/srep24771

Journal reference: Scientific Reports

Provided by: University of Wisconsin-Madison

With simple process, UW-Madison engineers fabricate fastest flexible silicon transistor

Published: Wednesday, April 20, 2016 - 15:34

One secret to creating the world's fastest silicon-based flexible transistors: a very, very tiny knife. Working in collaboration with colleagues around the country, University of Wisconsin-Madison engineers have pioneered a unique method that could allow manufacturers to easily and cheaply fabricate high-performance transistors with wireless capabilities on huge rolls of flexible plastic.

The researchers -- led by Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering, and research scientist Jung-Hun Seo -- fabricated a transistor that operates at a record 38 gigahertz, though their simulations show it could be capable of operating at a mind-boggling 110 gigahertz. In computing, that translates to lightning-fast processor speeds.

It's also very useful in wireless applications. The transistor can transmit data or transfer power wirelessly, a capability that could unlock advances in a whole host of applications ranging from wearable electronics to sensors.

The team published details of its advance April 20 in the journal Scientific Reports.

The researchers' nanoscale fabrication method upends conventional lithographic approaches -- which use light and chemicals to pattern flexible transistors -- overcoming such limitations as light diffraction, imprecision that leads to short circuits of different contacts, and the need to fabricate the circuitry in multiple passes.

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Source: University of Wisconsin-Madison

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Posted 6 days ago

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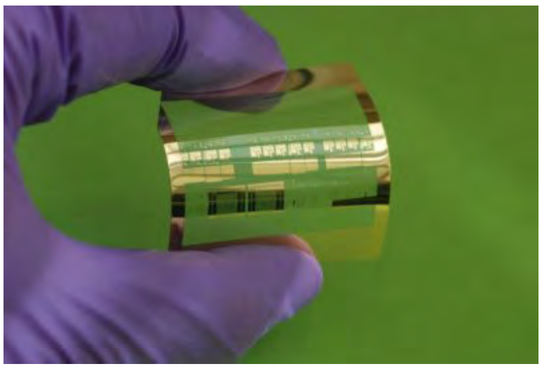

Using a unique method they developed, a team of UW–Madison engineers has fabricated the world's fastest silicon-based flexible transistors, shown here on a plastic substrate. Image credit: Jung-Hun Seo

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Additional authors on the paper include Shaoqin (Sarah) Gong of UW–Madison, L. Jay Guo and Tao Ling of the University of Michigan, Weidong Zhou of the University of Texas at Arlington and Alice L. Ma of the University of California, Berkeley.

Source: University of Wisconsin-Madison

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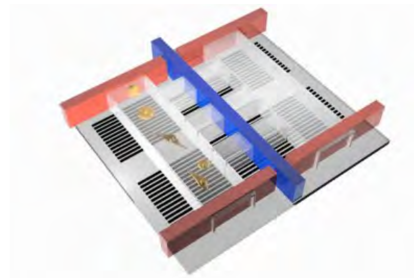

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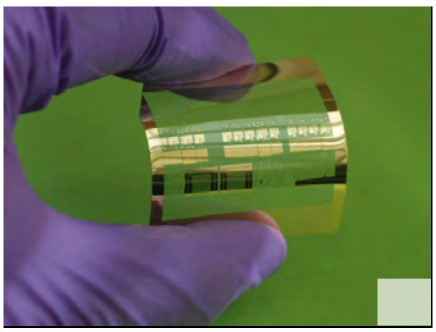
High-Speed Flexible Silicon Transistor May Soon Power Wearables

By **Deepthi B**, Tech Times | April 24, 4:51 AM



Using a unique method they developed, a team of UW–Madison engineers have fabricated the world's fastest silicon-based flexible transistors, shown here on a plastic substrate.
(Photo : Jung-hun Seo | University of Wisconsin-Madison)

An inexpensive approach to make flexible and high speed silicon-based transistors, which may soon be used in the next generation of hi-tech wearables, has been devised by a team of researchers from the University of Wisconsin-Madison.

A technique named nanoimprint lithography has been applied to create these flexible transistors.

In this process, a sheet of light sensitive material is blasted, using beams of electrons that create very narrow measuring shapes (about 10-nanometers-wide), to form a reusable mold with which a flexible silicon membrane is created.

A nanoscale knife is then used to precisely cut trenches of nanometer scale in the silicon membrane similar to the patterns in the mold, and then wide gates are added on top of the trenches to serve as switches.

This results in a small flexible transistor that can bend easily and has the ability to wirelessly transmit data with a potential to operate at 38 GHz, though it is believed that it can be pushed to a speed of 110 GHz, putting it in the same category as the fastest computers.

These transistor channels have the ability to send data or power, which when combined with flexibility and thinness, could lead to wearables that are much more powerful than what is available today.

The 3D pattern makes the transistor operate efficiently by consuming less power and energy. The molds are also reusable, making the technique quite inexpensive considering its speed and efficiency.

The technology has been formulated by Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering, research scientist Jung-Hun Seo, and their team.

According to Ma, the small size makes it possible to put more than one transistor on a device, which increases its speed and functionality. Also, since the mold is reusable, this technique can be used for roll-to-roll processing that allows manufacturers of semiconductors to mass produce several devices on a single roll of flexible plastic, repetitively.

"Nanoimprint lithography addresses future applications for flexible electronics," said Ma. "We don't want to make them the way the semiconductor industry does now. Our step, which is most critical for roll-to-roll printing, is ready."

The technology though is still at a nascent stage and wouldn't be used commercially as yet!

electrodes and the metal layer serve as reflectors.

"In this structure—unlike other photodetectors—light absorption in an ultrathin silicon layer can be much more efficient because light is not blocked by any metal layers or other materials," said Zhenqiang "Jack" Ma, a professor at UW-Madison, in a press release.

It is the combination of the device's high sensitivity and flexibility that are unique in a phototransistor.

"This demonstration shows great potential in high-performance and flexible photodetection systems," said Ma, in the press release. "It shows the capabilities of high-sensitivity photodetection and stable performance under bending conditions, which have never been achieved at the same time."

The upshot, say the researchers is that the flexibility allows the photodetector to better mimic mammalian vision by curving to fit the shape of the camera's optical system. "Currently, there's no easy way to do that," says Ma.

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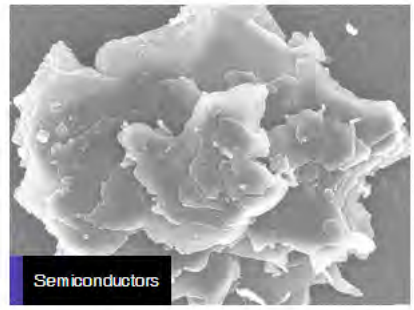

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Roll-to-Roll Flexible Electronics to Hit 100GHZ?

Julien Happich

4/25/2016 08:27 AM EDT

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RPARIS—Researchers from the University of Wisconsin Madison have leveraged the high carrier mobility of flexible silicon nanomembranes (NM) with the scalability of nanoimprinting lithography (NIL) to produce thin-film flexible RF transistors capable of operating at 38GHz.

According to their simulations, their manufacturing strategy could yield 100 GHz-capable thin flexible RF transistors to be manufactured at low cost and low temperature on large rolls of PET.

Their paper "Fast Flexible Transistors with a Nanotrench Structure" published in the journal Scientific Reports details how they overcome the limitations of conventional lithography.

Rather than try to dope selectively a silicon substrate to pattern transistors, the researchers indiscriminately doped a whole silicon nanomembrane (created from a silicon-on-insulator (SOI) wafer, hence keeping the superior charge carrier mobility of bulk silicon versus typically low-mobility organic materials.

They then used electron-beam lithography to carve out a nano-imprinting mold which they use to imprint an etching mask pattern through a photoresist layer, subsequently used to etch a deep nano trench in the Si NM (100nm wide by 250nm deep). After depositing source and drain electrodes and undercutting the buried oxide to release the Si NM, the active nanomembrane is flip transferred onto an adhesive coated PET substrate. Further dry etching defines the perimeter of the active region, then an Al2O3 gate dielectric and gold gate electrodes are deposited above the 100nm trench to finalise the transistor — see Figure 1.

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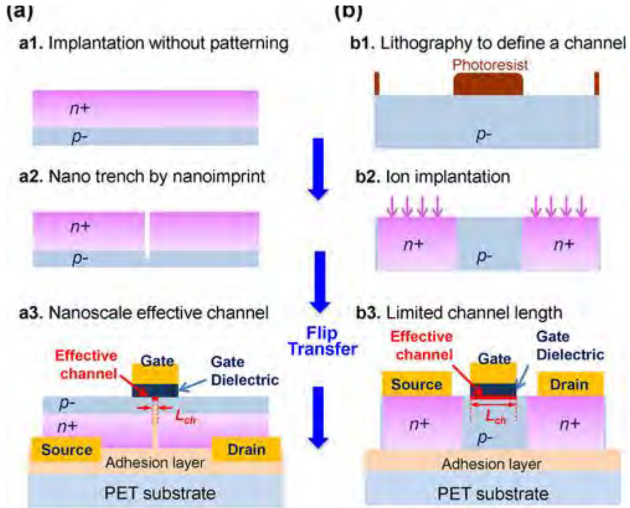


Fig. 1: Comparison of the device structures (cross-sectional view) and fabrication processes between (a) 3-D nano trench Si NM flexible RF TFTs, and (b) conventional 2-D TFTs. The effective channel lengths Lch are marked in red in (a3,b3). The smallest Lch of the nano trench TFT can reach down to 50 nm via NIL and that of the conventional TFT can only reach down to about 1.5 μm. (a1) Blanket phosphorous ion implantation and thermal anneal. (a2) Nano trench formation via nanoimprint. (a3) Final structure of nano trench TFT where the channel length Lch is defined by nanoimprint. (b1) Photolithography to define S/D regions for ion implantation. (b2) Selective ion implantation and thermal anneal. (b3) Final structure of conventional TFT where the channel length Lch is limited by gate electrode and dopant out-diffusion during ion implantation and thermal anneal. Source University of Wisconsin Madison.

Remarkably, all of the device fabrication processes were carried out at temperatures lower than 150°C (except for the first doping and recrystallization steps performed in a blanket fashion before releasing the Si NM from SOI).

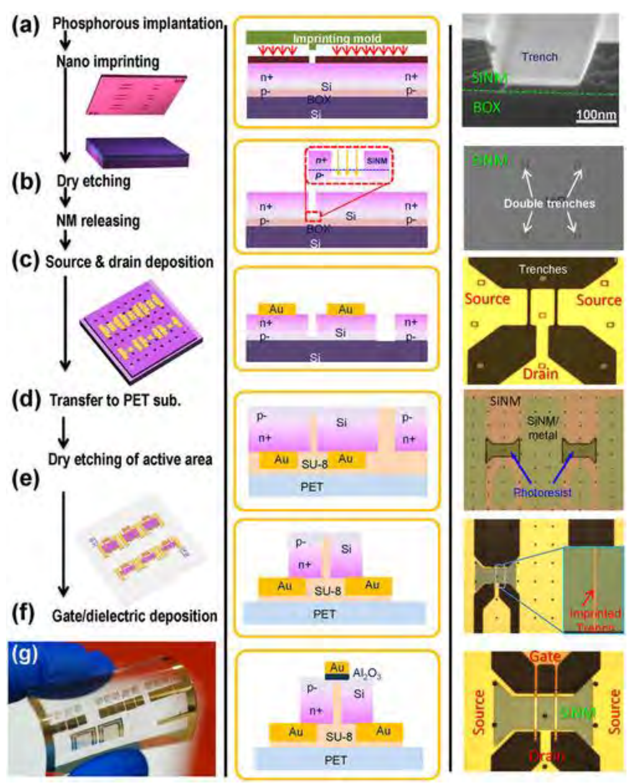
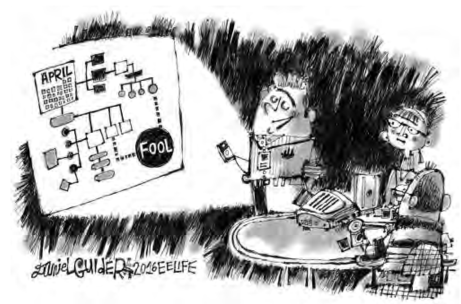


Fig. 2: Schematic illustration (left column), cross section structure (middle column), and corresponding microscopic images (right column) of nano trench Si NM flexible RF TFTs. (a) Defining a nano trench on a phosphorus implanted p− SOI substrate using NIL. (b) Dry etching to separate the n+ area in order to form a path of n+/p−/n+ from source to drain. (c) A partially completed TFT after undercutting the buried oxide to release the Si NM, which forms the active region, and forming the source and drain contacts. (d) Flip transfer of the Si NM with the source and drain electrodes onto an adhesive coated PET substrate. (e) Dry etching to define the perimeter of the



active region. (f) Deposition of an Al2O3 gate dielectric layers and gold gate electrodes above the trench. (g) Optical image of arrays of the bent TFTs on a PET substrate. Source University of Wisconsin Madison.

With a unique, three-dimensional current-flow pattern, the high performance transistor consumes less energy and operates more efficiently. And because the researchers' method enables them to etch much narrower trenches than conventional fabrication processes would allow them on silicon nanomembranes (notoriously difficult to process due to the diffraction of exposed light on the plastic substrate and the substrate's thermal plasticity), it also could enable semiconductor manufacturers to pack more transistors on flexible sheets, re-using the mold in a roll-to-roll manufacturing process for the mass fabrication of flexible electronics.

To put things in perspective, the smallest channel length of flexible transistors made on plastic substrates using the semiconductor nanomembranes is about 1 µm, report the researchers, an order of magnitude larger than their proposed design.

Visit the University of Wisconsin Madison at www.wisc.edu

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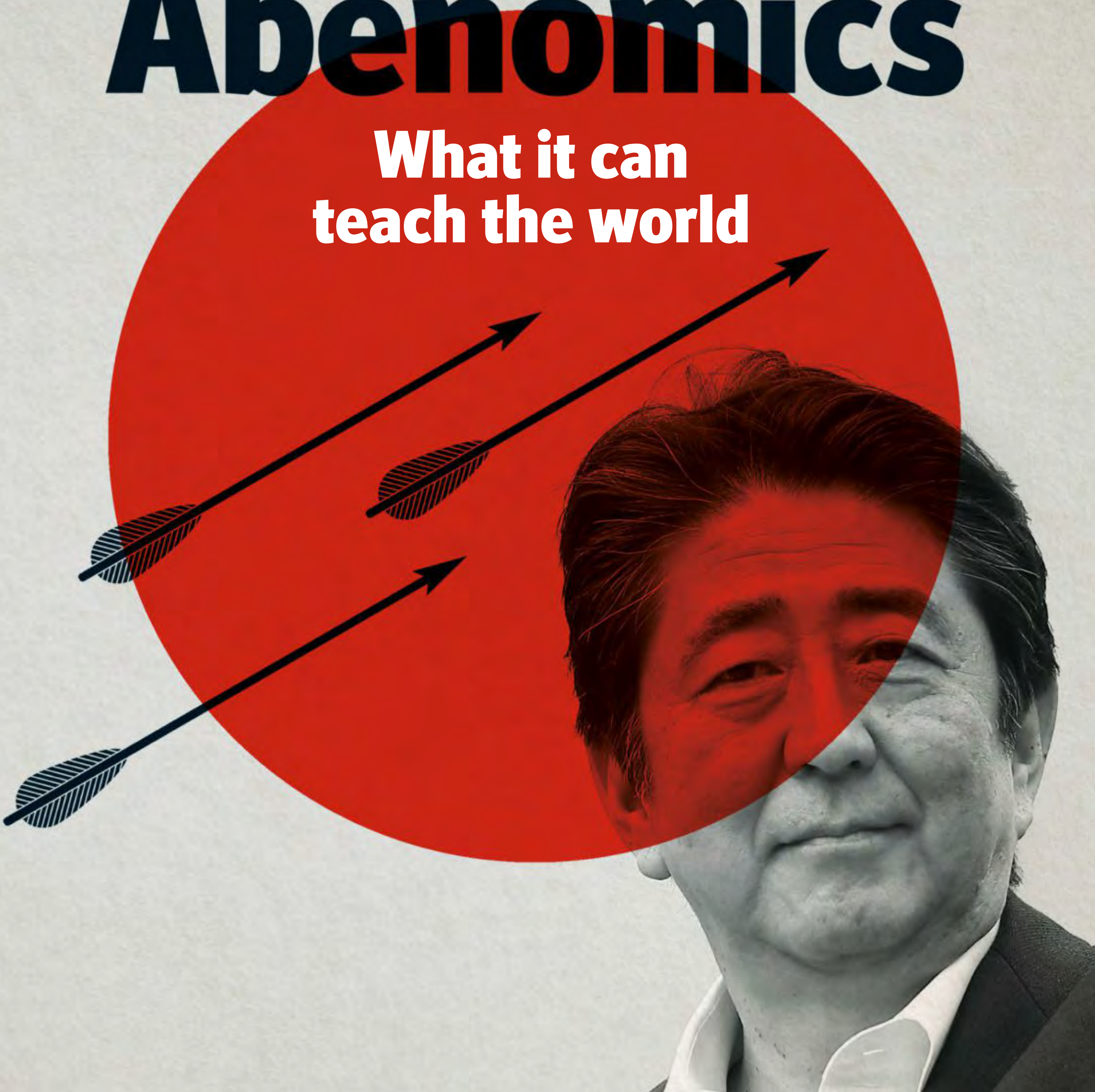

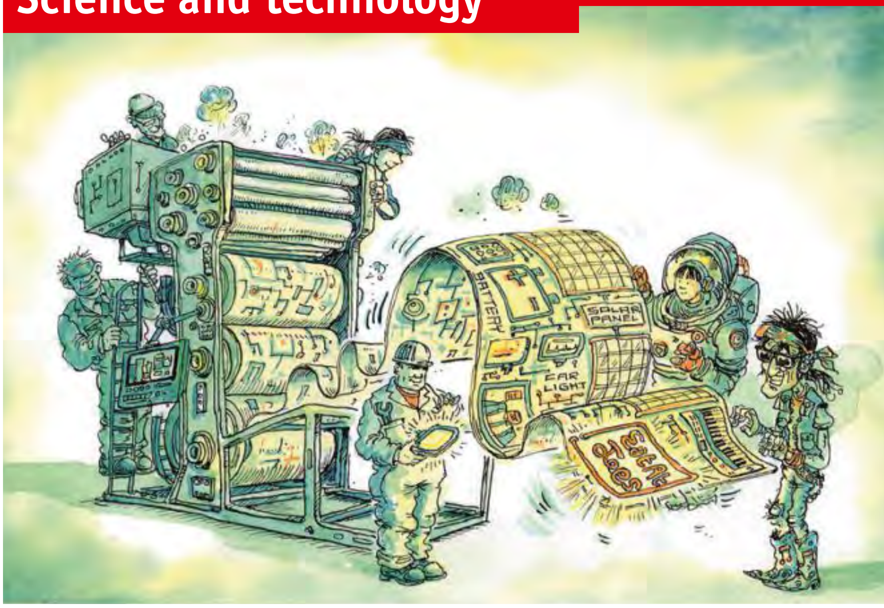

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Printed electronics

On a roll

ACCRINGTON

Printing with conventional rotary presses will create cheaper electronics

MAKING things with 3D printers is an idea that is being adopted by manufacturers to produce goods ranging from false teeth to jet engines. Conventional printing, though, has not remained idle. Machines that have their origins in the high-speed rotary presses that apply words and images to large reels of paper, like the ones which turn out the physical versions of this newspaper, have started making other things as well.

The extent of this transformation can be seen at a factory in Accrington, a town in one of Britain's former industrial heartlands, Lancashire. Here, Emerson & Renwick, founded in 1918, has expanded beyond its formative business of making wallpaper-printing equipment. The latest piece of kit to which the finishing touches are being added is part of the firm's Genesis range. It is about the size of a shipping container and is designed to coat and print electrical devices. Like a conventional printer it does so on long rolls of material, called webs. Then, just as printed pages are cut by guillotines from such webs for binding into newspapers, magazines or books, these printed items are cut out and used in products ranging from solar cells to display screens to batteries. One customer wants to print some of the main components of a new generation of smartphones.

Roll-to-roll printing of this sort is quick and efficient. Some of the fastest web-offset presses, in which an inked image is transferred to another roller and thence to the surface being printed, can churn out more than 20 newspapers a second. Flexographic presses, which use a flexible relief image on a cylinder to print things such as packaging, can belt along at 500 metres a minute. These methods have already been adapted to print basic electronic circuits, by replacing conventional graphic inks with conductive inks that can carry an electric current. Scientists and engineers, however, have loftier ambitions than these. They are developing ways to print not just circuits but also sophisticated electronic devices, such as thin-film transistors, using the mass-production capabilities of roll-to-roll processes.

Transistorised, at half the price

The machine in Accrington is one such offering. It puts sequential coatings onto webs of material such as plastic film, flexible glass and metal foil. Some coatings conduct. Some insulate. Some are semiconductors. Some emit light. Emerson & Renwick produces special carts, each the size of a large oven, which are wheeled into the printing system to configure it for different applications. Some carts contain equipment that accelerates ions from a plasma onto a source material, in order to spatter molecules from that source onto the web. That allows printing at the atomic scale. Others perform a similar trick using a beam of electrons. Others still employ chemically reactive gases to etch features such as holes and channels less than 50 nanometres (billionths of a metre) across into the coatings, for electrical connections. To avoid contamination, all of these processes take place in a vacuum.

As exotic as the Genesis machine may seem, though, many of its underlying technologies are, according to Colin Hargreaves, Emerson & Renwick's boss, similar to those found in a conventional graphics press. In particular, careful management of the web through its winding, tension and control is essential. A break in the web, as any newspaperman knows, brings production to a time-consuming and expensive halt. When printing electronics with such exacting processes in a vacuum, a web-break is potentially catastrophic as it could damage a whole reel.

Printing electronics requires special formulations of ink. Often, these are made with silver, which is a better conductor even than copper. But silver is expensive. An alternative, being worked on by Tawfique Hasan and his research group at Cambridge University, is to include flakes of graphene in such inks. Graphene is a form of carbon made from sheets a single atom thick. The result, Dr Hasan claims, can be manufactured and printed for a fraction of the cost of silver ink and is conductive enough for many applications, such as disposable biosensors used to test samples from patients, and packaging that can track and authenticate a product. Graphene ink could also be used to make electrodes for printed batteries.

Dr Hasan and his colleagues have demonstrated flexographic printing of conductive graphene ink at more than 100 metres a minute. They are working in collaboration with Novalia, a firm in Cambridge that has produced several printed touch-sensitive products, including a musical keyboard and interactive posters. They have also established a company called Inkling Cambridge to commercialise the ▸▸

formulation and develop other electronic inks, coatings and paints.

One idea they are exploring is "smart" wallpaper. In addition to graphene ink, this would use either organic light-emitting diodes (OLEDs) or quantum dots—crystals of semiconducting material just a few atoms across. Both of these emit light when excited by electricity, so wall coverings printed with such materials could be used to illuminate rooms.

Elsewhere, Taiwan's Industrial Technology Research Institute plans to open a roll-to-roll line in 2017, to make OLED lighting panels for display screens, decorative lighting, signage and exterior car lights. These will be printed on rolls of plastic film or ultra-thin flexible glass. The institute says its system will incorporate seven separate processes, including coating, baking and etching, into a single roll-to-roll machine. At the moment, each process requires a different apparatus, and the products have to be made one at a time, or in batches.

Another use for printed electronics of this sort is solar energy. Several groups are working on making thin-film solar panels in this way. Such panels, being cheap and lightweight, could readily be attached to walls and roofs, and even built into roofing tiles. In this context, a family of crystalline materials called perovskites is attracting particular interest for roll-to-roll printing. Whereas the best conventionally made silicon-based solar panels convert the energy in sunlight into electricity with an efficiency of just over 20%, researchers at the Lawrence Berkeley National Laboratory, in California, think they can push that to 31% using perovskites. And being small, crystalline grains, perovskites make ideal ingredients of ink.

Inkjet printing is also getting a roll-to-roll makeover, according to David Bird of the Centre for Process Innovation (CPI), a British government-backed organisation that helps companies commercialise new technologies. Inkjet printers are not particularly fast, but they are parsimonious, for they spray ink only where it is needed. Moreover, they are flexible and easily customised. To alter what is being printed requires only a software reload, rather than the changing of a printing plate. And lack of speed is relative. The CPI's inkjet machine can, for example, print copper circuits onto rolls of plastic at a rate of 17 metres a minute. These circuits are used for things like sensors and radio antennae. Electronics can be made with 3D printers, too. These produce objects by depositing successive layers of material. Like inkjet printers, 3D printers are flexible, but they build things one at a time or in small batches and are mostly used to print larger objects.

As Dr Bird points out, printing of any sort at speed demands good quality control. Single-sheet or batch production permits an error to be spotted before it is repeated, but high-speed roll-to-roll systems can churn out a lot of waste if there is any delay in identifying problems. Cameras can be used to detect errors in printed text or graphics, but they are not much cop at spotting faults in microscopic layers of transparent material whizzing past on a web—not least because there may be nothing to see. To help resolve this for the CPI's machines, researchers at the University of Huddersfield, across the Pennines from Accrington, in Yorkshire, have come up with a method that builds up a three-dimensional model of the web's surface using reflected light, and can raise the alarm if it detects any depressions that might indicate an uncoated spot.

A new meaning of "computer printer"?

How far printed electronics will go remains to be seen. At present such products tend to be used as components rather than complete systems. The technology is a long way from being able to roll-print powerful computer chips, which contain several billion transistors squeezed onto a tiny piece of silicon. These processors are currently made in batches in costly semiconductor fabrication plants.

Using roll-to-roll systems to print lots of transistors in the form of a processor is nevertheless an attractive proposition. In many applications these processors need not be very powerful. But they won't be wimps. Ma Zhenqiang of the University of Wisconsin-Madison and his colleagues recently fabricated a flexible transistor that operates at 110 gigahertz—making it fast enough to use in almost any electronic application. To make this transistor Dr Ma used an electron beam to etch shapes just ten nanometres wide in a mould that was then employed to form the transistor's circuitry in an ultra-thin flexible silicon membrane. As the mould can be reused, Dr Ma reckons his method could easily be scaled up for roll-to-roll processing. Printed media may be going out of style, then, but it looks as if their electronic replacements will still require the presses to roll. ■

Air pollution

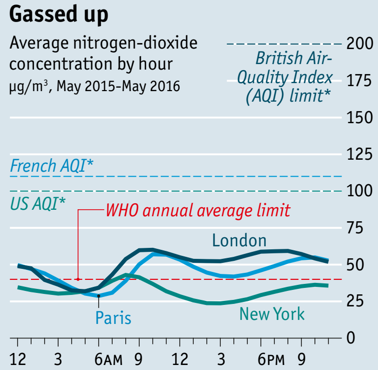
Breathtaking

Air-quality indices make pollution seem less bad than it is

SMOKING a whole packet of cigarettes in a day once or twice a year would certainly make someone feel ill, but probably would not kill him. Smoking even one cigarette every day for decades, though, might do so. That is the difference between acute and chronic exposure, and it is a difference most people understand. What they may not understand is that the same thing applies to air pollution.

