410 GHz

A new record frequency for a CMOS oscillator and antenna. Researchers from the University of Florida, in Gainesville, reported more than doubling last year's record. The achievement may lead to cheap terahertz security cameras that can see through clothes and packages.

Silicon Slivers for Flexible Circuits

Printing CMOS on plastic

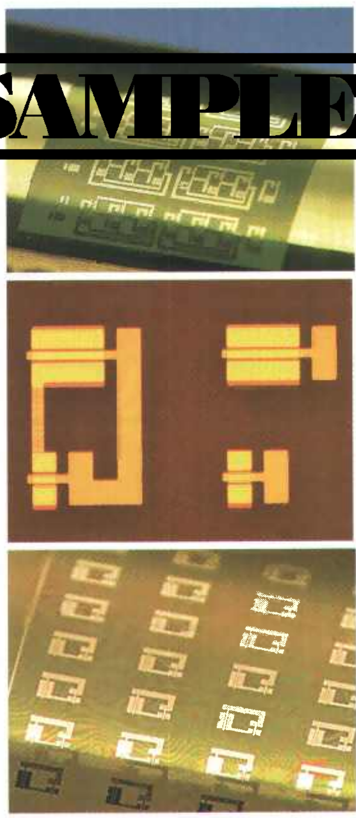
SILICON CIRCUITS that bend and stretch recently took an important step away from the world of science-fiction novels and Hollywood movies toward the real world of medical devices and media players.

A team of researchers at the University of Illinois at Urbana-Champaign (UIUC) says it has printed silicon circuits onto plastic in the form of the same CMOS circuits that dominate digital logic today. The breakthrough brings researchers closer to printing circuits on plastic that approach the performance and reliability of silicon chips.

The team, led by materials science and chemistry professor John A. Rogers, had earlier shown that they could form circuits by transferring thin ribbons of silicon onto glue-coated plastic using a patterned rubber stamp. But the resulting devices used only *n*-type silicon, whereas CMOS logic has both *n*-type and *p*-type. CMOS circuits are generally more power-efficient, because current should flow through them only when their bits are flipping. In any portable electronic device, that means longer battery life. But in the case of plastic electronics, CMOS is even more important, because it reduces the amount of heat produced—which, left unchecked, could melt the plastic.

Rogers's research, which was reported in January in *IEEE Electron Device Letters*, also showed that printed plastic circuits can reach speeds matching those of silicon chips. Rogers says his group has built silicon circuits on plastic that switch at about 500 megahertz, five times as fast as the clock in a 1995 Pentium microprocessor. "And there's no fundamental reason you couldn't go much higher," he says.

The speed of these circuits greatly outstrips those made using organic semiconductors, a key competitor in the plastic electronics race. The main problem of organics is inherently low charge-carrier mobility, the metric describing the speed at which charges move through a material. The best organics have mobilities of about 1 square centimeter per volt second versus 85 cm^2/Vs for Rogers's CMOS circuits.



PLASTIC POWER: Ring oscillators [top] and inverter circuits [center and bottom] made of silicon ribbons printed on plastic.

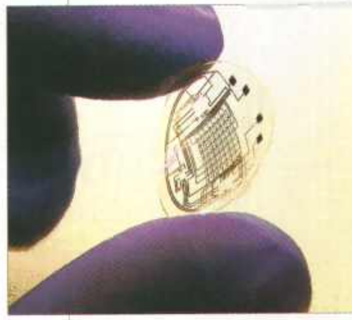
PHOTOS: JOHN A. ROGERS/UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The UIUC group's technology also competes with plastic circuits made from semiconductor nanowires, such as those under development at Palo Alto, Calif.–based Nanosys. Instead of etching off ribbons of semiconductor from a wafer as the Illinois group does, Nanosys and its partners chemically synthesize silicon nanowires by means of vapor deposition.

The UIUC and Nanosys approaches "are similar conceptually in that they take advantage of the fact that single-crystal silicon is a good material for charge transport compared with, say, organics," says Rogers. "And they both use silicon structures small enough so that they are flexible and can be integrated with plastic." But Rogers is convinced that making your own silicon when high-quality wafers are commercially available adds an unnecessary complication to the manufacturing process. Citing confidentiality agreements with Nanosys's commercial partners, the company's cofounder and vice president of business development, Stephen Empedocles, declined to make direct comparisons between the Nanosys and UIUC approaches.

Rogers's technology is under development at Semprius, a start-up based in Durham, N.C., of which he is cofounder. Besides refining the manufacturing process, Semprius is working on making silicon-based electronics that are not only bendable but stretchable. That involves making the silicon thin and then structuring "the material into a wavy shape so it becomes like the bellows on an accordion," says Rogers. One application the company is investigating is putting the stretchy circuits on spheres for electronic eye-type imaging systems.

—WILLIE D. JONES



news brief

EYE-PODS

Researchers at the University of Washington–Seattle and at Sandia National Laboratories, in Albuquerque, have unveiled the latest advance in head-up displays: a contact lens with an imprinted electronic circuit and red LEDs. Future versions will superimpose images over the user's view of the world and include wireless transceivers for two-way communication and solar cells for power. Now what's to stop future generations of students from furtively scanning crib sheets when the illicit notes are on displays built into their contact lenses?

PHOTO: UNIVERSITY OF WASHINGTON-SEATTLE