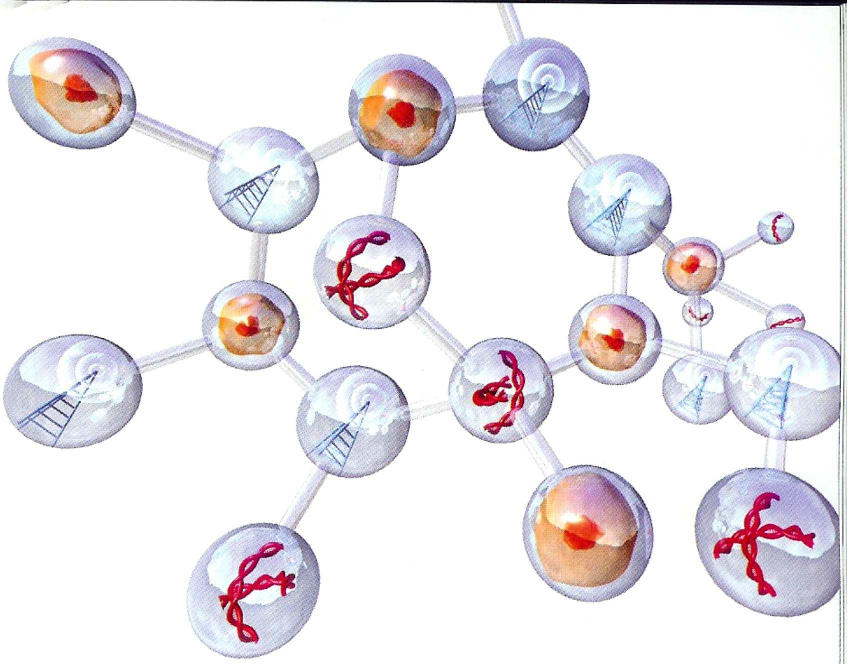


TechnologyReview

10 Emerging Technologies

EACH YEAR, *Technology Review* identifies 10 technologies that are worth keeping an eye on. This year's list spans a broad range of disciplines, from life sciences to nanotechnology to the Internet, but the technologies have one thing in common: they will soon have a significant impact on business, medicine, or culture. *Nanomedicine* and *nanobiomechanics* both illustrate nanotechnology's increasing contribution to the understanding and treatment of diseases. In biology, *epigenetics* is part of an exploding effort to understand the ways that chemical compounds can influence DNA, while *comparative interactomics* is a compelling example of how researchers are beginning to visualize the body's remarkable complexity. *Diffusion tensor imaging* is the most recent in a series of astonishing breakthroughs in imaging the brain. Meanwhile, *cognitive radio*, *pervasive wireless*, and *universal authentication* reflect the continuing struggle to keep the digital world accessible and secure. There is also controversy on the list: *nuclear reprogramming* describes the contentious hunt for an "ethical stem cell." Finally, some of the technologies, such as *stretchable silicon*, are just cool.

BRYAN CHRISTIE DESIGN

MICROELECTRONICS

Stretchable Silicon

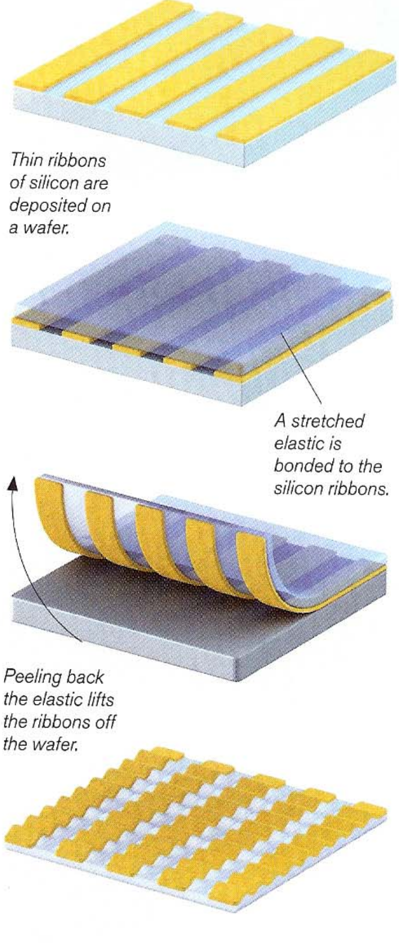
By teaching silicon new tricks, John Rogers is reinventing the way we use electronics.