On a day-to-day basis, the forecasts most cities offer turn red only when pollution levels rise to a point where they will cause immediate discomfort. That makes sense, for it lets people such as asthmatics take appropriate action. But it might also lead the unwary to assume, if most days in the place he inhabits are green, that the air he is breathing is basically safe. This may well not be the case. In London, for example, a study published last year by researchers at King's College suggested air pollution shortens the city's inhabitants' lives by nine to 16 months.

Gassed up



Source: Plume Labs

*Hourly limit for "low"/"good" band of official Air-Quality Index

To investigate the matter, *The Economist* crunched a year's worth of data collected from May 2015 onwards in 15 big cities. They were gathered by Plume Labs, a firm based in Paris, which uses them to produce a commercial air-quality app. The three pollutants of most concern in rich countries are nitrogen dioxide (NO_2, a brownish gas emitted by car exhausts, and particularly by diesels), ozone (a triatomic form of oxygen that irritates lungs) and soot-particles smaller than 2.5 microns across (which makes them tiny enough to get deep into the lungs). These pollutants can cause a variety of medical difficulties, including asthma, heart disease, lung cancer and stunted lung growth in children.

As the chart shows, levels of NO_2 in London and Paris are routinely higher than World Health Organisation (WHO) guidelines about what constitutes a long-term hazard, known as the annual average lim-

PUBLIC RELEASE: 30-OCT-2015

UW-Madison engineers reveal record-setting flexible phototransistor

UNIVERSITY OF WISCONSIN-MADISON

MADISON, Wis. -- Inspired by mammals' eyes, University of Wisconsin-Madison electrical engineers have created the fastest, most responsive flexible silicon phototransistor ever made.

IMAGE: DEVELOPED BY UW-MADISON ELECTRI ENGINEERS, THIS UNIQUE PHOTOTRANSISTOR FLEXIBLE, YET FASTER AND MORE RESPONSIVE THAN ANY SIMILAR PHOTOTRANSISTOR IN THE WORLD. view more ›

CREDIT: JUNG-HUN SEO

The innovative phototransistor could improve the performance of myriad products -- ranging from digital cameras, night-vision goggles and smoke detectors to surveillance systems and satellites -- that rely on electronic light sensors. Integrated into a digital camera lens, for example, it could reduce bulkiness and boost both the acquisition speed and quality of video or still photos.

Developed by UW-Madison collaborators Zhenqiang "Jack" Ma, professor of electrical and computer engineering, and research scientist Jung-Hun Seo, the high-performance phototransistor far and away exceeds all previous flexible phototransistor parameters, including sensitivity and response time.

The researchers published details of their advance this week in the journal *Advanced Optic Materials*.

Like human eyes, phototransistors essentially sense and collect light, then convert that ligl into an electrical charge proportional to its intensity and wavelength. In the case of our ey the electrical impulses transmit the image to the brain. In a digital camera, that electrical charge becomes the long string of 1s and 0s that create the digital image.

While many phototransistors are fabricated on rigid surfaces, and therefore are flat, Ma ar Seo's are flexible, meaning they more easily mimic the behavior of mammalian eyes.

"We actually can make the curve any shape we like to fit the optical system," Ma says. "Currently, there's no easy way to do that."

One important aspect of the success of the new phototransistors is the researchers' innovative "flip-transfer" fabrication method, in which their final step is to invert the finish phototransistor onto a plastic substrate. At that point, a reflective metal layer is on the bottom.

"In this structure -- unlike other photodetectors -- light absorption in an ultrathin silicon lay can be much more efficient because light is not blocked by any metal layers or other materials," Ma says.

The researchers also placed electrodes under the phototransistor's ultrathin silicon nanomembrane layer -- and the metal layer and electrodes each act as reflectors and impr light absorption without the need for an external amplifier.

"There's a built-in capability to sense weak light," Ma says.

Ultimately, the new phototransistors open the door of possibility, he says.

"This demonstration shows great potential in high-performance and flexible photodetectic systems," says Ma, whose work was supported by the U.S. Air Force. "It shows the capabilit of high-sensitivity photodetection and stable performance under bending conditions, whic have never been achieved at the same time."

###

The researchers are patenting the technology through the Wisconsin Alumni Research Foundation.

CONTACT: Zhenqiang "Jack" Ma, (608) 261-1095, mazq@engr.wisc.edu

Renee Meiller, (608) 262-2481, meiller@engr.wisc.edu

Engineers reveal record-setting flexible phototransistor

October 30, 2015

Developed by UW-Madison electrical engineers, this unique phototransistor is flexible, yet faster and more responsive than any similar phototransistor in the world. Credit: Jung-Hun Seo

Inspired by mammals' eyes, University of Wisconsin-Madison electrical engineers have created the fastest, most responsive flexible silicon phototransistor ever made.

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Researchers Develop Fastest and Most Flexible Silicon Phototransistor Ever

By Dexter Johnson
Posted 3 Nov 2015 | 21:00 GMT

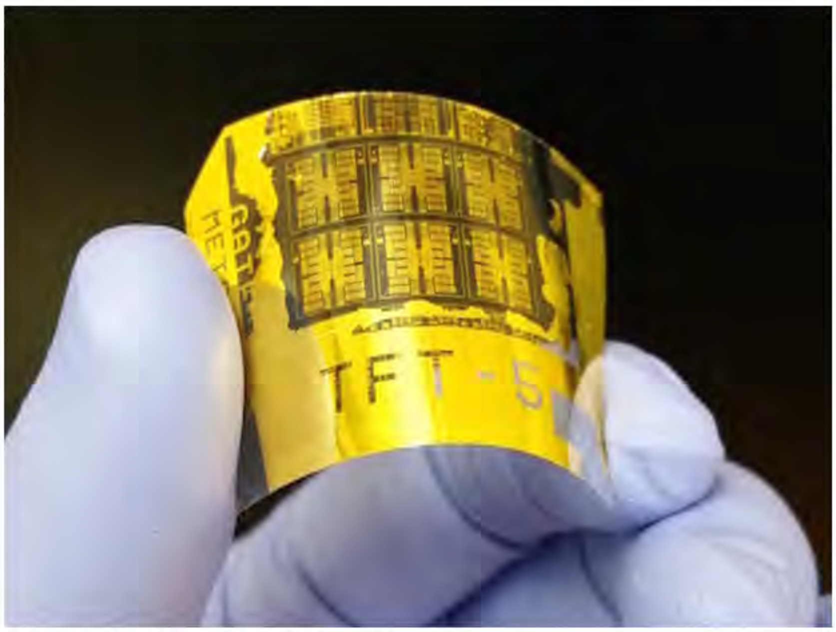

Photo: Jung-Hun Seo/University of Wisconsin-Madison

Researchers at the University of Wisconsin-Madison (UW-Madison) have developed a flexible phototransistor based on single-crystalline silicon nanomembranes (Si NM). They claim that this phototransistor is the fastest and most flexible one ever produced.

The flexible phototransistor could be incorporated into a wide range of applications. In a digital camera, for example, it could result in a thinner lens that would capture images faster and yield higher quality still photos and videos.

In research published in the journal *Advanced Optical Materials*, the silicon nanomembrane is used as the top layer of the phototransistor; it enables full exposure of the active region of the device to any light. The researchers used a technique known as "flip-transfer" in which they essentially flip the nanomembrane onto a reflective metal layer.

This arrangement allowed the researchers to boost the light absorption capabilities of the phototransistor without the need of an external amplifier. They simply placed electrodes under the nanomembrane layer; both the electrodes and the metal layer serve as reflectors.

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IEEE Spectrum's nanotechnology blog, featuring news and analysis about the development, applications, and future of science and technology at the nanoscale.

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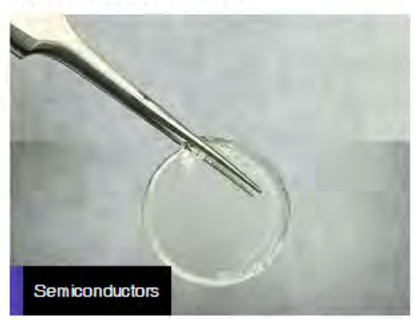

Nanomembrane May Bring Rechargeable Lithium-Metal Batteries Back

WISCONSIN ALUMNI RESEARCH FOUNDATION SEPTEMBER 2015

Accelerator Pipeline

NEWS FROM WARF'S TECHNOLOGY COMMERCIALIZATION TEAM

WARF
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TECHNOLOGY MONITOR

Helping to solve human error, wasting disease, the fuel crunch and more

The WARF Accelerator Program speeds the development of technologies with exceptional potential for commercial success. With targeted funding and expert advice from seasoned business mentors known as Catalysts, the Accelerator Program helps inventions clear technical hurdles and advance to the marketplace. The latest developments:

MEDICAL DEVICES AND IN VITRO DIAGNOSTICS

REAL-TIME GUIDANCE:

Magnetic resonance imaging (MRI) is one of the most empowering tools in medicine today. Walter Block, professor of biomedical engineering, wants to continue pushing the bounds of accuracy.

He has developed a new, computational approach to help doctors align devices such as catheters and biopsy needles. This could avert some of the errors that occur when an interventionalist relies on his or her own visual interpretation of images. Block's method uses a priori information about the device to calculate its orientation and position within milliseconds. While a high resolution image may require 1-2 seconds to acquire, the new computational approach can update the device's position roughly 5-10 times per second.

The technology is being used by the Block team to guide gene delivery experiments and may hold interest to several startups in the MR space.

ANTENNA UPDATE:

Microwave ablation antennas are used to deliver energy into tumors to heat and kill cancer cells. Electrical engineers Nader Behdad and Susan Hagness are designing new antennas that are less invasive, work at higher frequencies and could one day be used to treat hard-to-reach tumors.

The team has passed several key milestones, including proof-of-concept prototyping and ex vivo experimentation. They have compared one of their designs to commercially available antennas, with competitive results.

The team's main commercialization plan is to launch a startup company to market the technologies developed in this project. They say that participating in the Discovery to Product (D2P) program and working with one of the mentors-in-residence has helped them define and refine their value proposition. Based on what they learned through the course and in-depth interviews conducted to date, the team is working on identifying a niche market and application.

MRI DETECTS IRON OVERLOAD:

Iron is an essential nutrient for the human body but is toxic in excess. Iron overload is particularly hazardous to patients requiring regular blood transfusions. Accurate measurement of body iron levels is critical to prevent organ damage.

Radiology researchers Scott Reeder and Diego Hernando have developed a noninvasive method for detecting and quantifying iron overload in the liver using conventional MRI technology. Their method is fast, accurate and overcomes troublesome factors like background noise. Data acquisition has recently been successfully finalized, and data analysis and manuscript preparation are currently underway. They anticipate that this study will result in about six journal articles in the area of MRI-based liver iron and fat quantification.

continued on page 4 >

BUILDING MOMENTUM

It is always a pleasure to welcome new Catalysts to our program. New Catalysts bring new perspectives, valuable insights and the opportunity to establish new relationships with potential partners. All of our Catalysts contribute immensely to the value our Accelerator Program adds to WARF's technology commercialization efforts. This month we have two new Catalysts joining our team, both in our biopharmaceuticals market focus area.

Our first new Catalyst recently relocated from the West Coast to the Madison biotechnology community. John Clapham is the CEO of BioTechnique Inc., a subsidiary of PSC Biotech Corporation where he is also the CEO. BioTechnique is a contract pharmaceuticals manufacturing firm located at the University Research Park and focused on sterile liquid and lyophilized cytotoxic and injectable products. PSC Biotech is a worldwide consultancy organization doing business in 23 different countries, performing projects and augmenting staff in a variety of disciplines related to biopharmaceuticals. Clapham is a chemical engineer by training and a former president of the Los Angeles chapter of the International Society of Pharmaceutical Engineers.

Brad Henke is our most recent addition to the biopharma team. Henke was the director for chemistry for GlaxoSmithKline, located in Research Triangle Park, N.C., until he decided to organize his own consulting business earlier this year. Henke is an expert in drug development, particularly small molecule and peptide therapeutics for metabolic diseases including diabetes, obesity, endocrine disorders, diseases of the skeletal muscles and osteoporosis. He has experience in evaluating and selecting outside technologies for development by GSK. Henke received 12 R&D awards for his accomplishments during his tenure at GSK.

We very much look forward to working with John Clapham and Brad Henke. Please join me in warmly welcoming them both to the WARF Accelerator Program.

— Leigh Cagan, lcagan@warf.org

Accelerator Chronicle

The Practical Philosopher

JACK MA WANTS TO PUSH COMPUTING TO THE FRINGES OF SCIENCE FICTION. HE'S GOING BACK TO SQUARE ONE TO DO IT.

When an Intel team recently unveiled the world's first silicon laser chip, headlines proclaimed the "death of copper cables" and "computing at the speed of light."

The principle is elegant – replace the metal wiring between components with optical connections.

Today's computers depend on wire to move data. A single processor holds billions of transistors, each strung together with copper. The big data centers of Google and Facebook are steaming jungles of cables. Cooling accounts for half the operating costs, explains Zhenqiang "Jack" Ma, a UW–Madison professor of electrical and computer engineering.

Professor Jack Ma is developing laser technology to transmit data faster than ever before.

Trading those wires for laser beams has breathtaking consequences. Picture ultra-efficient servers, superfast laptops and data flying at 50 gigabits or more per second. That's fast enough to download a hi-def movie in less than one second.

Of course, fiber optic communication is already routine on the continental scale. Miles of fiber bundles crisscross the ocean floor to connect Internet users from London to New York, for example. But bringing that capability down to the chip level represents a new frontier.

The push towards a fiber optic revolution is attracting many dreamers, including Ma. He says that the technology is young and complicated. But industry has thrown the gauntlet, and researchers around the world are spoiling for the challenge.

There's a long way to go. Sitting at his computer in Engineering Hall, Ma points to his office wall.

"It's still all metal wires behind there," he says.

One challenge of bringing fiber optical technology down to the chip level is translating between electrical signals and light pulses. One of the keys, says Ma, is building a better laser. It must be much thinner than a human hair and almost weightless. It must fit comfortably on a silicon chip. It must be practical, efficient and compatible with semiconductor processing methods.

Ma thinks he's done it.

He and his collaborators have developed a new way to fabricate an ultra-compact laser (called a vertical cavity surface-emitting laser or VCSEL) thinner than 2 micrometers. It is so slim because it utilizes a single crystal membrane or film as a reflector.

"Put it on silicon and it won't feel like anything," says Ma. "The footprint is very small."

He says support from the Accelerator Program enabled the team to achieve a major milestone in the prototyping process.

"Accelerator gave us the most critical funding to help us realize the last step that was needed," he says. "We now have an approach, a methodology, a way to tell industry yes, we can do this."

Next, they plan to test the laser on a commercial chip, optimize the design and prove it's ready for prime time.

Ma is optimistic about licensing prospects and continues to work closely with WARF. He understands that catching industry's ear takes time, determination and extraordinary data.

But he knows how to make a splash.

Last spring, Ma made news of his own when he and a group of collaborators from academia and business landed a $4 million grant from the Department of Defense. The team plans to develop new ultraviolet lasers based on technology Ma patented through WARF several years ago.

One application could help soldiers in the field identify hazardous materials like explosives or biological agents. Imagine a laser pointer that reveals roadside bombs, he says.

Ma's staggering workload (his project list is 35 lines deep) goes well beyond lasers. His research interests have made him something of a celebrity.

continued on page 4 >

 ...continued from page 2

Many national outlets including the Wall Street Journal and Fox Business recently covered his work on biodegradable computer chips. By replacing the substrate with a cellulose material derived from wood, Ma says you could drop a chip in the forest and fungus would degrade it. The research may someday help alleviate the 3.2 million tons of electronic waste generated in the U.S. every year.

Ma, who pursued seven majors in 15 years before obtaining his Ph.D., says a broad knowledge base fuels his curiosity.

"I never stop studying or thinking. I know where the problems are," he says.

One source of inspiration is more unusual – philosophy.

Ma says the dialectical principles he learned in his youth teach him to approach problems from their root, taking nothing for granted. He explains that when concepts are pushed to their extreme, they change properties.

Some of his core engineering insights derive from this principle. He offers an example. "When metal wire, a conductor, is made extremely thin, then what does it become? An insulator or resistor."

"I teach my students to question from the fundamental level. I guess I'm a practical philosopher," he laughs.

His latest project illustrates the point. He describes a phenomenon called "efficiency droop" in light emitting diodes (LEDs). In essence, less light is produced at higher currents. It's a problem that puzzled scientists up until a few years ago and contributes to the relatively high cost of LED bulbs.

"It's been 22 years since the blue LED was invented and no one can solve the problem," he says.

Ma thinks he can, and hopes to build a new and improved prototype. (Blue LEDs are a critical component to making white light.)

The preliminary data is wildly exciting. He thinks he can achieve at least 40 times more light production than the best LEDs currently on the market, without sacrificing efficiency.

"It's the philosophy again," he says. "I'm taking this on from the root."

WARF
Wisconsin Alumni Research Foundation
www.warf.org

The **WARF Accelerator Pipeline** is published by WARF Communications, 614 Walnut Street, 13th Floor | Madison, Wisconsin, 53726.

For more information about available WARF technologies, please contact the technology commercialization team at *licensing@warf.org*.

THE WEEK

R&D: DANIEL AKST

A Newfangled Chip off the Old Wood Block

LUCI GUTIÉRREZ

GIVING NEW MEANING to the term "wood chip," scientists in a woodsy part of the country have come up with a way to make biodegradable computer chips from trees.

Zhenqiang Ma, a professor of electrical and computer engineering at the University of Wisconsin, says that he decided to pursue this line of research during a lunch break in 2007, when he read in an industry publication about the mountain of electronics discarded every year.

The U.S. Environmental Protection Agency has estimated that in 2010, Americans had 152 million mobile electronic products ready for "end-of-life management." Few were recycled. Many still worked.

Semiconductor chips at the heart of all these devices serve as their brains by performing such crucial functions as signal processing and memory. Silicon is the traditional material for these—thus the name Silicon Valley. More recently, gallium arsenide chips have spread widely, thanks to characteristics that make them ideal for mobile phones.

Dr. Ma says that both types of chips raise environmental issues: Producing the purified silicon needed for chips is energy-intensive, while gallium arsenide chips contain toxins and are difficult to recycle.

Dr. Ma tried to reduce this environmental burden by finding a more eco-friendly material for chips. To do so, he worked with colleagues at the University of Wisconsin and scientists at the Madison-based U.S. Department of Agriculture Forest Products Laboratory. The researchers had one big thing going for them: The business end of a computer chip is usually just a thin top layer. The rest is mere scaffolding, Dr. Ma says, albeit scaffolding with some special qualities.

So the researchers found a way to make that scaffolding out of paper—specifically, cellulose nanofibril (CNF) paper—entirely from wood. Nanotechnology products are manipulated on a very small scale. CNF chips, the scientists say, offer the strength, thermal conductivity and electrical properties needed for the substrate, or wafer, on which most chips are mounted.

To combat the tendency of wood products to suck up moisture and expand, the researchers coated the paper chips in epoxy resin. A handy coincidence is that the CNF paper is transparent, a property that might someday come in handy, Dr. Ma says, for displaying information or other purposes.

Prior experiments with biodegradable chip wafers often reported inadequate performance, but in lab tests, Dr. Ma and a Wisconsin biomedical engineering team led by Shaoqin Gong found that these CNF chips performed about as well as conventional chips.

The new chips are mostly biodegradable. In a test, they degraded fairly rapidly when subjected to common funguses; even with the epoxy coating, for example, they lost 10% of their weight in 28 days. Dr. Ma says that the coating would eventually break down as well.

A thin layer of gallium arsenide would remain, but overall, Dr. Ma says, the CNF chip would use 3,000 to 5,000 times less of that material than would a conventional chip. That change could make the new chip more economical as well as environmentally friendly.

"High-Performance Green Flexible Electronics Based on Biodegradable Cellulose Nanofibril Paper," Yei Hwan Jung, Shaoqin Gong, Zhenqiang Ma and 14 other authors, Nature Communications (May 26)

NEWS QUI

1. Last year, 64 million were recalled in the U. than double the 2013 A criminal probe of wh auto maker may have the increase?

- ○ **A.** Toyota
- ○ **B.** GM
- ○ **C.** Ford
- ○ **D.** Studebaker

2. An Italian bespoke feather bra is priced a How much for the ma sleeveless hoodie?

- ○ **A.** $8,500
- ○ **B.** $17,000
- ○ **C.** $34,000
- ○ **D.** $68,000

3. China sentenced its security czar to life in corruption and other c What's his name?

- ○ **A.** Zhou Yongkang
- ○ **B.** Zhou Enlai
- ○ **C.** Zhou Yun
- ○ **D.** Zhou Kehua

4. Lisa Lambert will r $125 million fund to b run by women and mi Who launched the fun

- ○ **A.** Google
- ○ **B.** Intel
- ○ **C.** Oprah Winfrey
- ○ **D.** Sheryl Sandberg

5. Triple Crown-winner American Pharoah may have a starting stud fee of $100,000—peanuts versus the $1

PHOTO OF THE WEEK

THE WALL STREET JOURNAL.

http://www.wsj.com/articles/scientists-develop-chips-made-mostly-from-wood-1434139825

LIFE | IDEAS | R AND D

Scientists Develop Chips Made Mostly From Wood

New products would be more biodegradable

By DANIEL AKST

June 12, 2015 4:10 p.m. ET

Giving new meaning to the term "wood chip," scientists in a woodsy part of the country have come up with a way to make biodegradable computer chips from trees.

Zhenqiang Ma, a professor of electrical and computer engineering at the University of Wisconsin, says that he decided to pursue this line of research during a lunch break in 2007, when he read in an industry publication about the mountain of electronics discarded every year.

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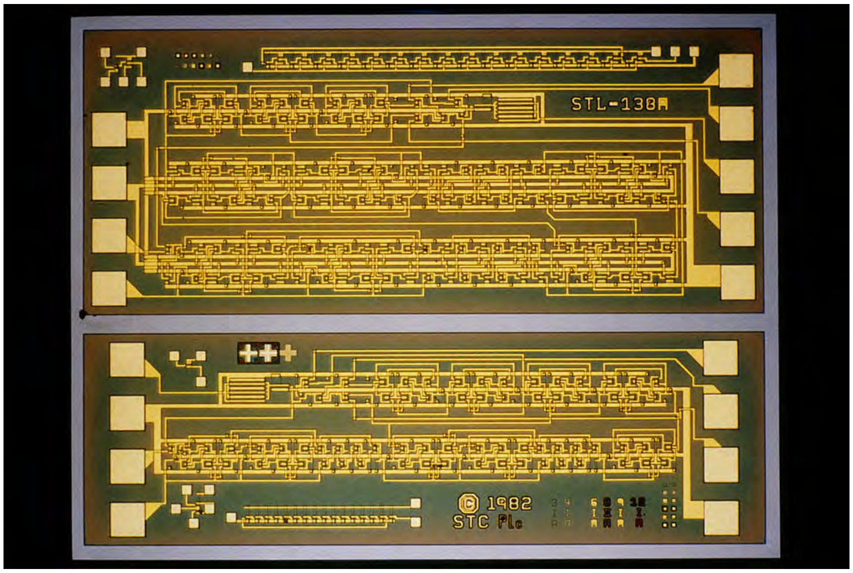

A section of a Gallium Arsenide microchip. Gallium arsenide has similar semiconductor properties to those of silicon, with the advantage of being intrinsically faster. PHOTO: SILICON TRANSISTOR CORPORATION/A. STERNBERG/SCIENCE SOURCE

So the researchers found a way to make that scaffolding out of paper—specifically, cellulose nanofibril (CNF) paper—entirely from wood. Nanotechnology products are manipulated on a very small scale. CNF chips, the scientists say, offer the strength, thermal conductivity and electrical properties needed for the substrate, or wafer, on which most chips are mounted.

To

MORE R AND D

- Vividly Imagining Fragrant Food May Lead to Weight Gain (http://www.wsj.com/articles/vividly-imagining-fragrant-food-may-lead-to-weight-gain-1432914761)
- A New Way to Battle Jet and Traffic Noises (http://www.wsj.com/articles/a-new-way-to-battle-jet-and-traffic-noises-1432315525)
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- A Tiny Robot Senses Humidity (http://www.wsj.com/articles/a-tiny-robot-senses-humidity-1427478730)

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Biodegradable, Flexible Silicon Transistors

www.aip.org/publishing/journal-highlights/biodegradable-flexible-silicon-transistors

Wisconsin researchers have developed a new biodegradable silicon transistor based on a material derived from wood, opening the door for green, flexible, low-cost portable electronics in future

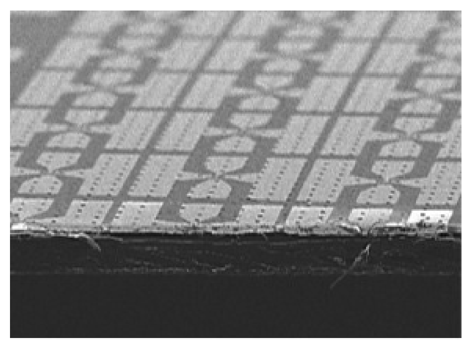
From the Journal:

Applied Physics Letters

By Zhengzheng Zhang

Washington, D.C., June 30, 2015 -- Portable electronics users tend to upgrade their devices frequently as new technologies offering more functionality and more convenience become available. A report published by the U.S. Environmental Protection Agency in 2012 showed that about 152 million mobile devices are discarded every year, of which only 10 percent is recycled -- a legacy of waste that consumes a tremendous amount of natural resources and produces a lot of trash made from expensive and non-biodegradable materials like highly purified silicon.

Now researchers from the University of Wisconsin-Madison have come up with a new solution to alleviate the environmental burden of discarded electronics. They have demonstrated the feasibility of making microwave biodegradable thin-film transistors from a transparent, flexible biodegradable substrate made from inexpensive wood, called cellulose nanofibrillated fiber (CNF). This work opens the door for green, low-cost, portable electronic devices in future.



In a paper published this week in the *Applied Physics Letters* from AIP Publishing, the researchers describe the biodegradable device.

"We found that cellulose nanofibrillated fiber based transistors exhibit superior performance as that of conventional silicon-based transistors," said Zhenqiang Ma, the team leader and a professor of electrical and computer engineering at the UW-Madison. "And the bio-based transistors are so safe that you can put them in the forest, and fungus will quickly degrade them. They become as safe as fertilizer."

Nowadays, the majority of portable electronics are built on non-renewable, non-biodegradable materials such as silicon wafers, which are highly purified, expensive and rigid substrates, but cellulose nanofibrillated fiber films have the potential to replace silicon wafers as electronic substrates in environmental friendly, low-cost, portable gadgets or devices of the future.

