

Materials News

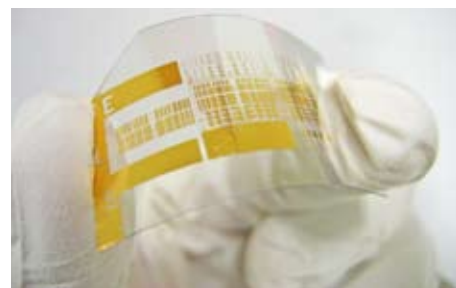
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MATERIALS SCIENCE PROGRAM

In UW-Madison's interdisciplinary Materials Science Program, you will find opportunities to conduct unique graduate research in a range of areas and draw on the expertise of faculty from departments campuswide. Read about some of the program's activities here, E-mail Diana Rhoads at rhoads@engr.wisc.edu to learn more about materials science graduate study, or visit www.engr.wisc.edu/interd/msp.

A pair of UW-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 LCD displays 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.



High-speed electronics have flexibility in their future, thanks to new lightning-fast thin silicon transistors.

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 displays, 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 on 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 therefore 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 the transistors are fabricated on. "That is the major obstacle to realizing the high speed operation of TFTs, regardless of the fact that high mobility

World-record speed for thin-film transistors could revolutionize flexible electronics

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 *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.



FACULTY NEWS

A recent issue of the journal *Applied Physics Letters* featured not one, but two articles co-authored by Electrical & Computer Engineering Lynn H. Matthias Professor II **Robert Blick**. Published back-to-back, the papers were co-authored by colleagues at UW-Madison and in Germany. "Magnetotransport through two dimensional electron gas in a tubular geometry" explores topology-dependent electron transfer in micron-sized tubes of two-dimensional electron gas. "Detection of coherent acoustic oscillations in a quantum electromechanical resonator" presents a nanoelectromechanical resonator equivalent to the coherent control of a quantum mechanical two-level system with applications in phasers.

A UW-Madison research team led by Assistant Professor of Electrical & Computer Engineering **Hongrui Jiang** has demonstrated a microfluidic cooling device that provides autonomous on-chip cooling function. Thermoresponsive hydrogels trigger cooling fluid recirculation and stop circulation when the temperature drops below

a critical level. On-chip cooling techniques potentially have wide applications in lab-on-chip technologies where on-chip cooling is necessary. The report by Jiang, graduate student Abhishek Agarwal, postdoctoral researcher Liang Dong, and Biomedical Engineering Professor **David Beebe** was published on the inside front cover of the March 2007 issue of *Lab on Chip*.

Using a unique combination of barium titanate and tin, UW-Madison researchers have made the first known material that's stiffer than diamond. In laboratory experiments, Wisconsin Distinguished Professor of Engineering Physics **Roderic Lakes** and his collaborators showed that if they embed barium titanate, which exhibits negative stiffness, within a tin matrix, which exhibits positive stiffness, the resulting composite material achieves stiffness approaching 10 times that of diamond. The group published its results in the February 2, 2007, issue of *Science*. Read more at www.engr.wisc.edu/news/headlines/2007/Feb14.html.

A team of UW-Madison engineers will work with researchers at the University of Illinois at Urbana-Champaign and the University of Texas-Arlington for a multimillion-dollar Multi-disciplinary University Research Initiative from the Air Force Office of Scientific Research. Led by Erwin W. Mueller Professor and Bascom Professor of Surface Science **Max Lagally** (materials science and engineering), the team will investigate various photonic and electronic applications for silicon nanomembranes, flexible single-crystal sheets of silicon. The researchers will explore such applications as flexible electronics, sensors, NEMS, low-temperature systems, thermoelectric devices and 3-D stacked electronics, to name a few. The UW-Madison team also includes Lynn H. Matthias Professor II in Electrical & Computer Engineering **Robert Blick**, Professor of Physics **Mark Eriksson** (also materials science and engineering), Assistant Professor of Electrical & Computer Engineering **Zhenqiang (Jack) Ma** and Assistant Professor of Mechanical Engineering **Kevin T. Turner**.

College honors **Chang-Beom Eom** for research

An internationally recognized researcher, Professor of Materials Science and Engineering Chang-Beom Eom has made exceptional contributions to the field of superconducting thin films. To honor his skill at developing both methods and materials, Eom received the 2007 Byron Bird Award for Excellence in a Research Publication for a series of three publications that have become standards in the fields of thin-film deposition and electrical connections. His innovation, insight and cheerful personality have earned respect from colleagues across the globe.

The first publication, his 1989 PhD paper, described a new deposition technique, off-axis sputtering, for high-temperature superconducting thin films. Before this revolutionary work, thin films were low-quality and plagued by defects. Today, off-axis sputtering is widely used to make high-quality thin films from complex materials for both commercial and research purposes, and the paper has been cited nearly 300 times.

The second and third papers detail a class of metallic oxide for electrical contacts that Eom developed using off-axis sputtering. The first of these two papers describes the general class of ruthenate-based materials, and the second focuses on one compound in particular, SrRuO₃, as a ferroelectric contact. Until then, platinum contacts were often used in ferroelectrics, but the polarization decayed with cycling. Ferroelectrics grown on Eom's material did not lose polarization, and SrRuO₃ is still one of the best contact materials for ferroelectric matter.

The method and materials described in these papers enabled researchers to overcome some of the biggest problems in thin-film epitaxy and helped turn thin film research into the thriving field that it is today. "These three publications describe truly pioneering research that is simultaneously remarkably mature, comprehensive and visionary," says a colleague. "What these papers have in common is a focus on fundamental scientific questions that—through absolutely first-rate experiments—turn out to have great potential technological impact.

"As you can see, Chang-Beom Eom truly has a nose for great, impactful science!"



Chang-Beom Eom
with Dean Paul Peercy