THESE DAYS, MOST ELECTRONIC CIRcuitry comes in the form of rigid chips, but devices thin and flexible enough to be rolled up like a newspaper are fast approaching. Already, "smart" credit cards carry bendable microchips, and companies such as Fujitsu, Lucent Technologies, and E Ink are developing "electronic paper"–thin, paperlike displays.

But most truly flexible circuits are made of organic semiconductors sprayed or stamped onto plastic sheets. Although useful for roll-up displays, organic semiconductors are just too slow for more intense computing tasks. For those jobs, you still need silicon or another high-speed inorganic semiconductor. So John Rogers, a materials scientist at the University of Illinois at Urbana-Champaign, found a way to stretch silicon.

If bendable is good, stretchable is even better, says Rogers, especially for high-performance conformable circuits of the sort needed for so-called smart clothes or body armor. "You don't comfortably wear a sheet of plastic," he says. The potential applications of circuitry made from Roger's stretchable silicon are vast. It could be used in surgeons' gloves to create sensors that would read chemical levels in the blood and alert a surgeon to a problem, without impairing the sense of touch. It could allow a prosthetic limb to use pressure or temperature cues to change its shape.

What makes Rogers's work particularly impressive is that he works with single-crystal silicon, the same type of silicon found in microprocessors. Like any other single crystal, single-crystal silicon doesn't naturally stretch. Indeed, in order for it even to bend, it must be prepared as an ultrathin layer only a few hundred nanometers thick on a bendable surface. Rogers exploits the flexibility of thin silicon, but instead of attaching it to plastic, he affixes it in narrow strips to a stretched-out, rubber-like polymer. When the stretched polymer snaps back, the silicon strips buckle but do not break, forming "waves" that are ready to stretch out again.



Thin ribbons of silicon are deposited on a wafer.

A stretched elastic is bonded to the silicon ribbons.

Peeling back the elastic lifts the ribbons off the wafer.

Releasing the tension on the elastic produces "waves" of silicon that can later be stretched out again as needed. Such flexible silicon could be used to make wearable electronics.

Rogers's team has fabricated diodes and transistors–the basic building blocks of electronic devices–on the thin ribbons of silicon before bonding them to the polymer; the wavy devices work just as well as conventional rigid versions, Rogers says. In theory, that means complete circuits of the sort found in computers and other electronics would also work properly when rippled.

Rogers isn't the first researcher to build stretchable electronics. A couple of years ago, Princeton University's Sigurd Wagner and colleagues began making stretchable circuits after inventing elastic-metal interconnects. Using the stretchable metal, Wagner's group connected together rigid "islands" of silicon transistors. Although the silicon itself couldn't stretch, the entire circuit could. But, Wagner notes, his technique isn't suited to making electrically demanding circuits such as those in a Pentium chip. "The big thing that John has done is use standard, high-performance silicon," says Wagner.

Going from simple diodes to the integrated circuits needed to make sensors and other useful microchips could take at least five years, says Rogers. In the meantime, his group is working to make silicon even more flexible. When the silicon is affixed to the rubbery surface in rows, it can stretch only in one direction. By changing the strips' geometry, Rogers hopes to make devices pliable enough to be folded up like a T-shirt. That kind of resilience could make silicon's future in electronics stretch out a whole lot further. **KATE GREENE**

OTHER PLAYERS

Stretchable Silicon

Researcher	Project
Stephanie Lacour *University of Cambridge, England*	Neuro-electronic prosthesis to repair damage to the nervous system
Takao Someya *University of Tokyo*	Large-area electronics based on organic transistors
Sigurd Wagner *Princeton University*	Electronic skin based on thin-film silicon

BRYAN CHRISTIE DESIGN