Cellulose nanofibrillated fiber is a sustainable, strong, transparent nanomaterial made from wood. Compared to other polymers like plastics, the wood nanomaterial is biocompatible and has relatively low thermal expansion coefficient, which means the material won't change shape as the temperature changes. All these superior properties make cellulose nanofibril an outstanding candidate for making portable green electronics.

To create high-performance devices, Ma's team employed silicon nanomembranes as the active material in the transistor -- pieces of ultra-thin films (thinner than a human hair) peeled from the bulk crystal and then transferred and glued onto the cellulose nanofibrill substrate to create a flexible, biodegradable and transparent silicon transistor.To create high-performance devices, Ma's team employed

But to make portable electronics, the biodegradable transistor needed to be able to operate at microwave frequencies, which is the working range of most wireless devices. The researchers thus conducted a series of experiments such as measuring the current-voltage characteristics to study the device's functional performance, which finally showed the biodegradable transistor has superior microwave-frequency operation capabilities comparable to existing semiconductor transistors.

"Biodegradable electronics provide a new solution for environmental problems brought by consumers' pursuit of quickly upgraded portable devices," said Ma. "It can be anticipated that future electronic chips and portable devices will be much greener and cheaper than that of today."

Next, Ma and colleagues plan to develop more complicated circuit system based on the biodegradable transistors.

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Article title:

Microwave flexible transistors on cellulose nanofibrillated fiber substrates

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Applied Physics Letters features concise, rapid reports on significant new findings in applied physics. The journal covers new experimental and theoretical research on applications of physics phenomena related to all branches of science, engineering, and modern technology.

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Engineers create wood-based electronics circuits

Robert Ferris | @RobertoFerris
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A file photo of a semiconductor wafer.

It's hoped that the development could someday help reduce the environmental impact from America's growing volume of discarded electronics. The flexible and transparent circuit also can be used in wearables and "smart" textiles. (Tweet This)

Consumers in the United States threw away 2.37 million tons of electronics in 2009, the most recent year for which data are available, and the country only recycled about 25 percent of that total, according to EPA estimates. About 152 million mobile phones were thrown away in that year alone. And that was in 2009.

"Many more gadgets may be discarded daily, considering the larger quantities and more varieties being produced in the recent years," the engineers wrote Tuesday in the journal *Applied Physics Letters*. "This will not only lead to a large amount of consumption of our limited natural resources, but also generate a large amount of waste that could pollute our environment."

Part of the problem with e-waste stems from types of materials used.

For instance, the silicon or gallium arsenide-based chips that make up much of the guts of electronics contain materials that do not decompose well and can leach chemicals into soil and water supplies.

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"If you open up a mobile phone, you have a battery and you have chips," said Zhenqiang Ma, one of the authors on the study. "The hardest things to recycle are the chips themselves."

Another route to reducing e-waste, and to conserving potentially precious ingredients, may lie in developing biodegradable alternatives.

Silicon chips, for example, use much more silicon than they actually need, the researchers say. A standard 12-inch silicon wafer is about 775 micrometers thick, but only a tiny fraction of that thickness—one micrometer—is actually used by circuits. The rest of the wafer just provides physical support for the circuits—which is really a waste of silicon, Ma said.

'Chip-wrecked': 4 plays in tech

Friday, 26 June 2015 | 4:00 CDT | 02:51

The "Fast Money" traders give you 4 plays in the weak chips sector.

Ma and his colleagues at the University of Wisconsin and the USDA Forest Products Laboratory used a substrate made out of wood pulp, called "cellulose nanofibrillated fiber," and combined it with only the thinnest layer of silicon needed for the transistors that do the work on chips.

Cellulose nanofibrils have been around and used in other applications, but Ma and his team have demonstrated that the material can work at the frequencies that would make it useful for use in wireless devices

The scientists say their material performed as well as conventional chip materials in their tests, and can biodegrade naturally over the course of several weeks. The amount of silicon used is so minimal that it's far below the limits set by the Environmental Protection Agency, Ma told CNBC.

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Ma said he doubts manufacturers that make conventional chips will voluntarily replace their current materials with wood-based alternatives in the near future, since they have little incentive to bear the upfront costs of retooling. As with other so-called green technologies, such as LED lighting and solar panels, the government may have to create incentives to induce companies to invest in wood-based chips.

In the meantime, there are other opportunities for commercializing the

TECHNOLOGY

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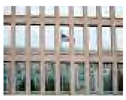

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OPM will temporarily suspend a program it uses to complete background investigations, following a data breach.

technology.

The wood-based material is more transparent than glass and more flexible than silicon, Ma said, so it could be used to make chips for devices that can be curved or bent, such as wearables and "smart" textiles. Ma said his team has already applied for patents, and the technology is ready to be licensed.

"We are going to see a lot of electronics that will be flexible in the future," he said.

Robert Ferris
Science Reporter

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Biodegradable, flexible silicon transistors

Biiodegradable silicon transistor based on material derived from wood

Date: June 30, 2015
Source: American Institute of Physics

Summary: Researchers have come up with a new solution to alleviate the environmental burden of discarded electronics. They have demonstrated the feasibility of making microwave biodegradable thin-film transistors from a transparent, flexible biodegradable substrate made from inexpensive wood, called cellulose nanofibrillated fiber. This work opens the door for green, low-cost, portable electronic devices in future.

FULL STORY

A fresh CNF based microwave silicon transistor chip. After three weeks of putting it in a woodpile, the chip was partially degraded with the help of fungi.

Credit: Jung-Hun Seo, Shaoqin Gong and Zhenqiang Ma/University of Wisconsin-Madison

Portable electronics users tend to upgrade their devices frequently as new technologies offering more functionality and more convenience become available. A report published by the U.S. Environmental Protection Agency in 2012 showed that about 152 million mobile devices are discarded every year, of which only 10 percent is recycled -- a legacy of waste that consumes a tremendous amount of natural resources and produces a lot of trash made from expensive and non-biodegradable materials like highly purified silicon.

Now researchers from the University of Wisconsin-Madison have come up with a new solution to alleviate the environmental burden of discarded electronics. They have demonstrated the feasibility of making microwave biodegradable thin-film transistors from a transparent, flexible biodegradable substrate made from inexpensive wood, called cellulose nanofibrillated fiber (CNF). This work opens the door for green, low-cost, portable electronic devices in future.

In a paper published this week in the Applied Physics Letters from AIP Publishing, the researchers describe the biodegradable device.

"We found that cellulose nanofibrillated fiber based transistors exhibit superior performance as that of conventional silicon-based transistors," said Zhenqiang Ma, the team leader and a professor of electrical and computer engineering at the UW-Madison. "And the bio-based transistors are so safe that you can put them in the forest, and fungus will quickly degrade them. They become as safe as fertilizer."

Nowadays, the majority of portable electronics are built on non-renewable, non-biodegradable materials such as silicon wafers, which are highly purified, expensive and rigid substrates, but cellulose nanofibrillated fiber films have the potential to replace silicon wafers as electronic substrates in environmental friendly, low-cost, portable gadgets or devices of the future.

Cellulose nanofibrillated fiber is a sustainable, strong, transparent nanomaterial made from wood. Compared to other polymers like plastics, the wood nanomaterial is biocompatible and has relatively low thermal expansion coefficient, which means the material won't change shape as the temperature changes. All these superior properties make cellulose nanofibril an outstanding candidate for making portable green electronics.

To create high-performance devices, Ma's team employed silicon nanomembranes as the active material in the transistor -- pieces of ultra-thin films (thinner than a human hair) peeled from the bulk crystal and then transferred and glued onto the cellulose nanofibrill substrate to create a flexible, biodegradable and transparent silicon transistor.

But to make portable electronics, the biodegradable transistor needed to be able to operate at microwave frequencies, which is the working range of most wireless devices. The researchers thus conducted a series of experiments such as measuring the current-voltage characteristics to study the device's functional performance, which finally showed the biodegradable transistor has superior microwave-frequency operation capabilities comparable to existing semiconductor transistors.

"Biodegradable electronics provide a new solution for environmental problems brought by consumers' pursuit of quickly upgraded portable devices," said Ma. "It can be anticipated that future electronic chips and portable devices will be much greener and cheaper than that of today."

Next, Ma and colleagues plan to develop more complicated circuit system based on the biodegradable transistors.

Story Source:

The above post is reprinted from materials provided by American Institute of Physics. Note: Materials may be edited for content and length.

Journal Reference:

1. ***Jung-Hun Seo, Tzu-Hsuan Chang, Jaeseong Lee, Ronald Sabo, Weidong Zhou, Zhiyong Cai, Shaoqin Gong, and Zhenqiang Ma. Microwave Flexible Transistors on Cellulose Nanofibrillated Fiber Substrates. Applied Physics Letters, June 30, 2015 DOI: 10.1063/1.4921077***

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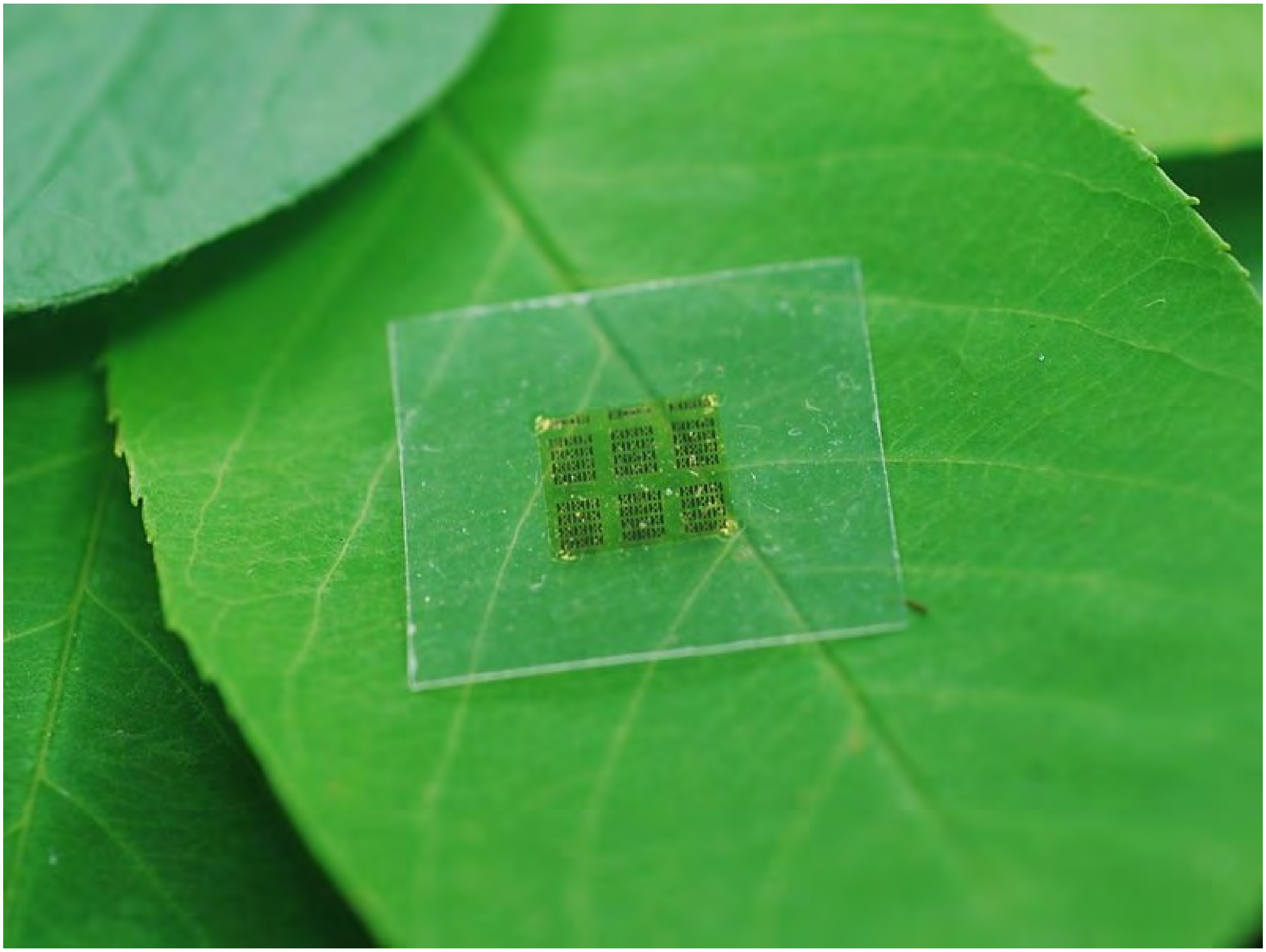
These New Computer Chips Are Made From Wood

A new technique replaces the bulk of smartphone-friendly microchips with a transparent, flexible material made from wood pulp



Cellulose nanofibril (CNF) chips made from wood could lead to flexible, biodegradable electronics that leach far less potentially toxic chemicals into the environment. (Yei Hwan Jung)

By Matt Safford
smithsonian.com
June 3, 2015

Our global obsession with ephemeral consumer electronics is fast resulting in a massive global garbage problem. As many as 50 million metric tons of our old smartphones, PCs, TVs and other devices were discarded last year in favor of the next new thing.

But researchers at the University of Wisconsin-Madison have developed a surprising way to make tossing out future smartphones and tablets easier on the environment and the conscience. They’re replacing the bulk of toxic and non-biodegradable materials in modern microprocessors with wood.

The research was done in collaboration with the U.S. Department of Agriculture Forest Products Laboratory and is detailed in a paper published recently in Nature Communications.

Specifically, the researchers' method replaces the rigid base or substrate material in smartphone and tablet chips, often comprised of the arsenic-containing compound gallium arsenide, with cellulose nanofibril (CNF). CNF is a flexible, transparent material made by breaking down the cell walls of wood to the nano scale and forming it into sheets, much like paper.

The tiny transistors and other components on the team's chips are still made of metals and other potentially toxic materials. But the amount of those materials used is so small that lead researcher and UW-Madison electrical and computer engineering professor Zhenqiang "Jack" Ma says the chips can be consumed by fungus and become "as safe as fertilizer."

Of course, wood-based CNF doesn't have the same characteristics as petroleum or metal-based materials more typically used as substrates in mobile chips. Like any wood-based material, CNF has a tendency to attract moisture and expand and contract with temperature changes—both major problems for tightly packed, moisture-averse microchips. To make the material more suitable for use in electronics, Zhiyong Cai at the U.S. Department of Agriculture and Shaoqin "Sarah" Gong at UW-Madison worked together to create a biodegradable epoxy coating, which keeps the material from attracting water and expanding. It also makes the material smoother, an important property for a material used to build tiny chips. Ma says the amount of epoxy used depends on how long the chip needs to last. Using less epoxy also means that fungus can break down the chip more quickly, but Ma says fungus will always eventually make its way through the epoxy.

Like gallium arsenide, CNF also needs to have a low radio frequency energy loss, so wireless signals being transmitted and received by the chip won't be degraded or blocked. "Our group did the radio frequency energy loss testing," Ma says, "and we found, oh cool, everything looks good."

Once the researchers were sure the material was a viable substitute, the next step was figuring out how to remove as much gallium arsenide from a chip as possible and replace it with CNF. For that, Ma borrowed a technique from some of his other work designing flexible electronics.

"When we do flexible electronics, we peel off a very thin layer of silicon or gallium arsenide, and the substrate [material underneath] can be saved," says Ma. "So why don't we just do the same thing and peel off a single layer of the original substrate and put it on CNF, this wood-based substrate."

Gallium arsenide is used in phones as a substrate, rather than the silicon that's common in computer processors, because it has much better properties for transmitting signals over long distances—like to cell phone towers. But Ma says despite the environmental and scarcity issues with gallium arsenide (it's a rare material), no one had created a thin-film-type transistor or circuit out of the material, and the existing techniques were using more of the potentially toxic substance than necessary.

As few as 10 transistors are needed for some types of chips, and the technique they've developed allows for many more than that to be created in a 4-millimeter-by-5-millimeter area. "Actually, we can build thousands of transistors out of that area, and just move those transistors to the wood substrate," says Ma. "This CNF material is surprisingly good and no one ever tried high-frequency applications with it."

Of course, there are other potentially toxic materials in portable electronics, including in batteries, and the glass, metal and plastic shells of the devices make up the bulk of e-waste. But advances in eco-friendly plastics and recent work using wood fibers to create three-dimensional batteries offer hope that we might one day feel better about replacing our aging devices.

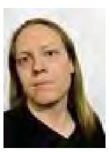
The real challenge, however, will likely be getting massive chip-fabrication plants, and the companies that employ or own them, to shift to newer, more eco-friendly methods when current techniques are so inexpensive. When scaled up however, the costs for creating CNF from renewable wood should be inexpensive as well, helping entice device makers to switch from more traditional substrates. After all, wood is abundant, and doesn't need to be mined from the ground like gallium. The nearly two-millennia history of wood-based paper should also help keep the cost of making CNF low. “The wood breakdown process is established very well,” says Ma.

The pliable nature of CNF will make it a good fit for the emerging field of flexible electronic devices. But Ma warns that the emergence of flexible, wearable, low-cost devices will also likely substantially increase the amount of e-waste in the not-too-distant future.

“We are on the horizon of the arrival of flexible electronics,” says Ma. “The number of flexible electronic gadgets will be much more than just one phone and one tablet or laptop. We are probably going to have ten PCs.”

Ma hopes the amount of potential e-waste generated by all these devices combined with the amount of rare materials—gallium arsenide and others—that can be saved by using wood-based materials in electronics will eventually make both financial and environmental sense.

About Matt Safford



Matt Safford is a freelance technology writer who spends his days testing gadgets, while daydreaming of returning to rural Scotland. His work has appeared in Popular Science, Consumer Reports, Wired, and MSNBC.

|

TECHNOLOGY

COMPUTER CHIPS CAN NOW BE MADE FROM WOOD

JUST CALL THEM WOOD CHIPS

By **Mary Beth Griggs** Posted May 27, 2015

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Computer In Tree

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Not quite what we had in mind

The woods are lovely, dark, deep, and filled with potential computer components.

In a paper published in *Nature Communications* this week, researchers announced the construction of computer chips made from wood.

But don't expect to see hipsters advertising hand-carved artisan computer chips. The wood product that the scientists are using is called cellulose nanofibril, or CNF. It is thin, flexible, and when a layer of epoxy is applied, it doesn't expand or attract moisture like wood normally does (think of a warped board--not something you want in a computer). The researchers were able to use CNF as a substrate or base layer for electronic circuits in lab tests, and they hope that their invention will be an eco-friendly solution to a growing electronic waste problem.

Wood is a renewable resource, unlike a lot of the petroleum-based alternatives that manufacturers use to build the bases of modern computer chips. But wood has another advantage: it can degrade.

else," lead researcher Zhenqiang "Jack" Ma, said in a press release. "Now the chips are so safe you can put them in the forest and fungus will degrade it. They become as safe as fertilizer."

It will be years before computers containing wood-based computer chips hit store shelves, but computers as fertilizer isn't a totally crazy idea.

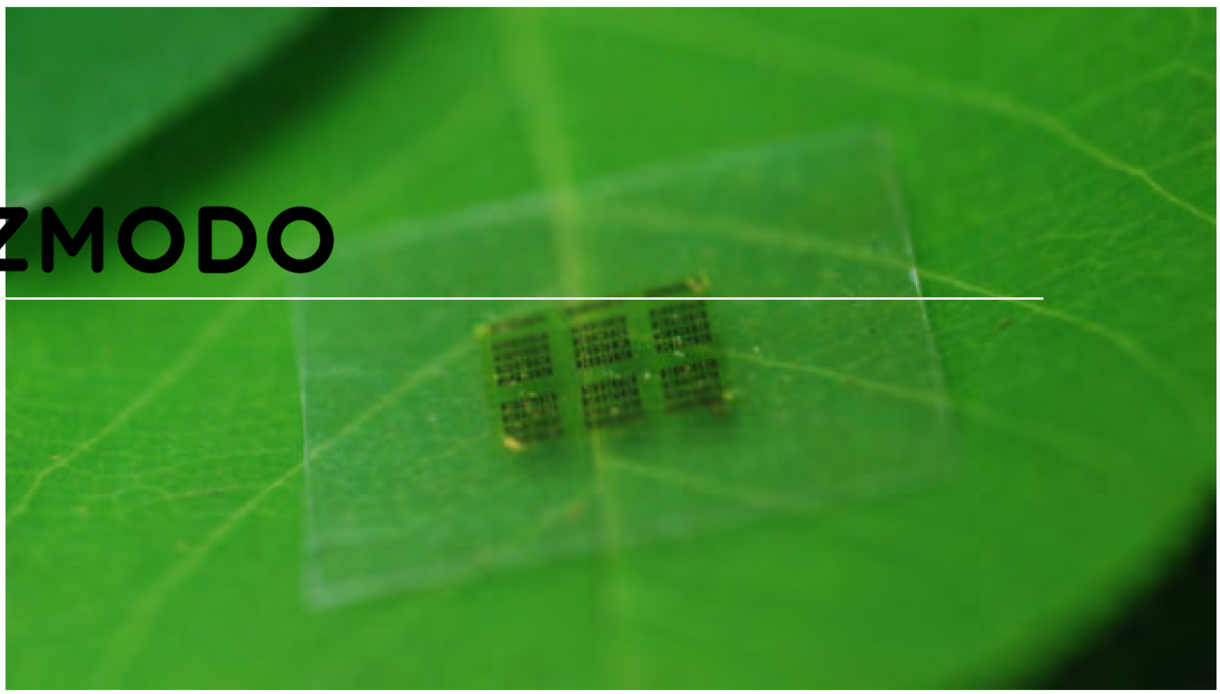
Society tends to treat electronics as disposable commodities. But unlike a glass bottle that gets recycled or food that hits a compost heap, once that broken laptop heads into the trashcan, it doesn't disappear.

Every year, 3.2 million tons of electronic waste are thrown out in the United States alone. Organizations are trying to recycle the waste or mine it for valuable resources like gold, but there's still a ton of electronics (well, a few million tons) headed for the landfill.

By changing the materials that we build electronics with, Ma, and others like him (another team is building dissolvable circuits) are trying to deal with the e-waste problem at the start--long before your phone gets stepped on or your computer crashes. Instead of waiting until they're headed to the trashcan to clean up the waste, they're tackling the problem at the very start of the supply chain.

We Can Now Make Computer Chips Out of Wood

Bryan Lufkin
Filed to: COMPUTER CHIPS 5/26/15 7:20pm



We're one step closer to biodegradable gadgets. These computer chips are made almost entirely out of wood.

Scientists at the University of Wisconsin, Madison teamed up with the U.S. Department of Agriculture's Forest Products Laboratory to fashion the new semiconductor chip. The paper was published today in Nature Communications.

See, most of a computer chip is composed of a "support" layer that cradles the actual chip. The research team replaced that support layer's non-biodegradable material with something called cellulose nanofibril (CNF), which is flexible, wood-based, biodegradable—all things that can make a device way less hazardous.

“Now the chips are so safe you can put them in the forest and fungus will degrade it,” says Professor Zhenqiang Ma, who led the team. “They become as safe as fertilizer.”

A possible roadblock was the fact that wood can expand or shrink based on how much moisture it sucks in from the air. The fix? Glaze the CNF film with an epoxy coating, a substance that makes CNF more resistant to water. In addition to wicking away moisture, the coating also made the CNF smoother.

The result: a sustainable “green chip” that’s cheaper and less toxic than the materials currently used in electronics. Every little bit helps when we’re piling landfills with thrown out phones, especially when dangerous chemicals in existing computer chips, like gallium arsenide, can leak into the ground. Perhaps this new technology could lead to, say, entire phones being made out of wood-based materials, creating a landscape of responsible electronic devices.

Most phones, tablets, and other portable gizmos are made out of stuff that isn’t biodegradable and is toxic to the environment. Plus, gadgets go obsolete so quickly, prompting folks to rapidly chuck older versions. But using a wood-based material to build the bulk of a computer chip could lead to less harmful devices in the future.

[ScienceDaily]

Image credit: University of Wisconsin

Joe_Limon ▸ Bryan Lufkin
5/26/15 7:30pm

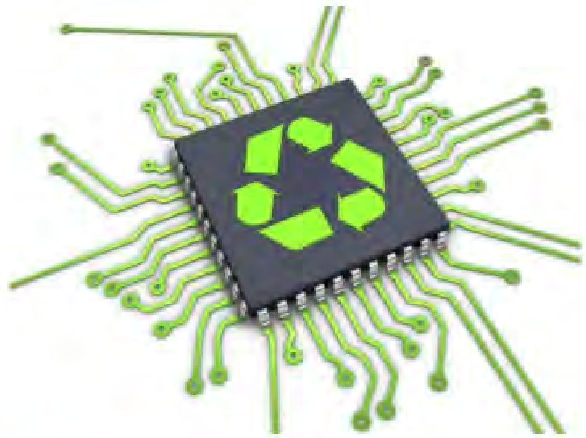
Wouldn’t the glaze layer make the chip far less biodegradable?

synthozoic ▸ Joe_Limon
5/26/15 7:39pm

Perhaps they’ve developed some biodegradable glazes?

Sicpup ▸ Joe_Limon
5/26/15 8:27pm

there are several “glazes” that are waterproof/vaporproof that still succumb to a variety of things like fungus or UV- they’ve not been used simply because there’s not been the need. Hell, even naturally occurring ammonia could do the dirty work in the process- much the way varnish from tree sap breaks down.



TECHNOLOGY PLANNING AND ANALYSIS

The wooden microchips and screens of the future

0 Posted by Dan Swinhoe on July 30 2015

There are literally billions of mobile phones, computers, tablets and other bits of technology out there. And with the arrival of the Internet of Things, analysts predict dozens of billions more being created every year. With eWaste already a 50 billion ton large (and growing) problem that causes plenty of harm to both people and planet, isn't it time we did something?

Why we need wooden microchips

"Eventually we are going to have more and more gadgets, gadgets that for the most part have not been imagined by us," says Professor Zhenqiang "Jack" Ma, an electrical and computer engineering professor at the University of Wisconsin-Madison. "All these devices will be dumped as time goes by, so that's why what I'm thinking about is that how we provide an alternative with wood, otherwise the materials will quickly be used up."

The alternative he's talking about is a new type of microchip he and his team of PhD students have developed. Instead of the usual materials such as gallium arsenide (GaAs) – a rare and toxic substance used for its semi-conductive properties – the semi-conductor's support layers (also known as the substrate) are replaced with Cellulose Nanofibril (CNF) subtrate, a flexible, transparent, biodegradable material made from natural wood crystals. Much in the same way graphene is ultra-

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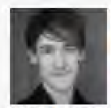

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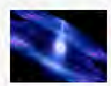

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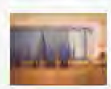

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So many elections, so little tech

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into sheets of paper, then coated in a thin layer of epoxy resin to protect it.

According to the team's snappily-named research paper, *High-performance green flexible electronics based on biodegradable cellulose nanofibril paper*, the chip performs on par with the kinds of chips you'll find in your own smartphone, yet can be left in the forest to decompose and are "as safe as fertilizer". The CNF chips still use a thin layer of gallium arsenide, but an amount that is around 3,000 to 5,000 times less than a normal chip would require.

The road to drinkable paper

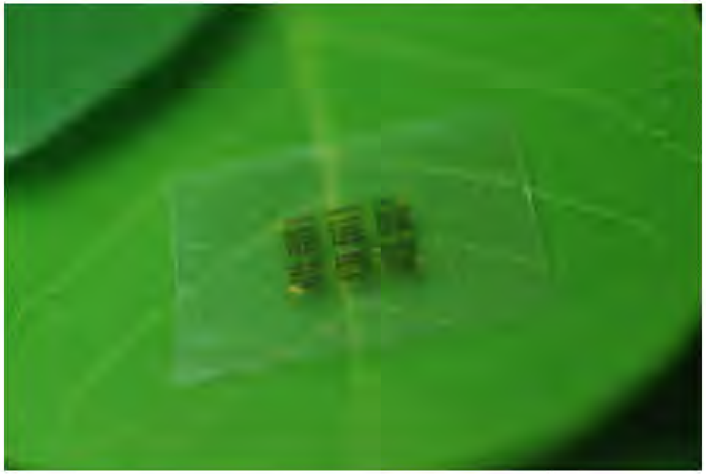
Professor Ma has long been concerned with the issue of eWaste. "In 2007, I read a magazine that reported that in US, per day, people were discarding 426,000 mobile phones that are still working. Those numbers shocked me." He recalls that most summers his university's hallways are full of dumped computers due to be replaced.

This meant he was happy to help when Professor Shaoqin "Sarah" Gong, a biomedical engineer who was working with the Madison-based US Department of Agriculture Forest Products Laboratory (FPL), came to see if there was a way to combine the flexible nanomembrane technology Ma and his team had been working on with wood-based biomaterial for new applications.

"I say 'let's talk'. I have no idea whether it's going to work or not. So then we sit together," he explains, "and I tell them, I feel like there's opportunity there.""

Those initial meetings led to two and a half years of development to make sure that these new chips were as good as the toxic incumbents. The first test was ensuring that it possesses the correct thermal qualities and wouldn't expand or melt at too low a temperature; the second was to ensure that it had a low level of radio frequency energy loss (an important factor in wireless communications). Early tests proved fruitful.

"We thought after testing, 'oh my god, this is great material'," says Ma. "It's very, very flexible, thermal expansion co-efficient is smaller than plastic we had been using."



The last issue to solve was ensuring the chip was biodegrable yet wouldn't turn to mulch is accidently exposed to moisture. "It's a wood-based material. Once you put it in water, get moisture, it's going to expand and then it's going to decompose, and we don't want that to happen."

The answer? A thin layer of epoxy to act a barrier, problem solved. While there was worry that this epoxy may impact how the chips decompose, the team found certain fungi had no problem with the extra layer. "After we've finished all transistors, circuitry etc. - the performance is as good as the one that other people are doing on the regular way. So that was really surprising."

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25 May 2018 is when the GDPR becomes law, so 24 May is your final deadline to achieve compliance.

Robert Edwards on GDPR: It's about privacy, not security

At least I now know that mine isn't the only voice in the wilderness. Well done, Ms FitzPatrick, not least for validating everything I've said...

Robert Edwards on GDPR: It's about privacy, not security

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SATYANARAYAN B on GDPR: It's about privacy, not security

Just to prove a point about how environmentally friendly these chips are, you could basically blend them into your smoothie. "Because we use so little [toxic material], we found if we throw these chips in the drinking water, it's still safe!" explains Ma – referring to the fact the chips use so little Gallium Arsenide, it passes Environmental Protection Agency standards for safe drinking water.

The potential for wooden screens and beyond

The paper industry is hundreds of years old, and so the processes are obviously about as mature and efficient as they're going to get – which bodes well for this technology. "Paper is co cheap; imagine a sheet of A4 – on paper this size you can make almost millions of transistors."

While the focus so far has been around consumer mobiles, it's not only microchips Professor Ma thinks this technology could help. The transparency of the CNF paper is greater than glass, and so offers a potential alternative for the millions of screens in the world as well as an option for solar cells, while if made thicker there's potential as a renewable phone casing. And that's just for a start.

"Flexible electronics components will be produced a lot more than regular ones in the next 10 or 20 years," says the professor, who thinks the thin and flexible nature of CNF could provide a low-cost alternative.

A patent for this technology was filed in May, and once that's cleared, Ma and his team will start looking for investors and work towards commercialising the technology [other stories on the paper have reported that one unnamed firm is interested in the technology]. For now the major challenge is getting the time to work on it. "We have over 30 projects we're working on, some of the things we are trying to commercialise, this is just one of them."

The future of microchips

Although there's still more research to be done, the technology is basically ready. Professor Ma says that a whole phone made of biodegradable material could be a reality within the next decade. "I feel like, technology-wise, less than five years, for sure. I think maybe in two or three years if we had the resources. There's no big technical barriers anymore."

"But the major thing is whether really we can really bring [it] to market." Because despite the potential of this technology, Ma doubts that we'll we see chipmakers changing their habits and adopting the concept any time soon. "Their profits and margins are getting smaller and smaller because of competition, the main reason they can earn money is because they can produce a lot. So will they [chipmakers] change their whole processes? I really doubt it. They don't care about the environment and nobody presses them to do it."

Despite his pessimism, Professor Ma does have faith that the industry can eventually change. "The final product assembly companies - like Apple or Samsung - they buy chips from the chip makers and put them together," he explains. "If their customers said, 'ok we want our devices - the Galaxies, iPhones etc. - to become flexible or transparent' they would think it's time to make a change. But that takes time."

For now Ma thinks that it's up to him and his team to create "something really fancy on the product side" to take to the likes of Samsung or Apple to show them that the technology really does work and is ready. "Technology-wise, I think it's easy. But in terms of how to steer the market direction, that takes a lot of effort."

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See-Through Sensors for Better Brain Implants

By Jeremy Hsu
Posted 24 Oct 2014 | 13:00 GMT

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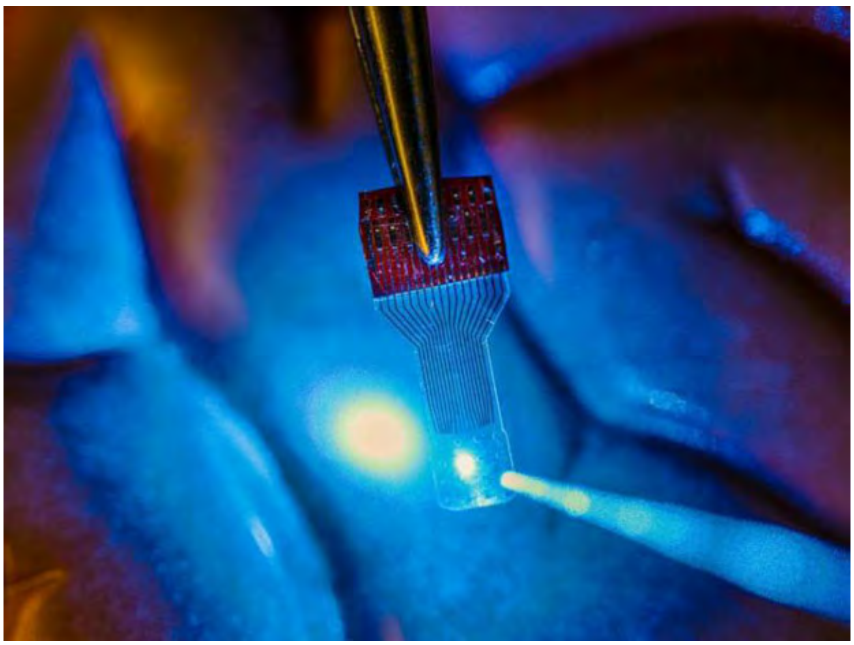


Photo: Justin Williams Research Group

The Human OS
Big Data Revolutionizes Medicine and Healthcare

Brain scientists first discovered how to use light to remotely control genetically-modified brain cells about a decade ago—a breakthrough that has enabled new scientific studies of depression, addiction and Parkinson's disease. Now a new generation of transparent brain sensors could record brain cell responses without blocking the light's access to the underlying brain tissue.

The brain control technique that seems to hearken from science fiction, called optogenetics, has traditionally relied on metallic sensors sitting on the surface of the brain to record the organ's responses to the light stimulation. Some transparent versions of the brain implants have tried electrodes made of indium-tin oxide, a brittle material that is ill-suited to the idea of flexible brain sensors and has limited transparency for certain wavelengths of light. In a study published this week in Nature Communications, a team of U.S. researchers working with a Thai colleague have shown how sensors made from graphene could work much better.

“A traditional implant looks like a square of dots, and you can't see anything under it,” said Justin Williams, a professor of biomedical engineering and neurological surgery at the University of Wisconsin-Madison, in a press release. “We wanted to make a transparent electronic device."

The new device mainly consists of four layers of graphene—each layer just one atom thick—sandwiched between two layers of moisture-proof polymer. Researchers had to strike a balance between having better conductivity with increasing material thickness and having better transparency with a greater thinness. Thinness also helps give the new device its flexibility so that the sensors can adjust to the surface of the brain.

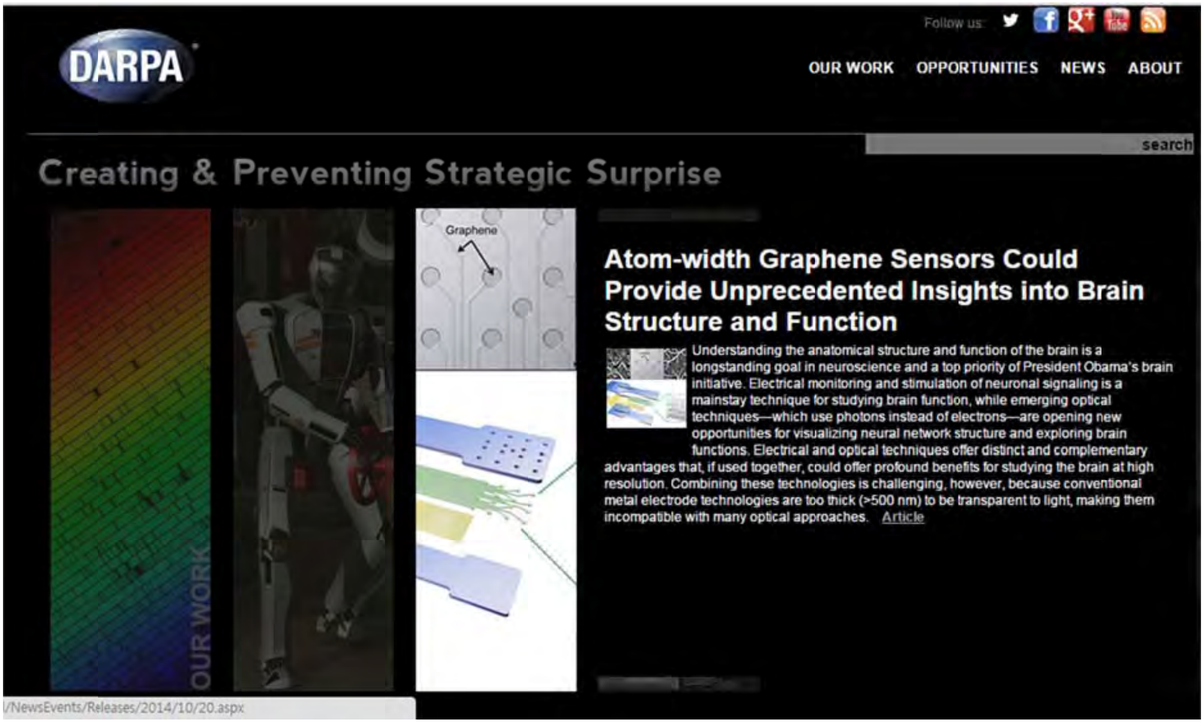
A thin graphene arrangement allowed more than 90 percent of light—from the ultraviolet to infrared—to pass through. By comparison, sensors made from indium-tin oxide allowed 80 percent of light through; traditional sensors made from thin metallic materials allowed just 60 percent . Researchers tested the brain devices by surgically implanting them in lab rats and mice.

“Other implantable microdevices might be transparent at one wavelength, but not at others, or they lose their properties,” said Zhenqiang (Jack) Ma, a professor of electrical and computer engineering at UW-Madison, in the press release. “Our devices are transparent across a large spectrum... We’ve even implanted them and you cannot find them in an MR scan.”

Such transparency should give a boost to optogenetics studies, which have already shown a remarkable ability to control the brain. One of the latest studies looked at using lasers to transform bad memories into good memories in mice.

The new transparent sensors should also be compatible with a wide range of brain imaging techniques that rely on various light wavelengths. That’s crucial for medical researchers trying to understand how newelectromagnetic or drug treatments can help patients with brain-related diseases such as epilepsy or Parkinson’s disease.

Transparent sensors could also spawn a wide variety of other medical uses. For instance, the UW-Madison team is working with the University of Illinois-Chicago on putting the transparent sensors on contact lenses as a way of monitoring retinal damage or diagnosing glaucoma early on.



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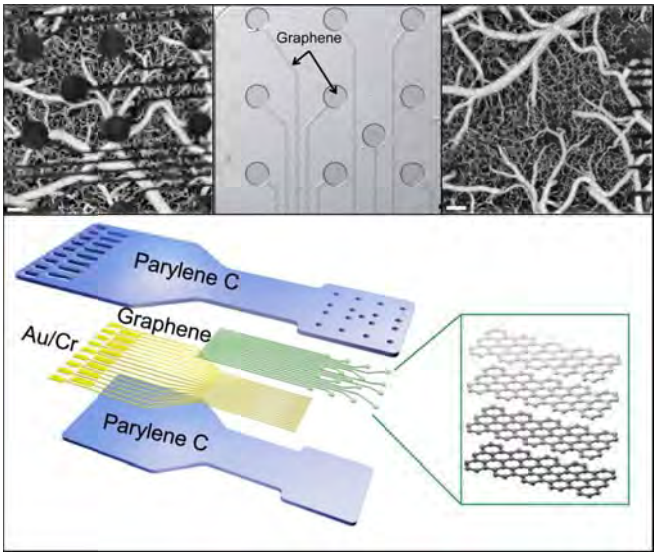
Atom-width Graphene Sensors Could Provide Unprecedented Insights into Brain Structure and Function
Understanding the anatomical structure and function of the brain is a longstanding goal in neuroscience and a top priority of President Obama's brain initiative. Electrical monitoring and stimulation of neuronal signaling is a mainstay technique for studying brain function, while emerging optical techniques—which use photons instead of electrons—are opening new opportunities for visualizing neural network structure and exploring brain functions. Electrical and optical techniques offer distinct and complementary advantages that, if used together, could offer profound benefits for studying the brain at high resolution. Combining these technologies is challenging, however, because conventional metal electrode technologies are too thick (>500 nm) to be transparent to light, making them incompatible with many optical approaches. Article
/NewsEvents/Releases/2014/10/20.aspx

DARPA press release

http://www.darpa.mil/NewsEvents/Releases/2014/10/20.aspx

ATOM-WIDTH GRAPHENE SENSORS COULD PROVIDE UNPRECEDENTED INSIGHTS INTO BRAIN STRUCTURE AND FUNCTION

October 20, 2014



Conventional metal electrode technologies (top left) are opaque, obstructing views of underlying neural tissue. DARPA's RE-NET program has developed new graphene sensors that are electrically conductive but only 4 atoms thick—hundreds of times thinner than current contacts (top middle). Their extreme thinness enables nearly all light to pass through across a wide range of wavelengths. Placed on a flexible plastic backing that conforms to the shape of tissue (bottom), the sensors are part of a proof-of-concept tool that demonstrates much smaller, transparent contacts that can measure and stimulate neural tissue using electrical and optical methods at the same time (top right).

New technology funded by DARPA's RE-NET program enables monitoring and stimulation of neurons using optical and electronic methods simultaneously

Understanding the anatomical structure and function of the brain is a longstanding goal in neuroscience and a top priority of President Obama's brain initiative. Electrical monitoring and stimulation of neuronal signaling is a mainstay technique for studying brain function, while emerging optical techniques—which use photons instead of electrons—are opening new opportunities for visualizing neural network structure and exploring brain functions. Electrical and optical techniques offer distinct and complementary advantages that, if used together, could offer profound benefits for studying the brain at high resolution. Combining these technologies is challenging, however, because conventional metal electrode technologies are too thick (>500 nm) to be transparent to light, making them incompatible with many optical approaches.

To help overcome these challenges, DARPA has created a proof-of-concept tool that demonstrates much smaller, transparent contacts that can measure and stimulate neural tissue using electrical and optical methods at the same time. Researchers at the University of Wisconsin at Madison developed the new technology with support from DARPA's Reliable Neural-Interface Technology (RE-NET) program. It is described in detail in a paper in Nature Communications (http://ow.ly/CSBNF).

"This technology demonstrates potentially breakthrough capabilities for visualizing and quantifying neural network activity in the brain," said Doug Weber, DARPA program manager. "The ability to simultaneously measure electrical activity on a large and fast scale with direct visualization and modulation of neuronal network anatomy could provide unprecedented insight into relationships between brain structure and function—and importantly, how these relationships evolve over time or are perturbed by injury or disease."

The new device uses graphene, a recently discovered form of carbon, on a flexible plastic backing that conforms to the shape of tissue. The graphene sensors are electrically conductive but only 4 atoms thick—less than 1 nanometer and hundreds of times thinner than current contacts. Its extreme thinness enables nearly all light to pass through across a wide range of wavelengths. Moreover, graphene is nontoxic to biological systems, an improvement over previous research into transparent electrical contacts that are much thicker, rigid, difficult to manufacture and reliant on potentially toxic metal alloys.

The technology demonstration draws upon three cutting-edge research fields: graphene, which earned researchers the 2010 Nobel Prize in Physics; super-resolved fluorescent microscopy, which earned researchers the 2014 Nobel Prize in Chemistry; and optogenetics, which involves genetically modifying cells to create specific light-reactive proteins.

RE-NET seeks to develop new tools and technologies to understand and overcome the failure mechanisms of neural interfaces. DARPA is interested in advancing next-generation neurotechnologies for revealing the relationship between neural network structure and function. RE-NET, and subsequent DARPA programs in this field, plan to leverage this new tool by simultaneously measuring the function, physical motion and behavior of neurons in freely moving subjects. This technology provides the capability to modulate neural function, by applying programmed pulses of electricity or light to temporarily activate neurons. Therefore, it could not only provide better observation of native functionality but also, through careful modulation of circuit activity, enable exploration of causal relationships between neural signals and brain function.

"Historically, researchers have been limited to correlational studies that suggest, but do not prove causal linkages between neural activity and behavior," Weber said. "Now, we have the opportunity to directly see, measure and stimulate neural circuits to explore these relationships and develop and validate models of brain circuit function. This knowledge could greatly aid how we understand and treat brain injury and disease."

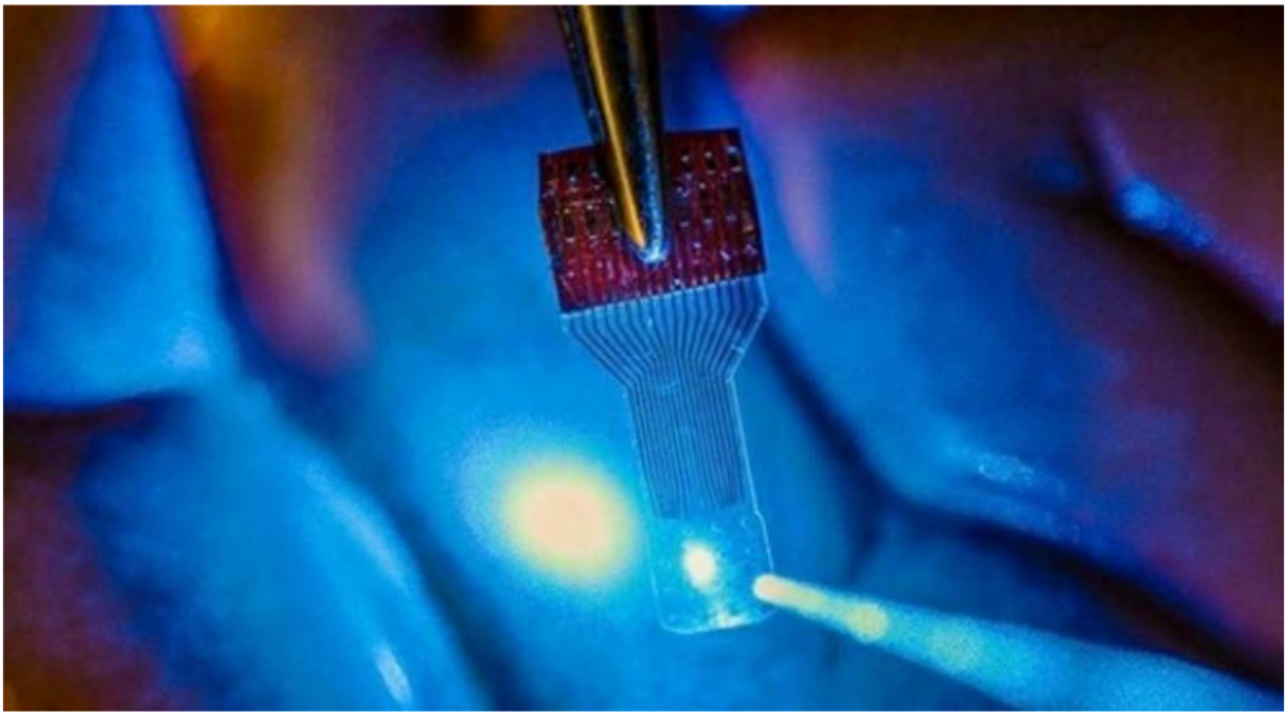
RE-NET is part of a broader portfolio of programs within DARPA that support President Obama's brain initiative. These programs include ongoing efforts designed to advance fundamental understanding of the brain's dynamics to drive applications (Revolutionizing Prosthetics, Restorative Encoding Memory Integration Neural Device, Reorganization and Plasticity to Accelerate Injury Recovery, Enabling Stress Resistance), manufacture sensing systems for neuroscience applications and therapies (Hand Proprioception & Touch Interfaces,Electrical Prescriptions) and analyze large data sets (Detection and Computational Analysis of Psychological Signals).

University of Wisconsin-Madison, and UPenn group

http://www.extremetech.com/extreme/192510-transparent-optogenetic-brain-implants-yet-another-amazing-use-for-graphene

Transparent optogenetic brain implants: Yet another amazing use for graphene

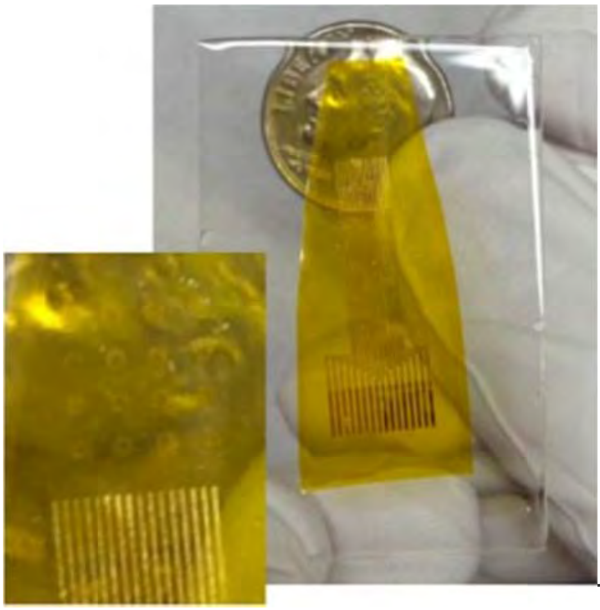
- By John Hewitt on October 21, 2014 at 12:32 pm
- **0 Comments**



Transparency is the key to many technologies. Thin conductive films, like those made from ITO (indium tin oxide) for example, can carry currents or create electric fields critical for displays or solar panels without blocking all the light. The most powerful brain implants being built today have exactly this same requirement. Namely, they need to record fast electric signals with conductive arrays while permitting light to pass out through them for high-resolution imaging — and just to take it up a notch — let light pass *in*for optogenetic control directly under the implant is the icing on the cake.

Unfortunately, ITO is generally too stiff and too brittle for brain implants. Even if it could be made flexible, the high temperatures required to process it are incompatible with many of the materials (like parylene) that are used in the implants. Furthermore the transparency bandwidth of ITO is insufficient to fully exploit the wide spectrum of new UV and IR capableoptogenetic proteins that have researchers fairly excited. The solution, now emerging from multiple labs throughout the universe is to build flexible, transparent electrode arrays from graphene. Two studies in the latest issue of Nature Communications, one from theUniversity of Wisconsin-Madison and the other from Penn, describe how to build these devices.

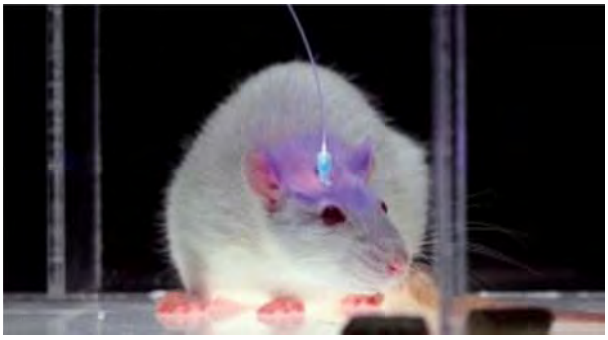
The University of Wisconsin researchers are either a little bit smarter or just a little bit richer, because they published their work open access. It's a no-brainer then that we will focus on their methods first, and also in more detail. To make the arrays, these guys first deposited the parylene (polymer) substrate on a silicon wafer, metalized it with gold, and then patterned it with an electron beam to create small contact pads. The magic was to then apply four stacked single-atom-thick graphene layers using a wet transfer technique. These layers were then protected with a silicon dioxide layer, another parylene layer, and finally molded into brain signal recording goodness with reactive ion etching.



The researchers went with four graphene layers because that provided optimal mechanical integrity and conductivity while maintaining sufficient transparency. They tested the device in opto-enhanced mice whose neurons expressed proteins that react to blue light. When they hit the neurons with a laser fired in through the implant, the protein channels opened and fired the cell beneath. The masterstroke that remained was then to successfully record the electrical signals from this firing, sit back, and wait for the Nobel prize office to call.

Read: MIT successfully implants false memories with optogenetics, may explain why we remember things that didn't happen

The Penn State group used a similar 16-spot electrode array (pictured above right), and proceeded — we presume — in much the same fashion. Their angle was to perform high-resolution optical imaging, in particular calcium imaging, right out through the transparent electrode arrays which simultaneously recorded in high-temporal-resolution signals. They did this in slices of the hippocampus where they could bring to bear the complex and multifarious hardware needed to perform confocal and two-photon microscopy. These latter techniques provide a boost in spatial resolution by zeroing in over narrow planes inside the specimen, and limiting the background by the requirement of two photons to generate an optical signal. We should mention that there are voltage sensitive dyes available, in addition to standard calcium dyes, which can almost record the fastest single spikes, but electrical recording still reigns supreme for speed.



What a mouse looks like with an optogenetics system plugged in

One concern of both groups in making these kinds of simultaneous electro-optic measurements was the generation of light-induced artifacts in the electrical recordings. This potential complication, called theBecqueral photovoltaic effect, has been known to exist since it was first demonstrated back in 1839. When light hits a conventional metal electrode, a photoelectrochemical (or more simply, a photovoltaic) effect occurs. If present in these recordings, the different signals could be highly disambiguatable. The Penn researchers reported that they saw no significant artifact, while the Wisconsin researchers saw some small effects with their device. In particular, when compared with platinum electrodes put into the opposite side cortical hemisphere, the Wisconsin researchers found that the artifact from graphene was similar to that obtained from platinum electrodes.

At this point both groups are busy characterizing the performance of their new devices in exacting detail. If workable as more permanent brain implants they may offer a nice compliment to other new approaches we have recently seen — flexible materials like silk for example. Where silk may offer biodegradability and reversibility, graphene may offer biocompatible permanence and reliability. The significant hype regarding optogenetics, well-founded in our opinion, seems to have died down for the moment. New advances like those just described may help refocus general attention on the huge potential benefit ofoptogenetics hold for humans.

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• Created analysis tools for reducing vibration damage in hypersonic aircraft,
• Pioneered technologies that combine infrared and visible light to produce high-resolution military surveillance images,
• Devised a new laser for on-chip optical connects that could give computers a huge boost in speed and energy efficiency,
• Improved tools for modeling vibrations so that space telescopes provide the clearest possible view of objects in space and on Earth,
• Developed fast, flexible, low-power 3-D computer chips for electronics such as small cameras with high resolution,
• And contributed many more key advances!
Congratulations to the Air Force Office of Scientific Research on 60 years of discovery!

Advanced Concepts in Space Situational Awareness (SSA) (2000-present)

Air Force Office of Scientific Research (AFOSR)-funded researchers invented the Physically Constrained Iterative Deconvolution (PCID) algorithm and proved that this algorithm achieves or closely approaches the theoretical limits of image quality. The initial development of PCID was funded by AFOSR in FY 2000 as an Air Force Research Laboratory Directed Energy (AFRL/DE) lab task. PCID is an iterative image-restoration algorithm. It estimates and removes atmospheric and system blurring from one or more frames of blurred imaged data to produce a single high-resolution picture. PCID is being further improved to incorporate additional data such as wavefront sensor measurements in order to generate even higher-quality image restorations. Armed with this essential fundamental knowledge of PCID capability, the Department of Defense (DoD) determined sufficient computational power existed to warrant investment in a large software development effort to produce an engineering tool that would be fast enough to provide timely operational SSA to the warfighting commands. Thus, the Institute for Space Situational Awareness was founded and funded to take advantage of this basic research accomplishment, which is in current SSA application as well as other uses.[92]

Bendable Electronics (2008-present)

AFOSR has provided research funding for fast, bendable electronics on two fronts: organic/polymeric materials and inorganic/semiconductor applications. Dr. Charles Lee, the AFOSR Program Manager who supports the organic/polymer effort, noted that because organic materials are flexible and can be printed onto large areas, they have potential uses in conformal electronics over large structural areas or antennas. Drs. Tobin Marks of Northwestern University and Zhenan Bao of Stanford University, working independently, have been making great progress regarding the charge transport speed, as well as creating air-stable negative charge conducting organics as well as positive charge conducting materials, a necessary combination to create sophisticated electronic circuits. Marks, in collaboration with a small company, has been able to demonstrate standard silicon (CMOS)-type circuitry based on organic materials. The organic/polymeric electronic materials research effort is now investigating materials that can be applicable to "stretchable" electronics. With advances in inorganic membrane research, flexible or bendable electronics can be fabricated from more traditional inorganic materials. For example, the research team led by Dr. Zhenqiang "Jack" Ma of the University of Wisconsin-Madison developed super-flexible silicon chips that can withstand impact and severe vibration. By adding pressure to the chips, Ma and Professor Max Lagally have increased chip performance to speeds 50 times faster than previous efforts. Ma is also working on flexible photodetectors,

or optoelectronics, which are applicable for high-speed photography. He relates the successes of his research to his progress with new forms of semiconductor material, particularly nanomembranes. The Air Force could have a number of new uses for his research with flexible electronics and optoelectronics, including compact antennae attached to airplane bodies and missiles, flexible sensors that detect mechanical changes, and 360-degree air surveillance applications. Dr. Gernot Pomrenke, the AFOSR Program Manager who supports this work, noted that this effort is a very timely and relevant area of research for the Air Force and DoD, as well as for the semiconductor material and device component industries. The ability to synthesize and manipulate extremely thin films of solid-state materials enables wholly new approaches for improving performance and reducing the size, weight, and power in defense and commercial systems.[93]

Updateable Holographic 3-D Displays (2006-present)

A group of AFOSR-funded scientists from the College of Optical Sciences at the University of Arizona developed unique, updateable holographic three-dimensional (3-D) displays that can be used in military applications. This is the first-ever rewritable hologram for 3-D image visualization. A team led by Dr. Nasser Peyghambarian is pioneering research using 3-D holographic images. Peyghambarian noted that, "3-D imaging allows a lot of data to be presented simultaneously, a task that is not possible with the use of 2-D pictures. Up until now, dynamic holographic 3-D images suitable for practical uses did not exist. Our newly developed displays exhibit memory and large size, which makes them stand out among other approaches to dynamic 3-D imaging. Dr. Charles Lee, the AFOSR Program Manager for this project, said, "This research is one of the fruits of continuing AFOSR support in the development of photorefractive polymers for the last 16 years." IBM first reported this polymer in the early '90s, during which time several AFOSR-supported groups were actively engaged in research in this area. Subsequent research has demonstrated the use of these materials for image correlation, wavefront correction, and optical signal processing. Peyghambarian also noted that, "In practical military applications, the holographic 3-D images can be used for command and control – viewing battlespace in nearly real time using realistic images that can be updated regularly at short intervals." The research team is able to achieve 3-D images by using holography to store the appearance of objects or scenes into thin films with the use of laser light, and they have gone one step further beyond static images by replacing fixed holographic storage materials with dynamic ones. Dr. Darrel G. Hopper and a team at the Air Force Research Laboratory Effectiveness Directorate at Wright-Patterson Air Force Base (AFB) in Ohio are also exploring "true 3-D" technologies for applications in air, space, and cyber command centers. Hopper uses the term true 3-D to distinguish systems like the AFOSR updatable holographic effort at the University of Arizona. The next steps in this program are to increase the size of the 3-D displays, make them in color, and increase the writing speed of the images. The psychological aspects of 3-D viewing and the question of how humans interact with 3-D displays also need to be examined. "For example, it's believed that pilots may react and make decisions much faster if [the information they are provided is 3-D,] which is much more realistic compared with the usual 2-D displays they currently use," said Peyghambarian.[94]

Advances in night vision from cow country

By Allison Barrie

Published January 10, 2013

Breakthroughs in flexible semiconductors may lead to better and easier night vision for the military and law enforcement, thanks to the University of Wisconsin.

To build goggles with more accurate night vision for pilots and soldiers, the DOD and USAF Office of Scientific Research worked with University of Wisconsin-Madison electrical and computer engineer professor Zhenqiang "Jack" Ma.

Wider Field

The Air Force Office of Scientific Research gave the school $750,000 in funding to support the first project: a new curved surface for night-vision goggles.

A curved surface can improve the field of view, making it wider, for night-vision goggles. But building a curved surface is tricky, and requires not just highly photosensitive materials but also a pliable material. 'They are looking for the highest resolution they can get. Something that can take one picture with everything in it.'

- University of Wisconsin professor Zhenqiang "Jack" Ma

Silicon used in many image sensors is simply not good enough; Ma’s solution was to use flexible germanium nanomembranes instead -- that’s the obscure element germanium from the periodic table, not geranium as in potted plants on the porch.

High “dark current” has made this flexible semiconductor material difficult to use in imagers. Dark current is background electrical current that flows through photosensitive materials whether or not the material is subjected to light. Germanium-based imagers have an elevated dark current and this causes noisier images. Ma solved the problem by reducing the dark current with new tech that makes this critical flexible material practical to use.

IR and visible image in one picture

In a second imaging project, Ma focused on the search for one picture combining IR and visible images in the highest possible resolution. The DOD gave him a second $750,000 in funding to develop a military surveillance imager that can span multiple spectra and combines infrared and visible light into a single image. Currently, the traditional approach uses one sensor for visible light, another for IR images and then the two versions of the image are combined. "They are looking for the highest resolution they can get," Ma said. "Something that can take one picture with everything in it." IR can penetrate obscurants like dust and smoke that visible light might find difficult. While visible light imagers can be made with relatively cheap silicon, IR imagers are made of materials that are not compatible with silicon. Ma solved the incompatibility problem by using a heterogeneous semiconductor nanomembrane and by layering the two incompatible materials in each pixel on top of each other. “Simultaneous visible and IR imaging allows [the military] to see everything," he said.

Ballet dancer turned defense specialist Allison Barrie has traveled around the world covering the military, terrorism, weapons advancements and life on the front line. You can reach her at wargames@foxnews.com or follow her on Twitter @Allison_Barrie.

MILWAUKEE WISCONSIN JOURNAL SENTINEL

BIG IDEAS 2012

Fifteen of Wisconsin's most interesting brainstorms

Dec. 29, 2012

A quiet scanner

General Electric Co.'s Waukesha magnetic resonance facility has developed a new machine that the company is calling "Silent Scan," a technology designed to deal with a persistent complaints about magnetic resonance scans - excessive noise. Conventional scanners can produce noise equivalent to a rock concert. The new GE Silent Scan technology (which runs on GE Optima MR450w system shown below) is designed to reduce scanner noise to the level of background noise. The new device does it through the use of new 3D "acquisition and reconstruction technique" called Silenz, in combination with GE Healthcare's advanced electronics. Sshhh!

MU's ultimate numbers guy

From the Milwaukee Journal Sentinel to The New York Times and Fox News, the Marquette University Law School Poll created quite a national buzz this year. Wisconsin, as usual, was a battleground state - and a center for politics because of an unprecedented recall election of Gov. Scott Walker. That made a credible poll a hot commodity. And the MU poll was - it was unbiased and accurate, predicting voter sentiment from the gubernatorial recall election to the Wisconsin presidential and senatorial races each within one point. The school conducted 15 polls throughout the year, which will provide a historical record that will be useful for many years.

Ma never steers you wrong - especially on silicon

At the University of Wisconsin-Madison, electrical and computer engineering professor Zhenqiang "Jack" Ma is devising ways to carve circuitry into flexible silicon membranes. The resulting microchips can operate at higher speeds and lower power than conventional rigid chips, lengthening the life of batteries in smartphones and other mobile devices. The university website reports that the "flexibility of these chips gives them much wider applications than better versions of the tech we already have; they're well-suited for everything from small-scale wireless communications to more comfortable, reliable biomedical devices." Ma says, "Because they are flexible, you can put them anywhere you want - on your skin, your clothes, wherever." "The applications are very, very broad," he says. Listen to Ma.

An innovative caregiver support system

An innovative caregiver support system developed at the University of Wisconsin-Milwaukee went commercial this year, allowing the program to help even more families. The TCARE System has been used by a number of state agencies and other organizations for several years. TCARE Navigator, a Milwaukee-based start-up company, will bring this system to a broader audience by promoting it to private insurers, accountable care organizations, self-insured employers and U.S. government agencies. TCARE (Tailored Caregiver Assessment and Referral) is a care-management process that helps family caregivers receive the support they need to help their aging and disabled family members. The system was developed by Rhonda Montgomery, Helen Bader Endowed Chair in Applied Gerontology in UWM's Helen Bader School of Social Welfare. Montgomery led the TCARE team that was the recipient of the 2010 Rosalynn Carter Leadership in Caregiving Award, the nation's highest honor given in the caregiving field. Searching for the source of diabetes

The Medical College of Wisconsin will use a new $4.3 million grant from the National Institutes of Health to try to track down the exact genes that contribute to the onset of Type 1 diabetes. A team of scientists will "knock out" genes suspected to be contributors to Type 1 diabetes in mice and try to begin narrowing down which specific genes are associated with the illness. The project aims to analyze 100 different genes over four years

SEMICONDUCTORS / OPTOELECTRONICS

NEWS

Very Thin Lasers Could Speed Computers

Slimmer vertical lasers could link microchips with light

By NEIL SAVAGE / JULY 2012

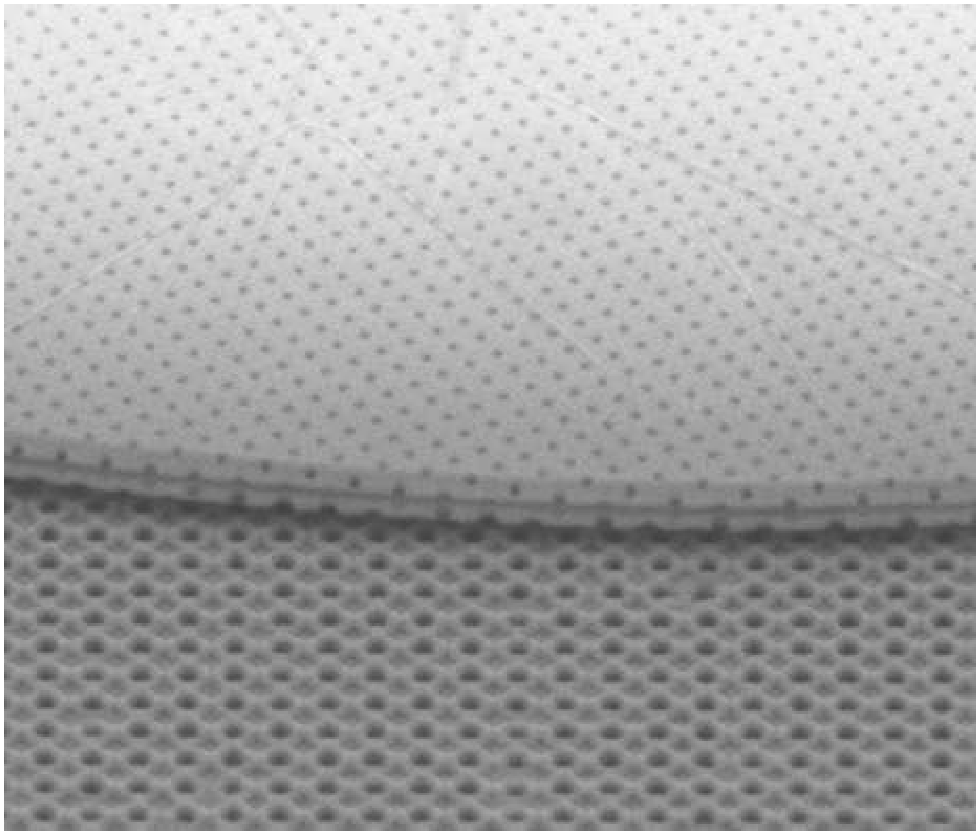


Image: Dr. Hongjun Yang

HOLY MIRRORS! Photonic crystal reflectors are made from a patterned piece of silicon, to keep the profile of a new kind of laser slim.

1 August 2012—A new type of ultrasmall laser could bring optical communications onto computer chips, breaking a bottleneck that limits computing speed.

The laser is small enough to allow an array of hundreds of them to be placed on a chip, the researchers who devised it say in a July online paper for *Nature Photonics*. “Once you make it so flat, thin, on-chip integration becomes very simple,” says Zhenqiang Ma, professor of electrical and computer engineering at the University of Wisconsin–Madison. Data transfer between processors is limited by the capacity of copper wires to carry signals, but this can be overcome by using beams of light, just as optical fiber is being used to replace copper cables in the telephone system.

Previous designs for this type of laser led to devices that were between 15 and 30 micrometers tall, toweringly high on a chip on which other features are measured in tens of nanometers. The new laser, designed by Ma and Weidong Zhou, a professor of electrical engineering at the University of Texas at Arlington, stands just 2 µm high.

The device is a vertical-cavity surface-emitting laser (VCSEL), which emits light through its top surface. Chip designers will most likely prefer VCSELs to more traditional, edge-emitting lasers, in which the beam comes out of one end. VCSELs are easier to manufacture, easier to align with elements like optical fibers, and easy to build into arrays of multiple lasers. Every laser needs a mirror at each end to bounce photons back and forth through the laser cavity, thus building up the light beam. Most VCSELs use distributed Bragg reflectors—alternating layers of material with different refractive indexes—to act as mirrors, but it’s these layers that make the laser so tall.

Instead of Bragg reflectors, Zhou and Ma used much thinner structures, photonic crystal mirrors made of a particular pattern of silicon and air-filled gaps. They built the active part of the laser out of indium gallium arsenide phosphide, a compound semiconductor.

Assembling the device required transfer printing, a technique developed by John Rogers, a materials scientist at the

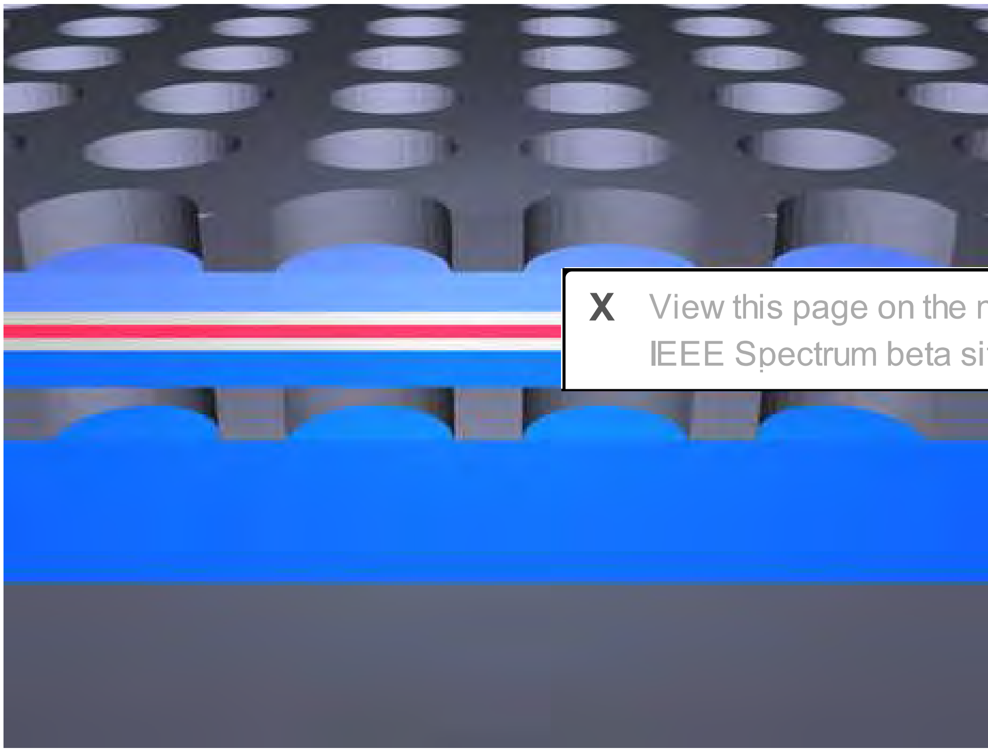


Image: Dr. Hongjun Yang

LOW PROFILE: Instead of being sandw iched by bulky Bragg reflectors, the active material [red] in this slim vertical cavity surface emitting laser lies betw een to photonics crystal mirrors [blue]. The laser is assembled on silicon using transfer printing.

University of Illinois at Urbana-Champaign. In that process, Ma and his colleagues pressed a sticky polymer gel onto each piece they wanted to transfer, such as the mirror. Lifting the gel rapidly pulled piece underneath up with much the same way ing off a Band-Aid pulls the hair on your arm. They then placed the piece where they wanted it and pulled the gel away slowly, leaving the piece behind.

In this case, the researchers built the first mirror directly on the chip and the laser cavity and second mirror each on separate wafers. Then they used transfer printing to place the laser cavity on top of the first mirror and put the second mirror on top of the cavity. Thin layers of silicon oxide between the layers held the whole thing together. The researchers say the technique is compatible with processes for making silicon logic chips, which can't tolerate the high temperatures needed for other laser-manufacturing approaches. "It's the only way to make a laser in a low-temperature process," Ma says.

The laser they built shines with a wavelength of 1550 nanometers, which is common in communications systems. Zhou says they could produce other wavelengths by altering the design of the photonic crystals or by using different semiconductor materials, allowing the arrays to send multiple streams of data over different wavelengths simultaneously and thus increasing bandwidth.

"This is an interesting piece of research and is novel in that they propose to use vertically emitting devices," says Jeffrey Kash, a senior researcher in the Center for Integrated Science & Engineering at Columbia University. "As a first step, it is a very nice result."

Kash adds, though, that a number of key improvements are needed to make the lasers practical. For one, the lasers will need to run on electricity; right now, they depend on another laser beam as a power source. The researchers also need to efficiently increase their power to at least 1 milliwatt. [[different antecedents]]

Zhou believes the research team will have an electrically pumped version of the laser within a year or two and that they will also be able to improve its other characteristics. "In theory, we believe our laser should have much better performance than conventional VCSELs, but, yes, we do have some ways to go," he says.

Zhou and Ma say their laser could be made commercially viable within about five years. They've formed a company, Semerane, to commercialize the technology.

About the Author

Neil Savage, based in Lowell, Mass., writes about strange semiconductors and amazing optoelectronics. In the April 2012 issue of *IEEE Spectrum*, he reported on molybdenum disulfide, a potential rival to graphene in nanoelectronics.

Laser Focus World

International Resource for Technology and Applications in the Global Photonics Industry

Printed photonic-crystal mirrors shrink size of on-chip lasers

07/26/2012

Posted by Gail Overton

Senior Editor

Madison, WI--In the July 22, 2012 issue of Nature Photonics, electrical engineers at the University of Wisconsin-Madison (UW-Madison) and the University of Texas at Arlington (UT Arlington) describe a new laser for on-chip optical connections that could give computers a huge boost in speed and energy efficiency. At just 2 micrometers in height, the suface-emitting laser's vastly lower profile could make it cheaper and easier for manufacturers to integrate high-speed optical data connections into the microprocessors powering the next generation of computers.

Traditionally, edge-emitter lasers are considered as the candidate for on-chip optical links. But since mirrors are hard to form in such lasers and because the lasers occupy a large chip area, researchers have been challenged to find a practical way to monolithically integrate the mirrors on silicon chips.

The engineers say that 20-30 micron-tall surface-emitting lasers mounted on a 1.5 micon chip dwarf their silicon surroundings. "It sits tall on the chip, like a tower," says Zhengiang Ma, A UW-Madison professor of electrical and computer engineering. "That is definitely not acceptable." In addition, another challenge is integrating the lasers into silicon chips, as silicon itself is not an efficient light emitter.

Ma and colleagues have collaborated to shrink on-chip lasers in recent years with funding from the U.S. Air Force Office of Scientific Research, Army Research Office and Defense Advanced Research Projects Agency. As a solution, the researchers propose replacing layers and layers of reflectors necessary in the traditional distributed Bragg reflector laser design with two highly reflective photonic crystal mirrors. Composed of compound semiconductor quantum well materials applied with a transfer printing process, each mirror is held in place with silicon nanomembranes, extremely thin layers of silicon.

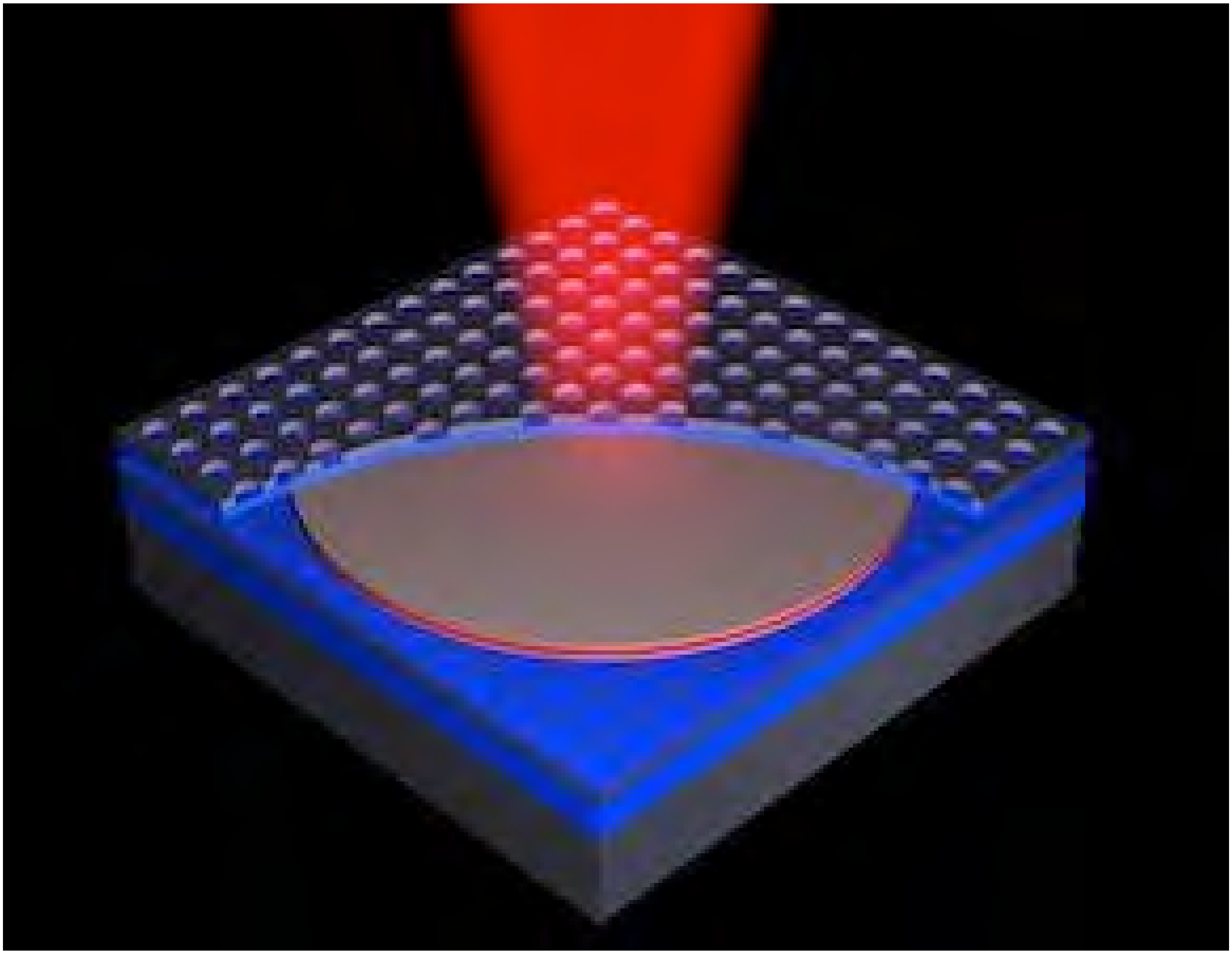
One layer of photonic crystal is equal to about 15 to 30 layers of dielectric reflectors found in conventional lasers. As a result, manufacturers could fabricate 2 micron high lasers for data links with performance that could equal current designs. The printing process also takes place at much lower temperatures that conventional designs, improving the process.

Although the Internet backbone is composed mainly of fiber-optic links between countries, cities, and houses, the data moves over to slower metal connections and wiring as it travels from a regional hub to your house, your computer ,and eventually between the CPU cores within of the processor powering your machine. "In the future, you'll see a move to optical at each step," Ma says. "The last step is within the chip, module-to-module optical links on the chip itself."

Through Semerane Inc., a Texas-based startup, the engineers hope to implement their production process in functional on-chip photonic crystal membrane lasers that could eventually be part of the next generation high-speed computer processors.

SOURCE: University of Wisconsin-Madison; www.news.wisc.edu/20895

IMAGE: An artist's representation shows a proposed on-chip laser design, created via transfer printing of photonic crystal between layers of silicon nanomembranes. (Courtesy Hongjun Yang, University of Wisconsin-Madison)



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Volume 11 • Issue

Forest Products Laboratory's

Newsline

FALL 2012

Recyclable, Compostable Stamps that Last "Forever"
FPL and the U.S. Postal Service Build on Their 20-Year Partnership

By Rebecca Wallace, Public Affairs Specialist

Forever Stamps have kept FPL researchers busy ensuring stamps remain useful, if not forever, at least close enough to qualify for the name.

Do you remember the last time you licked a stamp? Maybe not, and for good reason: 20 years have passed since the U.S. Postal Service (USPS) first started transitioning from "lickable" stamps to the peel-and-stick squares we use today, called "pressure-sensitive adhesive" stamps by those in the know.

FPL worked closely with the USPS throughout that transition, and in the two decades that have followed, to continuously improve stamps.

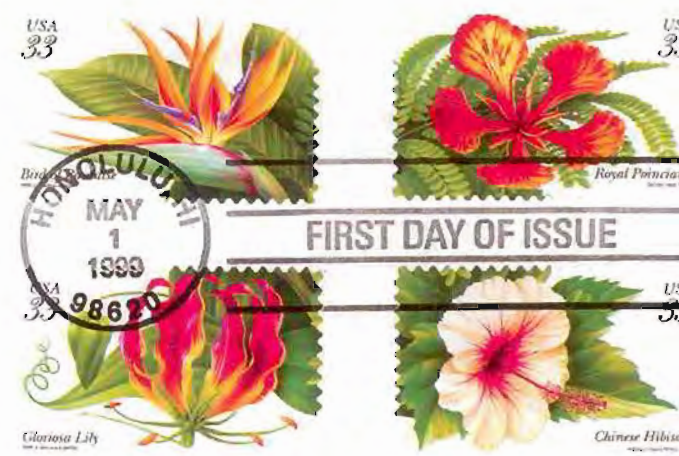
The earliest cooperative research between FPL and the USPS focused on developing pressure-sensitive adhesives that didn't gum up the equipment used to recycle paper. By developing an adhesive that was compatible with the recycling process, an additional 20 million tons of waste paper can be recycled each year.

This research project ended up reaching beyond just stamps, according to Carl Houtman, a chemical engineer at FPL. "Advancements made with the Postal Service work were of interest to the entire label industry," explained Houtman. "The Tag and Label Manufacturer's Institute has adopted the same standards as the USPS, so labels can now be certified as recycling compatible."

Today's work with the USPS is two-fold: improving stamp performance continues to be a priority, as well as reducing the environmental impact of stamp materials.

The introduction of the Forever Stamp has kept researchers busy developing improved performance and accelerated aging tests to ensure that the stamps indeed remain useful, if not forever, at least close enough to qualify for the name.

– Continued on page 7 –



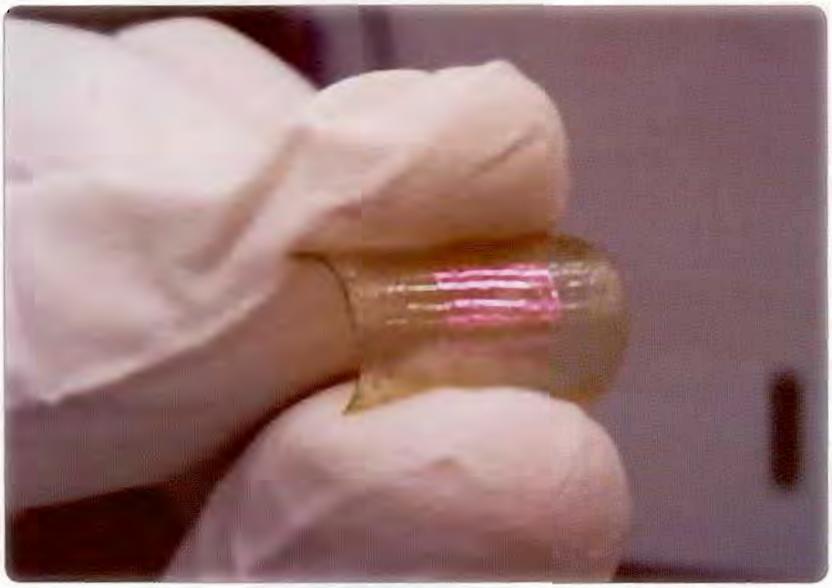
Recycling-compatible stamp using FPL-developed pressure-sensitive adhesives.

In this issue

Creating Flexible Electronics Using Nanocellulose

By Rebecca Wallace, Public Affairs Specialist

Not long ago it would have been hard to imagine throngs of people walking around with tiny computers in their pockets, able to communicate with someone around the globe instantly, just by tapping a screen. Imagining where these amazing technologies are headed next can be equally difficult.



Jung-Hun Seo, University of Wisconsin-Madison

Ron Sabo, a research materials engineer at FPL, and his partners at the University of Wisconsin (UW) have a few ideas, and they're looking to wood to make them happen—wood at the nanoscale, that is. "So far, most electronics are rigid and have glass coverings," Sabo says. "There is interest in advancing electronics by making them flexible, and we're finding nanocellulose could help make that happen."

Above and below: Nanocellulose film samples created at the Forest Products Laboratory.

Ron Sabo, USDA-FS FPL

Nanocellulose is simply wood broken down to the nanoscale. (A nanometer is approximately one-millionth the thickness of a U.S. dime.) At the nanoscale, wood is incredibly strong, lightweight, and transparent, all attributes that could enhance electronics. Flexible electronics present a wide range of possible applications, including displays, smart cards, solar cells, radio frequency tags, medical implants, and wearable computers.

Research and development have been ongoing in this arena, but some challenges have come up along the way. "The materials used to create these products must not only perform as intended," explains Sabo, "but also hold up to harsh production processes that can include drastic changes in temperature and being washed in acid."

"There is interest in advancing electronics by making them flexible, and we're finding nanocellulose could help make that happen."

High-speed flexible electronics are created by building a circuit on a very thin silicone membrane and then transferring it to a flexible substrate. Most research has used plastic as the substrate, but plastics can have drawbacks; namely, the large degree to which they expand and contract with changes in temperature. Sabo, along with UW researchers Jung-Hun Seo and Zhenqiang Ma, are studying nanocellulose composites substrates as an alternative to plastic and were recently able to successfully demonstrate the technology.

"We found several benefits to using nanocellulose composites in flexible electronics," said Sabo. "When heated, cellulose does not expand as dramatically as plastics do, and it is also a renewable resource, which is important considering how prolific electronic devices have become."

According to a U.S. Environmental Protection Agency report, in the United States alone, 129 million mobile devices were disposed of in 2009, and less than 12 million of those were

– Continued on page 7 –

material in biodegradable electronic parts, high-performance insulation aerogel material, and regenerated cellulose braided reinforced fabric.

"The Secretary was very interested in nanotechnology applications in forest products research," said Cai. "He was impressed with the impact that cellulose nanomaterial could bring to not only the forest products industry, but also electronics and other industries."

To view more photos of the Secretary's visit, including a slow-motion video of the hurricane-force 2 by 4 hitting a cross-laminated wall assembly, check out our website at www.fpl.fs.fed.us.

Steve Schmieding, USDA FS-FPL

Supervisory Research Chemist Alan Rudie tours Secretary Vilsack through FPL's new Nanocellulose Pilot Plant and shows nanocellulose samples.

Continued from page 1 – Recyclable, Compostable Stamps That Last "Forever"

FPL Research Materials Engineer John Considine conducts accelerated aging tests using a chamber and meteorological data from various locations in the United States. Considine can subject stamps to rapid cycles of heat and humidity, mimicking conditions the stamps might have to tolerate in the real world.

> *"Advancements made with the Postal Service work were of interest to the entire label industry,"*

Houtman's work, on the other hand, focuses on developing new pressure-sensitive adhesives that are environmentally friendly by looking at three key areas in the lifecycle of the product.

"We're developing adhesives that are made from renewable resources," Houtman says. "Additionally, we want the materials to be compatible with the recycling process and also biodegradable if they are thrown away."

Houtman is also developing experimental methods for determining the biodegradation rate of new materials. Currently, test samples are placed in a sludge inoculum that contains organisms that degrade, or "eat," the sample. The biodegradation rate can then be determined by measuring how much oxygen is consumed during the process.

Research and development will continue as FPL and the USPS work together to build on the successes of the past 20 years. And while stamps aren't something most of us give much thought to, perhaps next time you use one you'll at least be grateful that you don't have to lick it.

Continued from page 5 – Flexible Electronics Using Nanocellulose

recycled. Electronic waste is a serious environmental concern that the use of biodegradable materials such as cellulose nanofibers can help address.

Sabo's research is ongoing as the team works to refine the technology. They have improved upon their earliest work by coating the nanocellulose composite with a thin layer of epoxy on each side. The epoxy provided protection and created a smoother surface, improving the transfer of the circuit. Further research will focus on continuing to improve the composite material and testing to ensure the products developed will perform well under real-world conditions.

So are we looking at a future where televisions are high-tech wallpaper and tablet computers roll up and fit in your back pocket? Such developments are not out of reach, and wood could help us get there.

"Using cellulose nanofibers as a sustainable component for high-speed flexible electronics is extremely promising," says Sabo.

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Web address:
http://www.sciencedaily.com/releases/2009/01/090113155847.htm

Can You See Me Now? Flexible Photodetectors Could Help Sharpen Photos

Jan. 14, 2009 — Distorted cell-phone photos and big, clunky telephoto lenses could be things of the past.

This example of a curved photodetector array was developed by University of Wisconsin-Madison Electrical and Computer Engineering Associate Professor Zhenqiang (Jack) Ma and colleagues. Inspired by the human eye, Ma's curved photodetector made of flexible germanium could eliminate the photo distortion that occurs in conventional photo lenses. (Credit: courtesy Zhenqiang Ma)

University of Wisconsin-Madison Electrical and Computer Engineering Associate Professor Zhenqiang (Jack) Ma and colleagues have developed a flexible light-sensitive material that could revolutionize photography and other imaging technologies.

Their technology is featured on the cover of the January 5 issue of Applied Physics Letters.

When a device records an image, light passes through a lens and lands on a photodetector—a light-sensitive material like the sensor in a digital camera. However, a lens bends the light and curves the focusing plane. In a digital camera, the point where the focusing plane meets the flat sensor will be in focus, but the image becomes more distorted the farther it is from that focus point.

"If I take a picture with a cell phone camera, for example, there is distortion," says Ma. "The closer the subject is to the lens, the more distortion there is."

That's why some photos can turn out looking like images in a funhouse mirror, with an enlarged nose or a hand as big as a head.

High-end digital cameras correct this problem by incorporating multiple panes of glass to refract light and flatten the focusing plane. However, such lens systems—like the mammoth telephoto lenses sports photographers use —are large, bulky and expensive. Even high-quality lenses stretch the edges of an image somewhat.

Inspired by the human eye, Ma's curved photodetector could eliminate that distortion. In the eye, light enters though a single lens, but at the back of the eye, the image falls upon the curved retina, eliminating distortion. "If you can make a curved imaging plane, you just need one lens," says Ma. "That's why this development is extremely important."

Ma and his group can create curved photodetectors with specially fabricated nanomembranes—extremely thin, flexible sheets of germanium, a very light-sensitive material often used in high-end imaging sensors. Researchers then can apply the nanomembranes to any polymer substrate, such as a thin, flexible piece of plastic. Currently, the group has demonstrated photodetectors curved in one direction, but Ma hopes next to develop hemispherical sensors.

"We can easily realize very high-density flexible and sensitive imaging arrays, because the photodetector material germanium itself is extremely bendable and extremely efficient in absorbing light," Ma adds.

Ma's co-authors include UW-Madison Materials Science and Engineering Professor Max Lagally and University of Michigan Professor Pallab Bhattacharya.

Story Source:

The above story is based on materials provided by **University of Wisconsin-Madison**.

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Close

Electronics miniaturization

Federal, defense, and commercial organizations partner to bring nanotechnology and microelectromechanical systems ever closer to the battlefield.

By Courtney E. Howard

Nanotechnology and microelectromechanical systems (MEMS), though small in size, are growing in functionality and adoption in military and aerospace applications. Nanotechnology and MEMS are ideal for mil-aero applications, given the increasing need for small, light weight, and low-power solutions.

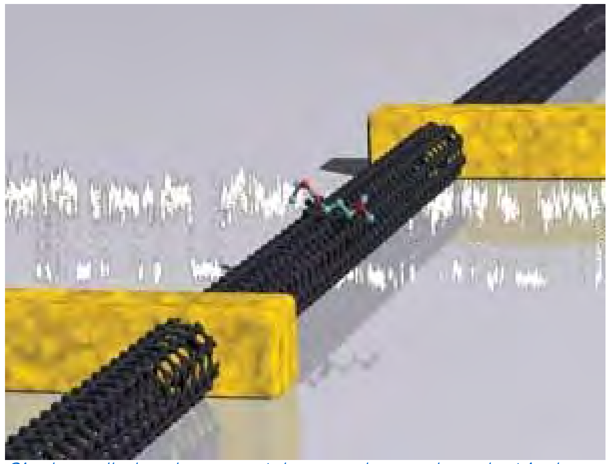
"They enhance performance while reducing size and space requirements at the same time," explains Thomas A. Jacob, regional manager of Dyconex Inc. in Mesa, Ariz. Unmanned vehicles and robotic devices will benefit perhaps first and greatest from miniaturized technology, which will enable the design of a vast amount of unmanned flying, walking, and driving robotic devices for reconnaissance sooner than later, he continues.

MEMS and nanotechnology are high priorities in the global mil-aero community, as engineers, academics, manufacturers, and government and defense personnel around the world endeavor toward miniaturized electronics innovations.

"Nanotechnology is increasingly being viewed as a competitive advantage by DOD," says Peter Antoinette, president and CEO of Nanocomp Technologies Inc. in Concord, N.H. "The evidence is in the level of funding and increasing trend towards technology adoption."

International investment

In the U.S., a wealth of private-sector businesses, academic institutions, and federal research-and-development laboratories are specifically focused on the advancement of MEMS and nanotechnology-many with an eye toward mil-aero environments. The Institute for Soldier Nanotechnologies at the Massachusetts Institute of Technology (MIT), founded by a $50 million contract with the U.S. Army Research Office, is a research center in Cambridge, Mass., dedicated developing nanotechnology to improve the survivability of soldiers.


Single-walled carbon nanotubes can be used as electrical wires on the molecular scale.
Click here to enlarge image

The U.S. Air Force has logged yet another milestone in the use of nanotechnology for flexible electronics, this time for surveillance radar applications. Professors at the University of Wisconsin-Madison in Madison, Wis., in partnership with the Air Force Research Laboratory Nanoscience and Technology Strategic Technology Team, harnessed silicon nanomembranes to produce fast, flexible electronic devices.

"Created specifically for Air Force missions, these high-speed, flexible electronics enable large-area, conformal radio-frequency surveillance radar in manned and unmanned aircraft and in spacecraft," reveals an AFRL official. "Thin electronic circuits on flexible polymer substrates offer dramatic advancements in airborne (manned or unmanned) and spaceborne surveillance radars essential to the Air Force and to national security."

Compared to conventional rigid-chip systems, these nanomembrane-based electronics are thinner and more flexible, making them a viable choice for missiles, rockets, and smart bombs, which suffer space constraints and extreme vibration. They also enable attachment to irregular surfaces, mounting in limited space, and resistance to damage from impact and vibration. The nanotechnology solution features a large active area that improves the radar signal, and offers a reduction in the aerodynamic weight, drag, complexity, and cost associated with most protruding radar antennae. An unnamed U.S. aerospace manufacturer is evaluating its application to conformal radio-frequency antennae on next-generation military aircraft.

This accomplishment was achieved by prof. Zhenqiang Ma and prof. Max Lagally at the University of Wisconsin-Madison. Funds were provided by the Air Force Nanotechnology Initiative Program at the Air Force Office of Scientific Research.

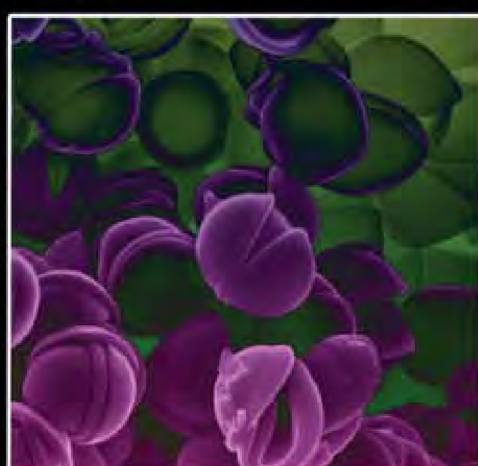
Nanobattery news

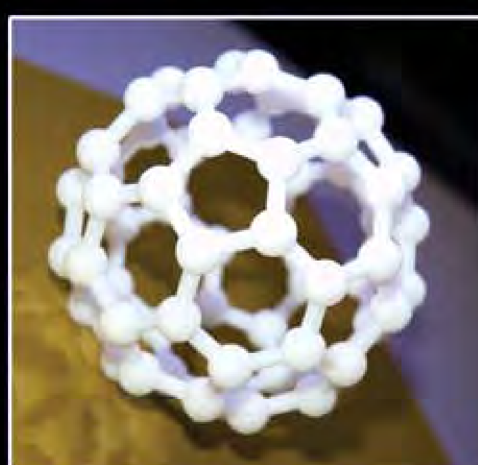
Warfighters on today's digital battlefield know well the value of reliable battery power in their packs, but they are also keenly aware of the weight burden this represents. For this reason, various nanotechnology firms are working to perfect nanobatteries, and defense organizations are funding the research and development.

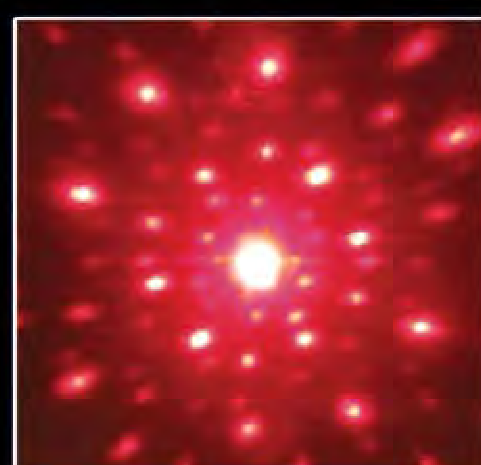
Officials at the U.S. Army Research Office issued a Phase II Small Business Technology Transfer (STTR) grant, part of the SBIR program, to mPhase Technologies Inc., a nanotechnology development company in Little Falls, N.J., to produce a miniature, long-life battery for powering

AFRL Nanoscience Technologies

Applications, Transistions and Innovations



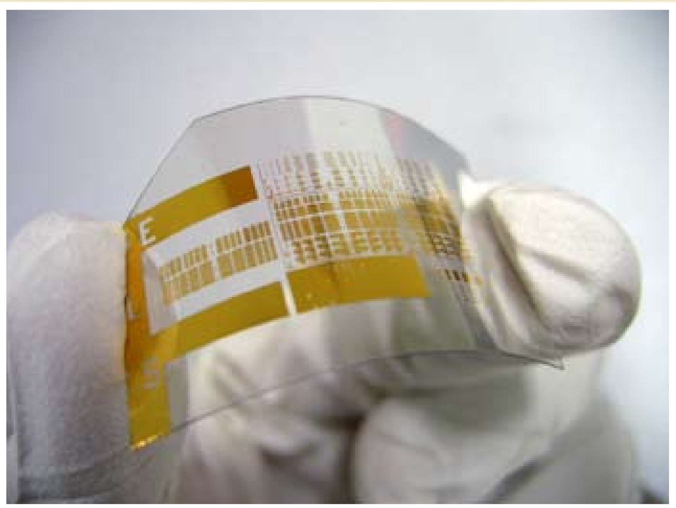




Nano-Membrane Flexible Electronics for Surveillance Radar

Accomplishment: New processing techniques for the formation, doping and transfer of silicon nano-membranes were developed and used to produce the world's fastest flexible electronic devices.

Impact: Created specifically for Air Force missions, these high speed flexible electronics enable large-area, conformal radio-frequency surveillance radar in manned and unmanned aircraft and in spacecraft. The large active area improves the radar signal, and conformal attachment reduces aerodynamic weight (by 90%), drag, complexity and cost (by 90%) associated with current protruding radar antennae. Application to conformal radio-frequency antennae is now being evaluated by a major US aerospace manufacturer for next-generation military aircraft.



Motivation and Approach: Thin electronic circuits on flexible polymer substrates offer dramatic advancements in airborne (manned or unmanned) and spaceborne surveillance radars essential to the Air Force and to national security. Their primary advantage over conventional rigid-chip systems is their thinness and flexibility, which allow conformal attachment to irregular surfaces, mounting into limited space, and resistance to damage from impact and vibration. Conformal attachment dramatically reduces the complexity, weight and drag compared to current protruding radar antennae, thus significantly improving the operational reliability of the transport aircraft. Flexible electronics are also important in missiles where space for electronics is very limited but high processing speed is needed. The electronics developed here are very robust against damage from impact and severe vibration, making them valuable for rockets and smart bombs, where significant vibration is unavoidable.

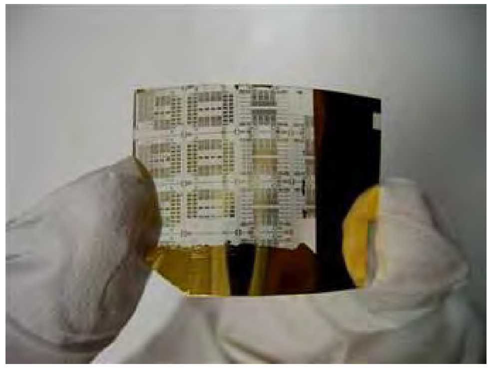
The critical component in flexible electronics is a very thin layer of silicon that is doped (alloyed with very small amounts of other elements) to give a high charge carrier mobility. Silicon is typically rigid, but is flexible when produced as 200 nanometer-thick films and bonded to a polymer substrate. However, previous processing methods were not able to perform the high temperature doping process without damaging the flexible polymer substrate. In this work, the high-temperature doping was performed while the silicon nano-membrane was supported by a silicon substrate, after which the doped silicon nano-membrane was transferred at low temperature to a flexible polymer substrate.

Team: This accomplishment was achieved by Prof. Zhenqiang Ma and Prof. Max Lagally at the University of Wisconsin-Madison. Funds were provided by the Air Force Nanotechnology Initiative Program at the Air Force Office of Scientific Research (Dr. Gernot Pomrenke, program manager) in partnership with the Air Force Research Laboratory Nanoscience and Technology Strategic Technology Team.

Scientist demonstrates bendable electronics

by Molly Lachance
Air Force Office of Scientific Research Public Affairs

2/1/2008 - **ARLINGTON, Va. (AFPN)** -- Air Force Office of Scientific Research officials here recently have provided research funding for fast, bendable electronics to attach to unevenly shaped objects like airplane bodies or engines.



The flexibility of super-thin silicon transistors, such as the one pictured, could lead to electronics attached to unevenly shaped objects like airplane bodies or engines. Air Force Office of Scientific Research officials here recently have provided research funding for fast, bendable electronics to attach to unevenly shaped objects like airplane bodies or engines. (Courtesy photo)

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A research team led by Dr. Zhenqiang Ma of the University of Wisconsin-Madison has developed super-flexible silicon chips that can withstand impact and severe vibration.

By adding pressure to the chips, Dr. Ma and Max Lagally have increased chip performance to speeds 50 times faster than previous efforts.

Dr. Ma is also working on flexible photodetectors, or optoelectronics, which are applicable for high-speed photography.

"When the optoelectronics are arranged in a hemispherical or spherical shape, the half space or the entire space of interest can be put under surveillance without a moving lens," Dr. Ma said.

He said he relates the successes in his research to his progress with new forms of semiconductor material, particularly nanomembranes.

"We have developed a number of innovative methods to manipulate these flexible nanomembranes so that their electrical properties can be tailored at will," Dr. Ma said.

The Air Force could have a number of new uses for his research with flexible electronics and optoelectronics, Dr. Ma said. These uses include compact antennae attached to airplane bodies and missiles, flexible sensors that detect mechanical changes, and 360-degree air surveillance applications.

The research is timely and relevant for the Air Force and the Department of Defense, as well as for the semiconductor material and device component industries, said Dr. Gernot Pomrenke, an AFOSR program manager.

"The ability to synthesize and manipulate extremely thin films of solid-state materials enables wholly new approaches for improving performance and reducing the size, weight and power in defense and commercial systems," Dr. Pomrenke said.

By funding research like this, AFOSR officials continue to expand the horizon of scientific knowledge through its leadership and management of the Air Force's basic research program.

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Forward

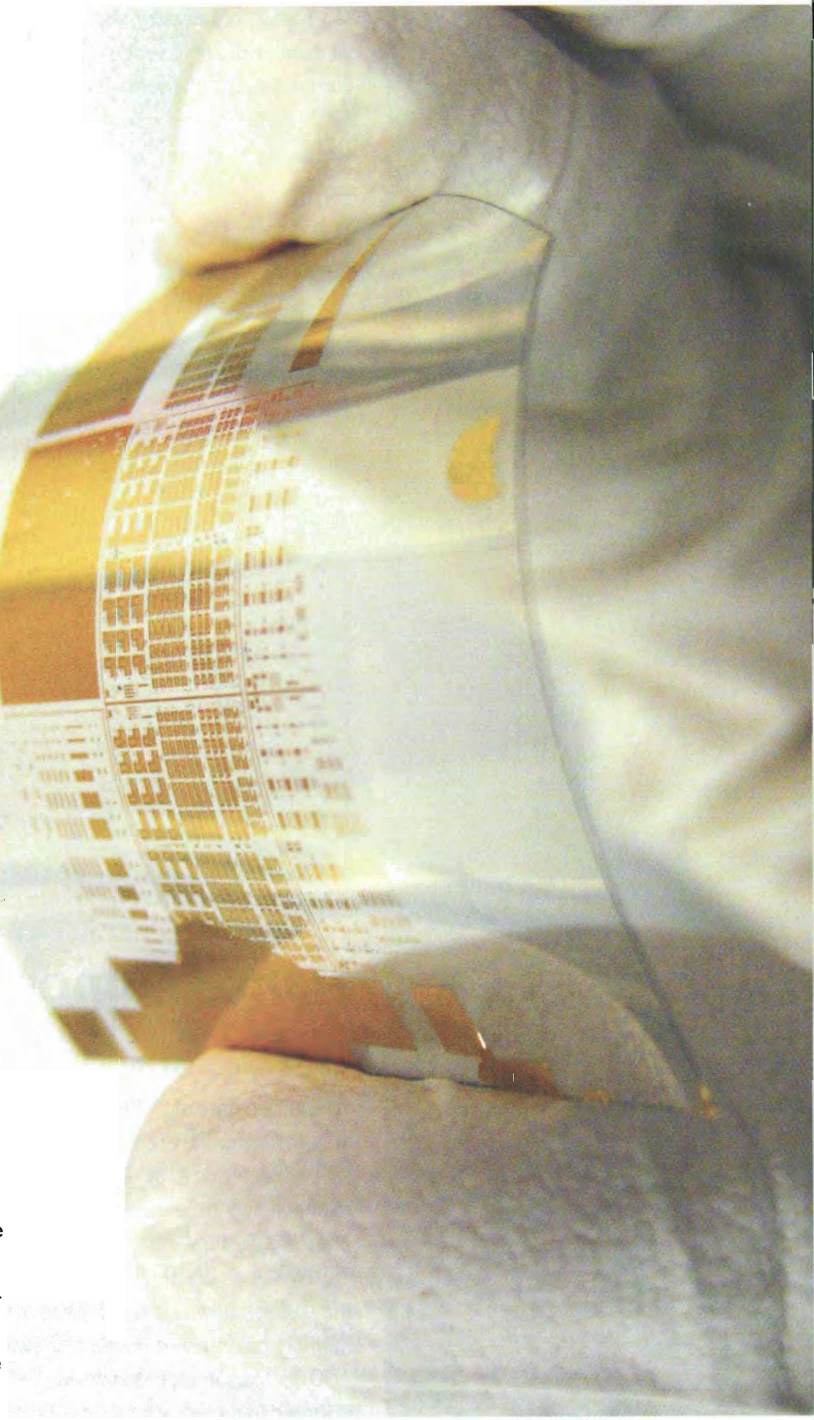
TECHNOLOGY REVIEW MARCH/APRIL 2007

HARDWARE

Fast, Bendable Computers

Already, flexible-but-slow polymer electronics have made their way into technologies like roll-up digital displays. If superfast silicon electronics could also be made flexible, we might be able to do things like weave computing devices into clothing, or mold antennas around an airplane's fuselage, making for more precise radar. Now researchers at the University of Wisconsin–Madison have made ultrathin silicon transistors that are 50 times as fast as their predecessors.

Previously, researchers at the University of Illinois at Urbana-Champaign showed that nanometer-thin films of single-crystal silicon transistors could be made flexible. But Wisconsin researchers Zhenqiang Ma, professor of electrical and computer engineering, and Max Lagally, professor of materials science and physics, improved the transistors' performance by putting strain on the silicon's crystalline structure, increasing electron mobility. And by altering fabrication methods to reduce electrical resistance, Ma achieved a transistor speed of 7.6 gigahertz—fast enough for, say, a flexible sensor that could send and receive Wi-Fi signals. Ma says he expects to reach speeds of 20 gigahertz; military antennas are a likely first application. **Kate Greene**



Transistors made of superthin silicon and applied to a flexible plastic substrate are fast enough to send and receive Wi-Fi signals.

ZHENQIANG MA, UNIVERSITY OF WISCONSIN–MADISON

Technology Review
AN MIT ENTERPRISE

Thursday, January 11, 2007

Record-Breaking Speed for Flexible Silicon

A new method of making ultrathin transistors could pave the way to flexible and wearable electronics.

By Kate Greene

Researchers at the University of Wisconsin, Madison, have made ultrathin silicon transistors that operate more than 50 times faster than previous flexible-silicon devices. The advance could help make possible flexible high-end electronics that would be useful in a variety of applications, from computers to communication. Zhenqiang (Jack) Ma, professor of electrical and computer engineering and lead researcher on the project, is interested in using flexible electronics to redesign large-scale antennas that could be molded in the shape of, say, an airplane. For instance, radar antennas could be made to cover a large area on an airplane, he says, increasing sensitivity and area of coverage.

Most flexible electronics, such as those used in e-paper and roll-up displays for mobile devices, rely on transistors made of either organic polymers, printed directly on a plastic substrate, or amorphous, or noncrystalline, silicon. However, transistors made of these materials can't perform at the gigahertz speeds needed for complex circuitry or antennas. "People have for some time been able to make slow flexible electronics," but the speed of the transistors has been limited, says Max Lagally, professor of materials science and physics at the University of Wisconsin and collaborator of Ma. The next step, he says, has been to make the transistors out of high-quality, single-crystal silicon instead of organic polymers and amorphous silicon because electrons simply move faster in single-crystal silicon.

Ma says his research, published in *Applied Physics Letters*, is an extension of the previous work done to put high-quality, single-crystal silicon on a flexible plastic substrate. While single-crystal silicon is normally stiff, it can bend if made thin enough. Previously, researchers at the University of Illinois, Urbana-Champaign, have shown that nanometer-thin films of single-crystal silicon transistors can be fabricated and successfully transferred to flexible and stretchable substrates. (See "Stretchable Silicon.")

Work by Ma and Lagally at Wisconsin further increased the performance of the silicon by adding strain to its crystalline structure, a technique used by Intel and other chip makers to increase the electron mobility of the material. (See "High-Quality Flexible Silicon.") But, says Ma, "high electron mobility is not equal to high device speed." Speed of a device is also dependent on its engineering, he says, specifically the resistivity of the contact connections--the points on the transistor where electrons flow in and out of the device.

But here's the problem: the resistivity of the contact connection is usually modified at temperatures of more than 800 ºC. Plastic can withstand no higher than 200 ºC.

The contact resistivity is due to the chemical makeup of two transistor components, called the source and the drain, between which electric current flows. To make low-resistivity sources and drains, the researchers blasted phosphorous ions at the silicon while it was still on its original, rigid substrate and let the material bake at 850 ºC.

The researchers next peeled off the thin film of silicon and stuck it to a plastic with a layer of epoxy to help it adhere. Then, Ma says, the gate--the part of the transistor that turns the current on and off--was added at room temperature. Usually, silicon dioxide is employed as the gate material, but the researchers used silicon monoxide. The advantage here, says Ma, is that silicon monoxide can be made thinner than silicon dioxide.

The researchers' approach is a "clever way of mounting the circuit on a flexible substrate without having to deal with high temperatures," says Ed Croke, researcher at HRL Laboratories, an electronics and information-sciences lab in Malibu, CA. "They do all their processing before they undercut the silicon [from its original substrate]," he says.

John Rogers, professor of materials science, engineering, and chemistry at the University of Illinois, says that the recent advance is "a nice piece of device engineering work that exploits the previously demonstrated approach of using thin-film single-crystal silicon on plastic." Ma's research is important, he says, because it helps show that the same sort of performance, previously only possible in a rigid silicon chip, is possible with flexible electronics.

In the current paper, the Wisconsin researchers report transistor speeds of 3.1 gigahertz; in an upcoming paper, the group will report a speed of 7.8 gigahertz. Both are significant gains over the previous 0.5-gigahertz speed demonstrated in Rogers's lab, says Ma. With further fine-tuning of the fabrication process, including reducing the size of the transistors' gates, he expects to achieve at least 20-gigahertz speed.

In order to be used in complex circuits such as the microprocessors found in computers, these transistors would still need to operate about twice as fast. However, transistors that operate from 2.4 to 20 gigahertz could be used for antennas that send and receive a range of signals, from radar to Wi-Fi.

FOX47 TV News, January 14, 2007, 9pm CST

ABC27 TV News, January 14, 2007, 10pm CST

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Record Speed For Thin-Film Transistors Could Open Door For Flexible Electronics

1/16/2007 Madison, WI -- A pair of University of Wisconsin-Madison researchers have developed a method of making flexible, thin-film transistors (TFTs) that are not only inexpensive to produce, but also capable of high speeds -- even microwave frequency, impossible before now.

Assistant professor of electrical and computer engineering Zhenqiang (Jack) Ma and graduate student Hao-Chih Yuan recently demonstrated flexible TFTs capable of operating at a world-record speed of 7.8 GHz.

TFTs are transistors that are currently widely used in electronics such as liquid crystal displays (LCD) and electronic and radio-frequency tags. For example, in an LCD screen, TFTs control individual pixels for high-quality images. TFTs made on flexible substrates could have a variety of applications, says Ma, including flexible and wearable electronics, flexible sensors, large-area surveillance radar, embedded signatures and more.

Until now, flexible TFTs have been relatively slow, operating in the 0.5 GHz range, says Yuan. This is fine for applications such as LCD, but not for applications such as military surveillance antennas that require high-performance but flexible circuitry for easy storage. "The application of current low-speed TFTs is very limited," says Ma. "Fast TFTs offer significant advantages in terms of power consumption and operation frequency, beside their flexibility and robustness against breakage."

Flexible TFTs are usually made of organic materials or amorphous or poly silicon, but the research team instead uses nanoscale-thin membranes of single-crystal silicon, which has greater electron mobility and greater speed. The membranes can be peeled off from the bulk silicon used for fabrication with an inexpensive, patent-pending method. But mobility is not enough to bring the TFTs up to speed, Ma says. Low-resistance electrode contacts are also important.

However, achieving this is challenging because the high temperatures needed to activate low-resistance contact connections melt the polymer substrates on which the transistors are fabricated. "That is the major obstacle to realizing the high speed operation of TFTs, regardless of the fact that high mobility has been already demonstrated in single-crystal silicon on flexible substrate," says Ma.

Ma and Yuan overcame this obstacle with an innovative technique. They made the transistors in "hot" and "cold" steps. First, they made the contact connectors on a bulk silicon substrate to achieve low resistance, and then transferred the single-crystal nanomembranes to the flexible substrate to continue fabrication. Ma and Yuan published a paper detailing this novel method in a recent issue of Applied Physics Letters.

Another factor in the new TFT's speed is that instead of the usual silicon dioxide, they made the gates of silicon monoxide, which carries the advantage of lower processing temperatures. "In addition, silicon monoxide has higher electric capacity and can be made thinner than the dioxide. As a result, the device speed becomes even faster," says Yuan.

The next step, says Ma, is developing even more advanced processing technologies and materials for even higher speed TFTs. He also hopes for the realization of potential applications, including an entire flexible radio-frequency system. "We opened numerous possibilities with this breakthrough," he says.

SOURCE: University Of Wisconsin-Madison

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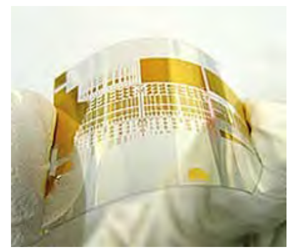
Record speed for thin film transistor paves way to flexible electronics

15 January 2007



A team at the University of Wisconsin-Madison led by Jack Ma, assistant professor of electrical and computer engineering, has developed a method of making flexible, thin-film transistors (TFTs) that are not only inexpensive to produce, but also capable of operating at a world-record speed of 7.8 GHz, more than 50 times faster than previous flexible TFTs.

Until now, flexible TFTs have been relatively slow, operating in the 0.5 GHz range. This is fine for applications such as LCD, but not for applications such as military surveillance antennas that require high-performance but flexible circuitry for easy storage.

Several factors contribute to the record-breaking speed of their TFTs:
1. *Nanoscale-thin membranes of single-crystal silicon*, which has greater electron mobility and greater speed, are used, while previous TFTs are usually made of organic materials or amorphous or poly silicon.
2. *Low-resistance electrode contacts*, which has been rather challenging because the high temperatures needed to activate low-resistance contact connections melt the polymer substrates on which the transistors are fabricated. The team overcame this obstacle by using two steps. First, they made the contact connectors on a bulk silicon substrate to achieve low resistance, and then transferred the single-crystal nanomembranes to the flexible substrate to continue fabrication.
3. *The TFT gates are made of silicon monoxide*, not the usual silicon dioxide. Silicon monoxide has lower processing temperatures, higher electric capacity, thus can be made thinner than the dioxide. As a result, the device speed becomes even faster.

This research has been published in Applied Physical Letters.

(Image credit: Jack Ma)

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Plastic Logic secured $100M investment to build flexible display facility

11 January 2007

UK Cambridge-based, six year old start-up Plastic Logic has secured equity funding of $100m to help fund the building of a production facility in Dresden, the first to manufacture plastic electronics on a commercial scale.

Based on the firm's proprietary plastic transistor technology, the facility will produce flexible active-matrix display modules for portable electronic reader devices – a product category that is predicted to grow to 41.6 million units in 2010. It will have an initial capacity of more than a million display modules per year and production will start in 2008.

With Philip' Polymer Vision receiving $26M investment, this has been the second business announcement in flexible display market in early January 2007.

See here and here for our earlier coverage on Plastic Logic.

(via EW)

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Philips' flexible display business receives $26M investment

Technology Review
AN MIT ENTERPRISE

High-Performance Flexible Silicon

A new way to make bendable high-speed silicon devices could result in advanced circuits on virtually any surface.
By Kate Greene

The same high-quality form of silicon that is used inside many new computers could soon be rolled up on a sheet of plastic. Researchers from the University of Wisconsin, Madison, have shown that the type of high-speed silicon used for the past few years in Intel's microprocessors, called "strained" silicon, can be made thin enough to be transferred to a flexible substrate.

The ability to put sheets of strained-silicon transistors on malleable materials could lead to high-quality flexible displays and solar cells -- or eventually even to improved prosthetics, or computerized clothes, according to the researchers.

For the most part, flexible electronics are made of organic polymers, which, although bendable, produce relatively poor performance. So researchers have been giving silicon -- the standard material in electronics -- a second look as a way to make pliable circuits (see "Stretchable Silicon").

Although silicon is usually brittle, it can bend when thin enough. In particular, the Wisconsin researchers set out to make flexible forms of strained silicon, a type of high-performance silicon recently commercialized by Intel. Electrons move through strained silicon 80 percent faster than in conventional silicon, and transistors switch on and off up to about 30 percent faster.

Until now, however, strained silicon has been far too bulky -- micrometers thick -- to flex. The Wisconsin researchers, led by Max Lagally, professor of materials science, found a way to thin out the material to a couple of hundred nanometers, as well as to effectively remove it from a silicon wafer, allowing its use in flexible and high-speed electronics. (Their work is described in a recent issue of *Journal of Applied Physics*.)

Strained silicon is typically fabricated using multiple layers of a material called silicon germanium, which has larger spaces between its atoms than silicon. Each layer of silicon germanium is chemically altered to gradually introduce more space between the atoms. Finally, a thin layer of silicon is deposited on top. When the silicon atoms (naturally spaced closer together than the silicon germanium atoms) contact the top layer of silicon germanium, they "strain" to bond to it. "If you strain the silicon lattice, then you can improve the electron mobility and performance in your device," says John Rogers, professor of material science at the University of Illinois, Urbana.

But by using multiple layers of silicon germanium, the device becomes too thick to bend. To make the strained silicon thin enough to flex, Lagally and his team first start with a silicon wafer with two additional layers on top: a silicon oxide layer and a thin layer of silicon. On top of the thin layer of silicon they apply only one layer of silicon germanium, just 150 nanometers thick. Since the silicon layer below the silicon germanium is fixed, the silicon germanium atoms, while spaced wider than silicon, squeeze together, compressing to conform to the silicon layer below it. Then, the researchers add a thin layer of silicon on top of the silicon germanium, forming a sandwich 250 nanometers thick.

At this point, Lagally explains, there's no strain in the silicon; there's only compression in the silicon germanium. In order to add strain, the sandwich is removed from the silicon wafer by bathing it in hydrofluoric acid, which eats away at the silicon oxide -- the layer connecting the sandwich to the wafer. Once the device is free, the spacing of the atoms in all the layers adjusts slightly: the silicon germanium atoms, formerly compressed, loosen up, and the silicon atoms, which had normal spacing before, developed strain.

Removing the device from the wafer not only adds strain to the silicon, but also allows it to be transferred to another material, says Lagally. From here, the device is pressed into a flexible material, which it sticks to with the aid of special glue.

Sigurd Wagner, professor of electrical engineering at Princeton University, says the work is "a well-executed example of transferring high-quality devices to a low-quality substrate." Importantly, he says, it proves that strained silicon retains its properties after the transfer process, something that hadn't been shown before. In addition, says Rogers, the process could be applicable to most inorganic materials, from strained silicon used in microprocessors to gallium arsenide transistors in light-emitting diodes.

Lagally expects that this type of flexible, high-speed silicon will find its way into commercial products within a few years, most likely initially in flexible imaging systems and high-quality displays.

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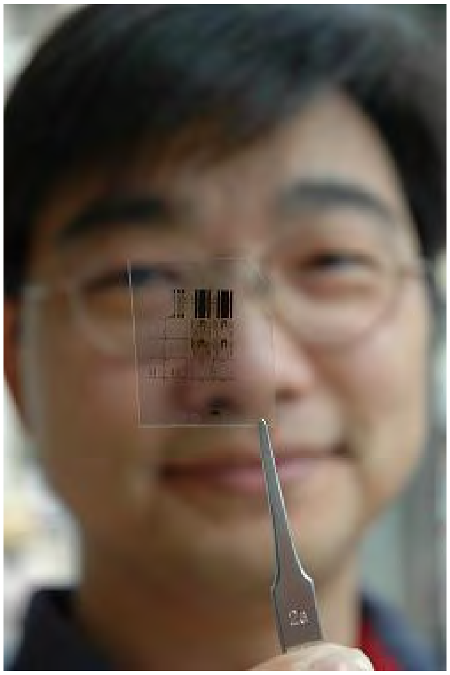
Image of the Week

New Flexible Semiconductors



(Credit: Jim Beal)

Researchers, led by Zhenqiang Ma and Max G. Lagally, at the University of Wisconsin-Madison have invented a manufacturing technique for transferring semiconductors to flexible substrates. This new technique will enable engineers to add semiconductors to glass, plastic, or even fabric for new electronic devices. In the image, electrical and computer engineering graduate student Hao-Chih Yuan holds a sample of a semiconductor film on plastic.

In this process, a single-crystal semiconductor film of strained silicon is removed from the substrate on which it is grown and transferred to a flexible polymer substrate. The films range from 5 to 200 nanometers, a thickness at which the films are very flexible. By stacking one thin-film semiconductor layer on top of another, it is possible to create three-dimensional electronic devices.

A semiconductor is a solid crystalline material, such as silicon, with electrical conductivity intermediate between that of a metal and an insulator, and is a necessary component of microelectronic and optoelectronic devices such as microchips and solar cells. In recent years, strained silicon has been developed and used to increase chip speed. Strained silicon is created by layering silicon on top of a germanium layer whose atoms are spaced farther apart. This spacing causes atoms on the top layer to stretch and match up to the atoms on the substrate layer. Strain in silicon increases the speed of electrons across the semiconductor. This thin-film semiconductor manufacturing technique could result in more powerfule flexible electronics.

This work is sponsored in part by grants from the National Science Foundation Materials Research Science and Engineering Center, the Department of Energy, and the Air Force OFfice of Scientific Research.

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Two groups create electrically injected InP hybrid lasers on silicon

Two research groups have reported independent approaches to the fabrication of the first electrically injected indium phosphide (InP)-based diode lasers on silicon. Such lasers, if practical, would help to usher in low-cost but extremely rapid data transmission. In both approaches, the light from the lasers was coupled into silicon-on-insulator (SOI) waveguides on silicon chips. In the method developed by a group from Intel (Santa Clara, CA) and the University of California–Santa Barbara (Santa Barbara, CA), an oxide layer a few nanometers thick is created on the InP component, which is heated and pressed against the SOI, bonding them. The silicon serves as the continuous-wave laser cavity, which is 800 μm long. The technology should make data-transmission speeds of 20 to 40 Gbit/s over distances of tens of feet possible, says Intel. *Contact Barbara Bronson Gray at* bbgray@engineering.ucsb.edu.

In the approach taken by researchers at Ghent University (Ghent, Belgium) and the Technical University Eindhoven (Eindhoven, The Netherlands), an InP-based laser structure is bonded to SOI with an adhesive called DVS-BCB. A polymer waveguide adiabatically couples 0.9 mW of 1550 nm laser light (via tapering) into an SOI waveguide. In this setup, the laser (if made shorter) can be used as a photodetector with a responsivity of 0.23 A/W. *Contact Gunther Roelkens at* Gunther.Roelkins@intec.Ugent.be.

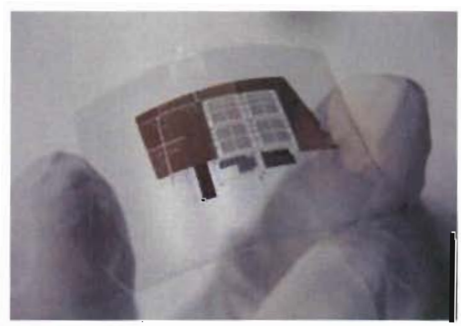
Nanosphere-embedded liquid crystals create tunable metamaterial

Researchers are actively involved in the exploitation of electro-optic and nonlinear effects that produce zero-index and negative-index materials. By embedding aligned nematic liquid crystals with coated dielectric nanospheres, researchers at Pennsylvania State University (University Park, PA) have demonstrated the possibility of creating a new type of metamaterial with a refractive index that is tunable from negative, through zero, to positive values.

The material properties of this new metamaterial are predicted using Maxwell Garnet mixing-rule equations for a medium with three regions: the host liquid crystal, the nanosphere outer shell, and the nanosphere core. Though these materials are nonmagnetic with relative permeability equal to 1, the combination of the permittivities at the appropriate resonances in conjunction with the electric- or magnetic-field-induced permittivity change in the liquid-crystal host material enables the refractive-index tunability over a wide dynamic range from the visible to the microwave region. *Contact Iam Choon Khoo at* ick1@psu.edu.

Flexible silicon expands application possibilities

Single-crystal semiconductor materials such as silicon (Si) and gallium arsenide have previously been transferred to flexible polymers to create thin-film transistors (TFTs) on plastic; however, the process is limited and cumbersome. Researchers at the University of Wisconsin-Madison (Madison, WI) have instead developed a simpler, more versatile transfer technique that allows them to create strained-silicon TFTs with high drive current and high transconductance, making them excellent candidates for use in displays, solar cells, and biosystem implants.



The TFT active layer is formed as a thin membrane on silicon-on-insulator (SOI) substrates. Both strained- and unstrained-silicon TFTs are fabricated in a similar process using a sandwich structure of Si and silicon-germanium alloy. Photolithography is used to pattern the membrane, which is then transferred (using a "dry" printing method) to a flexible polyethylene substrate onto which a layer of photoresist has been applied that serves as both an adhesive and as the gate-dielectric layer for the TFTs. *Contact Zhenqiang Ma at* mazq@engr.wisc.edu.

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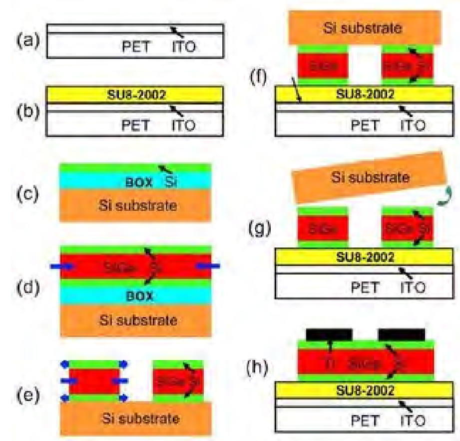
High-speed Si TFTs on Flexible Polymers

22 August 2006

A team at University of Wisconsin-Madison, led by electrical and computer engineer Zhenqiang (Jack) Ma and materials scientist Max Lagally, have developed a simpler process to transfer thin films of single-crystal silicon (only a couple of hundred nanometers thick) to flexible polymers, opening a wide range of possibilities for flexible electronics.



Transferring single-crystal Si and GaAs to create thin-film transistors (TFTs) has been first demonstrated by John Rogers's group in UIUC in 2004 (See reference for further readings). The method used by Roger's group is "rather cubersome and somewhat limited". In a recent paper in Journal of Applied Physics , the Wisconsin team reported a simpler and more versatile dry-printing technique. In addition, they combine it with a membrane fabrication method to create strained-Si TFTs, which show much higher drain current and peak transconductance values than the identical unstrained-Si TFTs.

References:

1. Yuan HC, Ma ZQ, Roberts MM, et al. JOURNAL OF APPLIED PHYSICS 100 (1): Art. No. 013708 JUL 1 2006
2. E. Menard, K. J. Lee, D.-Y. Khang, R. G. Nuzzo, and J. A. Rogers, Appl. Phys. Lett. 84, 5398 (2004).

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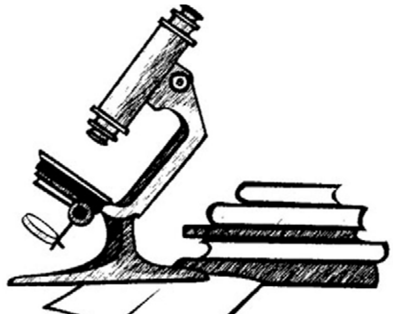

Nitride LEDs, lasers and HEMTs

Patent disputes are in the news again with the start of litigation between Osram and Kingbright. This is not the first such defence of IP, nor will it likely be the last in the area of LEDs. Below are some recent examples of patents involving nitride-based materials and devices.

A Japanese company that has been involved in battles over LED IP is Toyoda Gosei. It is also one of the more prolific patenters of its technology. Recently, it has been awarded several key new ones including US Patent #7,045,829, for Koike, *et al.*, which involves a III-nitride multiple layer structure having, amongst other things, a p-type cladding layer with a forbidden band sufficiently wider than the forbidden band of the emission layer in order to confine electrons injected into the emission layer.

In US Patent #7,042,153, Uemura *et al.*, the LED includes a light-emitting layer for blue light and a second layer for emitting green light. These are combined to provide a third light having a blue-green light.

Taiwanese companies are also hot on the trail of LED-related IP. For instance, US Patent #7,042,019, for Wu, *et al.*, of Formosa Epitaxy Inc., describes a GaN multi-quantum well (MQW) LED n-type contact layer structure. Instead of using Si-doped GaN as commonly found in conventional GaN-based MQW LEDs, the n-type contact layer provided by this invention achieves high doping density ($>1x10^{19}cm^{-3}$) and low resistivity through a superlattice structure combining two types of materials: $Al_mIn_nGa_{1-m-n}N$ and $Al_pIn_qGa_{1-p-q}N$, each having its specific composition and doping density. In addition, by controlling the composition of Al, In, and Ga in the two materials, the n-type contact layer would have a compatible lattice constant with the substrate and the epitaxial structure of the GaN-based MQW LEDs. This n-type contact layer, therefore, would not degrade from the heavy Si doping, have a superior quality and reduce the difficulties of forming n-type ohmic contact electrode. In turn, the GaN-based MQW LEDs would require a lower operation voltage, they claim.

Probably the top short wavelength LED provider in Japan is, of course, Nichia. It also publishes patents fairly often. For example, #7,042,017 for M Yamada, who also has covered MQW active layer devices.

Present approaches to achieve white light have some problems. For instance, when mounting several LED chips on the same stem to produce white light, they have to be as close as possible to each other in order to improve colour mixing. But the finite sizes of the chips limit the improvement. Also, when using a fluorescer to produce the white light, a step for applying fluorescer on the chip is required, which is complicated. Plus the luminous efficiency is theoretically reduced compared to the multi-chip approach. The new Nichia invention is directed to providing such a light-emitting device which can emit white light by itself.

Nichia is also well-known for its diode laser know-how. In US Patent #7,015,053 for Kozaki, *et al.*, a nitride laser with improved stability of the lateral mode under high output power and a longer lifetime, is described. The device can be applied to write and read light sources for DVDs. It has a waveguide region of a stripe structure formed by etching from the p-side contact layer. The stripe width provided by etching is within the stripe range of 1 to 3-microns and the etching depth is below the thickness of the p-side cladding layer of 0.1-microns and above the active layer.

Interest in nitride devices is not restricted to optoelectronics. Naturally, Cree has a major stake in LEDs but is bringing on III-nitride microelectronics. For instance, in US Patent #7,045,404, for ST Sheppard, *et al.*, 'nitride-based transistors with a protective layer and a low-damage recess and methods of fabrication thereof' are described.

In SiC, Cree, Inc., has a new patent #7,033,912, for AW Saxler, where a device is formed by SiC on diamond substrates.

These high-power, high-frequency devices include diamond to increase thermal conductivity of the resulting composite wafer. Thereafter they reduce the thickness of the SiC part while retaining sufficient thickness to support epitaxy and adding a Group III nitride heterostructure to the prepared SiC face. Also in this area, the author has a patent (#7,030,428) describing strain balanced nitride heterojunction transistors.

Yoshida, *et al.*, from Furukawa Electric Co. Ltd., have been awarded US Patent #7,038,253, for a GaN-based FET of a normally-off type. They reckon it is a new field-effect transistor with an extremely small on resistance during operation which is capable of a large-current operation.

SiGe HBT beats record

Record-breaking results from SiGe are almost expected these days. One such recent example comes from Zhenqiang (Jack) Ma, Assistant Professor, at the Department of Electrical and Computer Engineering, University of Wisconsin-Madison. He and his team reported their recent breakthrough on high frequency and high power SiGe power HBTs in the May issue of IEEE Electron Device Letters. The work was supported by the National Science Foundation.

"With a new compact design and upscaling method of emitter stripe widths, we have made a new record performance for SiGe power HBTs. This is more than five times improvement over the previous state-of-art, reaching $3.8x10^5mWGHz^2$. This is a similar order of performance as shown by GaAs-based power HBTs operating in the similar frequency band.

A testimonial came from Prof. Katehi, a member of National Academy of Engineering and

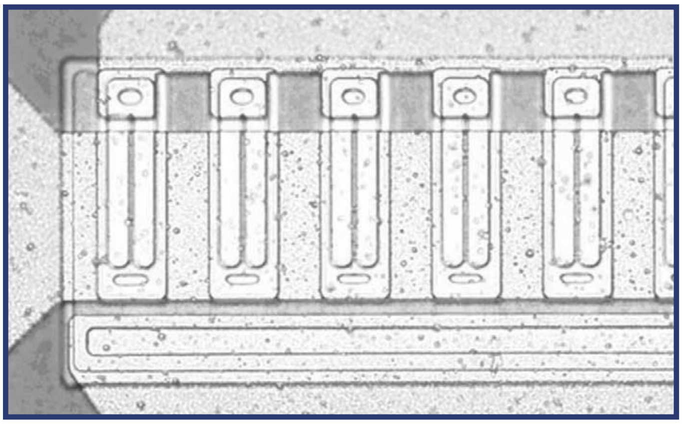

Figure 1. SEM photomicrograph of fabricated mesa-type multifinger CB SiGe HBT. The total emitter area AE is 1340μm^2, the WE is 3μm with a total of 14 emitter stripes. Stripe length was 30μm.

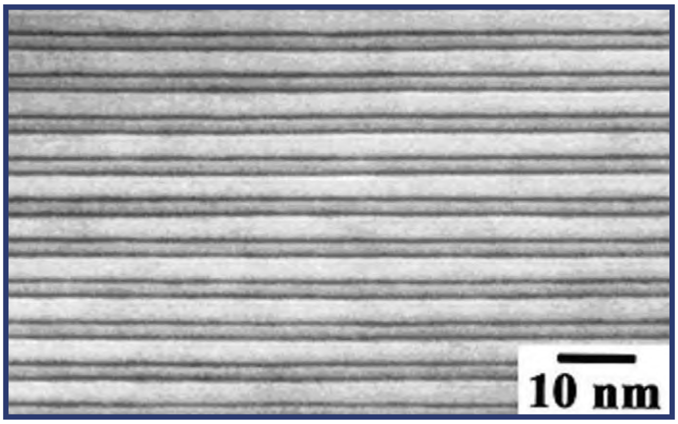

Figure 2. A transmission electron microscope image of am InAs/ GaSb superlattice, with InSb-like interfaces, showing the GaSb (bright) and InAs (medium-dark) layers. The dark lines delineate the intended interfaces.

an expert of microwave engineering. She said, "these results are amazing. Usually you have to resort to Class E or F power amplification mode to reach the PAE (61%) level that we got at this high frequency. In fact, we used only class AB mode."

The paper, which appears in *IEEE Electron Device Letters*, Vol. 27, No. 5, May 2006 371, is entitled "Ultrahigh-Performance 8-GHz SiGe Power HBT" and contributors were Guogong Wang, Hao-Chih Yuan and Zhenqiang Ma. It demonstrates state-of-the-art SiGe HBTs in common–base configuration giving a continuous wave output of 27.72dBm with a concurrent power gain of 12.19dB at a peak power-added efficiency of 60.6%. This was measured on a single SiGe HBT with a 3-μm emitter finger stripe width, see Figure 1 with a 1340μm^2 total emitter area.

Jack says that the highest power-performance figure of merit resulted from their optimized SiGe heterostructure together with its

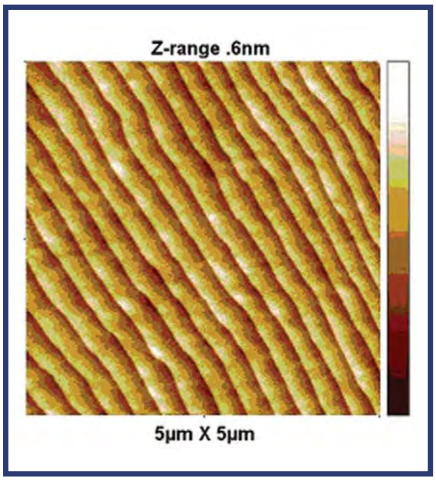

Figure 3. An atomic force microscope image of the 22Å In As/27Å GaSb superlattice, with InSb-like interfaces scanned over 5x5μm^2 area showing atomic step growth.

compact device layout. This was made possible with a heavily doped base region.

Unfortunately, high-PAE values (>50%) have never been achieved for single SiGe power HBTs operated at X-band and beyond with an output power of over 0.5W. While SiGe HBTs have shown the promise for RF and microwave applications with a higher level integration than the III–V counterparts, it is vital to develop high-frequency (C and X-bands) power SiGe HBTs that exhibit a higher power gain and a higher efficiency to make these devices fulfil the requirements of power amplification in these frequency ranges.

Mid-infrared detectors

Development of uncooled detectors for the mid-IR detection range is important for a broad range of potential applications. Today's IR imaging arrays are based on either HgCdTe or intersubband quantum well photon detectors, but these are well known for the problems, associated with cryogenic cooling in order to produce high sensitivities.

A new material system, based on alternating thin layers of InAs and GaSb, is attractive owing to its intrinsic flexibility for tailoring the band gap, see Figures 2 and 3. Moreover, the band structure can be designed to reduce the Auger recombination and tunnelling current making room temperature operation possible.

New advances in realizing this system have been reported in the paper entitled "Pushing the envelope to the maximum: Short-period InAs/GaSb type-II superlattices for mid-infrared detectors" written by Heather Haugan and her colleagues (F. Szmulowicz, G.J. Brown, B. Ullrich, S.R Munshi, L. Grazulis, K. Mahalingam and S.T. Fenstermaker) at the US Air Force Research Laboratory in Ohio, USA. The team used a new iteration of their envelope function approximation model to design a series of superlattices for the mid-IR (3-5μm) detection threshold. The new feature of the model is its inclusion of symmetry lowering at interfaces due to the presence of either GaAs- or InSb-like bonds between InAs and GaSb layers. The model predicts that the thinner designs hold a promise of higher mobilities and longer Auger lifetimes, thus higher detector operating temperatures.

The suggested short-period designs ranging from 50 to 21 Å were grown by molecular beam epitaxy. The band gap measured by 5-K photoluminescence from various designs was around 340-320 meV. Although the low temperature wavelength threshold is near 4 μm, by room temperature, this cutoff wavelength would shift to around 5 μm, thus covering the full 3-5 μm atmospheric window for infrared sensing. The overall material quality grown by this group was excellent, as shown in Figure 2 and 3. After in-situ annealing, the photoluminescence spectra exhibited a remarkably narrow full-width at half maximum of 5 meV for the luminescence peak.

Heather says "Since our superlattice system has the unique type-II band alignment, its band gap can be tuned to the mid-IR detection range by growing short-period SLs. But growth of high-quality uncooled mid-IR detectors using superlattice materials is still quite challenging due to the complexity of growing alternating thin layers. Even so, by selecting the proper theoretical model and continuous efforts on material improvements, the research will lead us closer to achieving uncooled mid-IR detectors.

Roy Szweda

In the last issue the overview was more of a retrospective, this time it showcases some of the exciting III-V-related device technologies in prospect, such as improved HBTs. Amongst more intriguing longer-term prospects are magnetic materials nanowhiskers, and new formats for existing devices such as 'electronic skins'.

Into the 2005 crystal ball

The annual IEDM meeting has always been a useful barometer - the 2004 meeting which celebrated the half-century, naturally included some major new developments. This article will, however, not be restricted to the IEDM but take a broader view so as to try to better reflect progress in the compounds. The IEDM concentrates on silicon-related devices but because some of the best performance can only be achieved in III-Vs, the record-breakers are often in GaAs and the like.

For example, T Hussain *et al*, at HRL Laboratories described a device combining speed with the lowest power consumption ever reported for an HBT: 430GHz (f_{max}) and 370 GHz (f_t) using only 6mA of current. HRL said the emitter widths are the smallest of any III-V devices reported to date (less than 250nm wide) hence the impressive power efficiency. They expect to be able to further reduce base resistance by 50% to give f_{max} of 500 GHz.

Impressive device performance is reliant not only on the semiconductor, but also on the packaging materials. One group's work can be taken as an example of the importance of having a package with low thermal resistance mounting - in this case by an in-house developed flip-chip soldering process on diamond or AlN submounts. A flip-chip mounted 26V GaInP/GaAs power HBT was reported by P Kurpas, *et al*, of the Ferdinand-Braun-Institut fuer Hoechstfrequenztechnik (FBH) in Berlin in conjunction with United Monolithic Semiconductors. Their high-voltage HBT power cells deliver up to 14W at 2 GHz with a PAE up to 71% and high gain of 14dB.

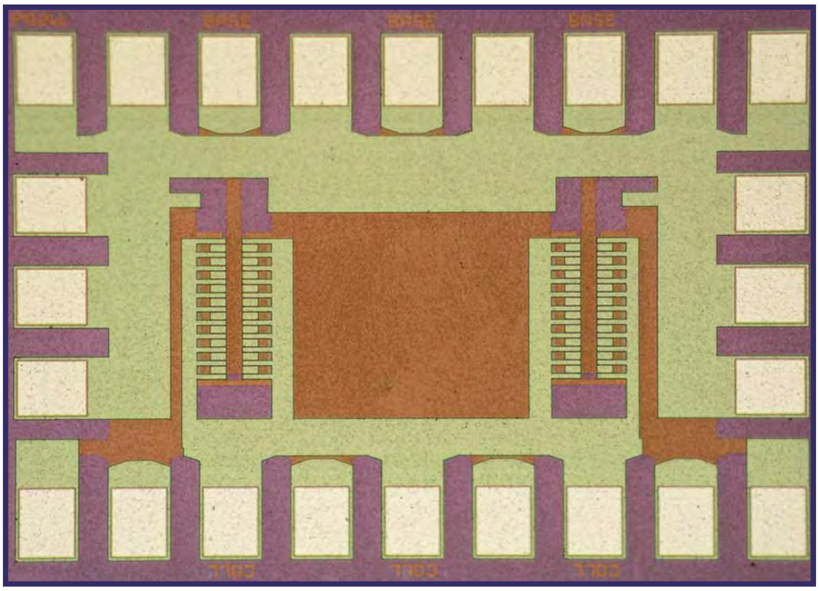

Figure 1: Micrograph of a 3-W power SiGe HBT module, consisting of 160 emitter fingers with 0.9x30.3µm² emitter area each

Compare this to some of the benchmarks being set in SiGe! 2005 will no doubt see these moved even higher. IBM's M Khater *et al*, have reduced the emitter width in their SiGe HBTs by reducing the spacing between the base and emitter. In so doing they lifted f_{max} and f_t, to 340 GHz and 300 GHz, respectively, at a 1.7V breakdown voltage.

Power output importance

Of course power output is also important; 3W RF power with concurrent 67% PAE and power gain of 9.8dB has been achieved from 0.9µm emitter finger power SiGe HBTs. This translates to an RF power density of 1.13 mW/µm^2. The work was reported in new papers from Assistant Prof Zhenqiang Ma and his colleagues at the Dept of Electrical and Computer Engineering, University of Wisconsin, in conjunction with Jazz Semiconductor. These were developed using Jazz Semiconductor's 4-metal SiGe BiCMOS platform for 1.9GHz portable wireless communications (see Figure 1).

" These results show the great potential of SiGe HBTs for on-chip high-power amplification. The increasing RF performance exhibited by SiGe HBTs has enabled these devices as a new contender for many microwave wireless applications wherein GaAs-based devices had to be used previously," he said. 'The ease of Si processing allows SiGe HBTs to be manufactured into very small emitter feature sizes with relatively low cost. The compatibility between SiGe HBTs and CMOS has made single-chip mixed-signal integration feasible."

The power SiGe HBTs in question were high-voltage devices, consisting of 160 emitter fingers, with dimensions of $0.9 \times 20.3 \mu m^2$ for each finger. The total emitter area is about $2900 \mu m^2$ and is optimised for thermal stability and high PAE.

Before moving on, it is worth noting that R&D is by no means static in the application of III-V alloys in the HBT field. There are likely to be more key announcements over the New Year if recent papers are a guide. For example, C-doped GaAsSb base HBTs without hydrogen passivation are under investigation at NTT Photonics Labs in Japan. Recently, Yasuhiro Oda *et al,* reported their MOVPE-based work which found that hardly any hydrogen atoms are incorporated into C-doped GaAsSb if the annealing is performed under a hydride atmosphere. Hydrogen concentration in the base was under the detection limit of SIMS measurement. Results like these could mean that the HBT fabrication can be simplified. A relatively high-performance HBT (β40, f_T300 GHz, f_{max}200 GHz, and BVCEO6 V) was made without any dehydrogenation.

Hydrogen is also a factor in other devices notably in HEMTs. A national collaboration in Korea has provided some insight into the performance behaviour of AlGaAs/InGaAs p-HEMTs and how this can be applied to an E/D-mode HEMT. In-Ho Kanga *et al*, from the Dept. of Information and Communications, Gwangju Institute of Science and Technology (GIST), exposed the gate region of the p-HEMTs to a hydrogen plasma in an RIE chamber, followed by a thermal annealing, prior to gate metallisation.

They found a strong dependence of the threshold voltage, the gate leakage current, and low-frequency noise characteristics on the RF power of the hydrogen plasma and annealing temperature. The selective hydrogen pretreatment (SHP)

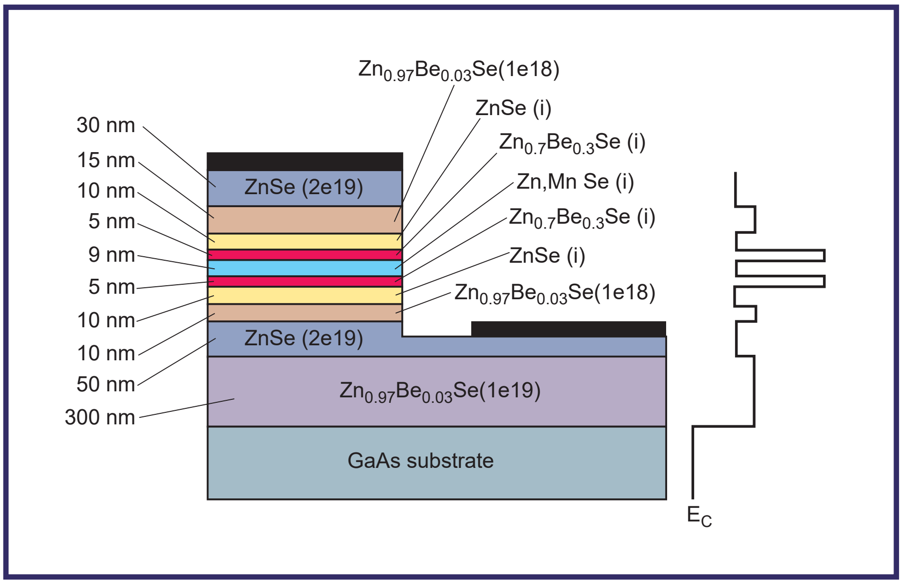

Figure 2: Schematic drawing of the all-II-VI resonant tunnelling diode with (Zn.Be) Se barriers

produced improved gate leakage current, breakdown voltage, and low-frequency characteristics. These results indicate the potential of the selective hydrogen pretreatment for use in an easier fabrication of E/D-HEMTs.

Meanwhile, M A Mastro *et al* at the US Naval Research Lab, Power Electronic Materials Section, have reported results from their studies of Group III-nitride HBTs. Potentially, these have much to offer for high current handling, high breakdown voltage, and device linearity, etc.

"Despite the many attractive features," he says, "Progress in III-nitride bipolar electronic devices has lagged the successes enjoyed by AlGaN/GaN HEMTs. This is due to difficulties associated with growth and processing. There is an alternative which combines the advantages of SiC and GaN systems to yield n-GaN/p-SiC/n-SiC HBTs. This HBT is theoretically capable of higher output power at microwave frequencies and should have a better linear response than SiC BJTs or nitride HBTs. Into the bargain it is much simpler to fabricate than a nitride HBT."

However, there are problems relating to leakage currents through the n-GaN/p-SiC heterojunction, due to the poor quality of the interface which ultimately limits the output gain. Nevertheless, progress has been forthcoming - his team have, for the first time, modelled the influence of strain and polarisation fields in (Al)GaN films grown directly on 4H-SiC substrates, yielding band diagrams as well as device I-V parameters. Apparently leakage is made worse by the profusion of dislocations in the (Al)GaN films grown on 4H-SiC without low-temperature GaN or insulating AlN layers. But, as the team showed, onset of misfit dislocation formation can be avoided by nano-heteroepitaxy of (Al)GaN emitters in confined areas or on mesas.

Nanowhiskers

Attention now turns to the more exotic. There has been much discussion in the electronics press as to the potential for nanostructures, as if this was new.

For compound semiconductors this is not the case, since the fabrication of nm-dimension devices has almost become routine. In particular, GaAs quantum wires have been extensively studied because of their potential applications to electronic devices. These quantum effects provide a means of artificially controlling the electrical properties of materials and could lead to the development of new devices. The tools and procedures are in place and numerous interesting developments are underway worldwide. These are likely to be significant for the medium to long term on commercial terms

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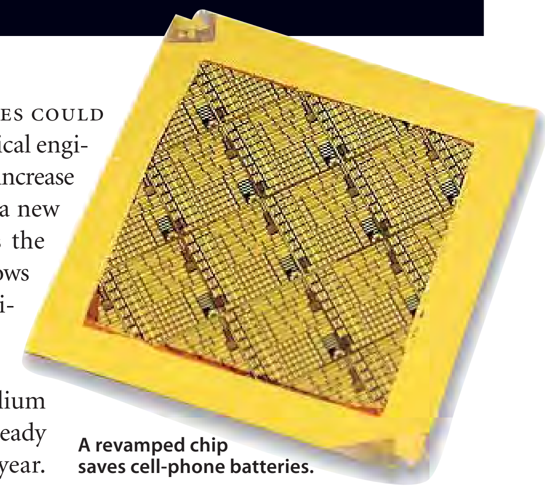
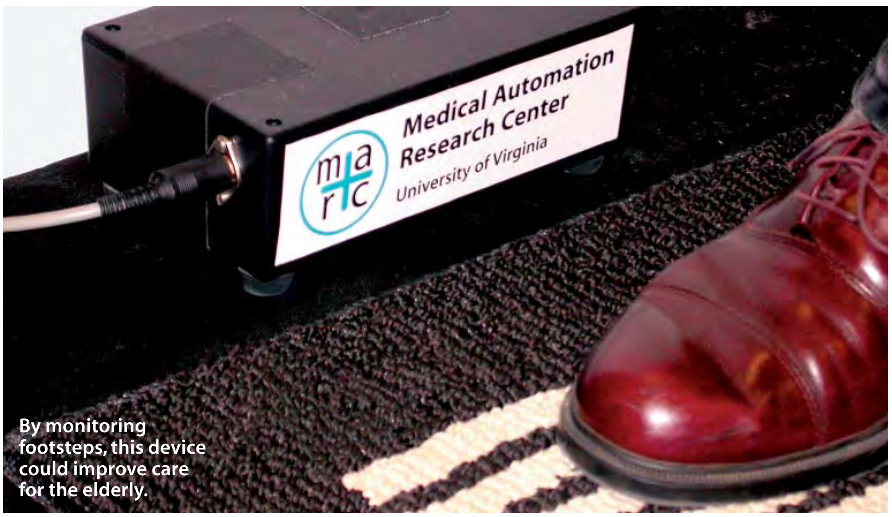


A revamped chip saves cell-phone batteries.

BATTERY-HOGGING, STATIC-RIDDEN CELL PHONES AND OTHER WIRELESS DEVICES COULD soon be a thing of the past. Zhenqiang Ma, a University of Wisconsin-Madison electrical engineer, says he has redesigned a key electronic component in wireless devices so that it can increase the strength of outgoing signals while saving battery power. Ma has come up with a new arrangement of transistors for the power amplifier, the component that boosts the strength of an electrical signal before sending it to a device's antenna. The new design allows for easier and more uniform heat dissipation. Since excessive heat lowers power amplification, this translates into a stronger signal and less wasted battery power; a cell-phone user could get 25 percent more talk time out of each battery charge. Ma has produced silicon chips that use his new design and is now working on versions made from gallium arsenide, the most common semiconductor for cell phones. He says his technology is ready to be licensed by a chip maker and could be on the market as early as the end of this year.



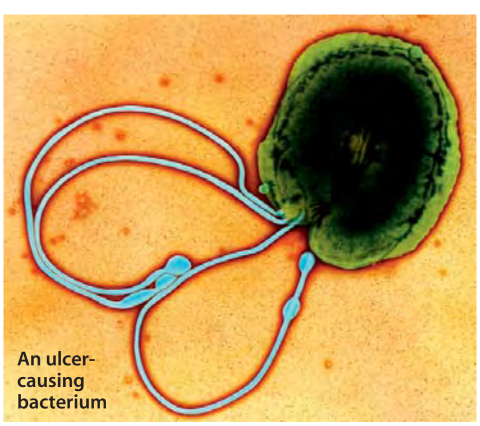
By monitoring footsteps, this device could improve care for the elderly.

HEARING STEPS

THE FLOORS HAVE EARS. BIOMEDICAL ENGINEER MAJD ALWAN AND HIS COLLEAGUES AT the University of Virginia have developed a device that analyzes the footstep patterns of the elderly to detect falls and give early warning of certain diseases. Unlike monitors that require users to wear sensors, walk on special platforms, or be videotaped, this device sits on the floor unobtrusively. The brick-size box contains a sensor that measures tiny vibrations and a microprocessor that learns a person's normal walking habits and uses signal-processing algorithms to detect changes. If the person falls, or limps or shuffles—warning signs of diseases such as osteoarthritis or Parkinson's—the monitor alerts a computer to send a message to a caregiver. The goal, says Alwan, is to "bring gait analysis out of the lab and into the home." His team recently spun off a company to commercialize the device, which could be placed in homes and assisted-living facilities within a year.

CAR POOL COORDINATION

It's already happening in a few cities. Lone drivers who want to use car pool lanes can stop at informal gathering spots to pick up passengers who need rides. But passengers aren't always going to the same destinations as drivers—and some drivers prefer quiet passengers to talkative ones. So information science researchers Paul Resnick of the University of Michigan in Ann Arbor and Marc Smith at Microsoft are creating a computerized system that will make it easier for drivers and passengers in any city to find happy car pool matches. Called RideNow, the system starts with a Web interface where users can log in, specify their preferences, and enter their destinations and the approximate times at which they want to travel. Software matches up drivers and passengers, calls both parties' cell phones, and patches the calls together so that the users can negotiate a meeting place. Resnick says tests of the system should start this fall in Ann Arbor. Later, Resnick hopes, startups might want to commercialize the service in cities without extensive public transportation, perhaps charging a subscription fee.



An ulcer-causing bacterium

ZAPPING ULCERS

IF YOUR DOCTOR THINKS YOU HAVE AN ULCER, YOU MAY HAVE TO SWALLOW A special camera called an endoscope to find out for sure. The good news: in about a year doctors may be able to quickly and painlessly cure the ulcer at the same time, thanks to a device from Boston, MA-based startup LumeRx. The company is developing a fiber-optic device that can be passed into the stomach alongside the endoscope. In a procedure that takes only five to 10 minutes, the device beams out blue light specially tuned to kill a bacterium called *Helicobacter pylori*, which causes up to 90 percent of ulcers. Should the approach prove itself in human tests planned for this summer and gain U.S. Food and Drug Administration approval, it could offer an alternative to today's standard ulcer treatment: a one- to two-week course of antibiotics that can cause nausea and other side effects and which could ultimately promote the development of resistant strains of bacteria.

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