across them, this technique allows researchers to directly trace connections between sections of the brain. The Connectome team had Siemens customize its top-of-the-line MRI machine to let them alter its magnetic field strength more rapidly and dramatically, which produces clearer images.

Each imaging modality has its limitations, so combining them gives neuroscientists their best view yet of what goes on inside a human brain. First, however, all that neuroimaging data needs to be purged of noise and artifacts, and it needs to be organized into a useful database. Dan Marcus, director of the Neuroinformatics Research Group at the Washington University School of Medicine, developed the image-processing software that automatically cleans up the images and precisely aligns the scans so that a single "brainordinate" refers to the same point on a diffusion MRI and fMRI scan. That processing is computationally intensive, says Marcus: "For each subject, that code takes about 24 hours to run on our supercomputer."

Finally, the team adapted open-source image analysis tools to allow researchers to query the database in sophisticated ways. For example, a user can examine a brain simply through its diffusion images or overlay that data on a set of fMRI results.

Some neuroscientists think that all this data will be of limited use. Karl Friston, scientific director of the Wellcome Trust Centre for Neuroimaging, at University College London, applauds the project's ambition, but he criticizes it for providing a resource "without asking what questions these data and models speak to." He'd prefer to see money spent on hypothesis-directed brain scans, which can investigate "how a particular connection changes with experimental intervention or disease."

But the Connectome team thinks the open-ended nature of the data set is an asset, not a weakness. They're hoping to provoke research questions they never anticipated, and in fields that they know nothing about. "You don't have to be a neuroscientist to access the data," says Marcus. "If you're an engineer or a physicist and want to get into this, you can."

—ELIZA STRICKLAND

NEWS

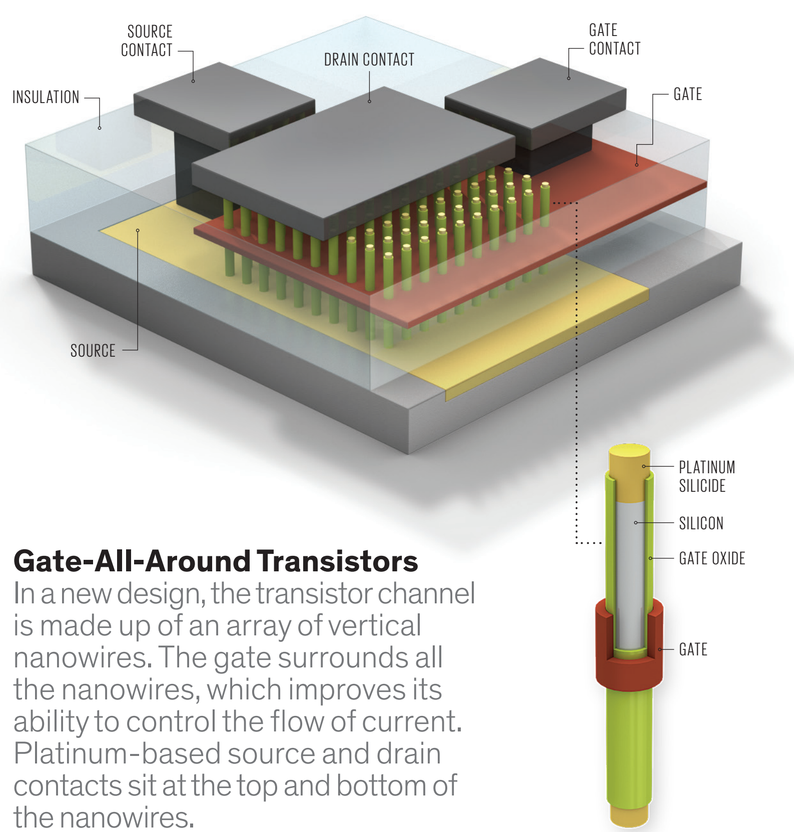
RING AROUND THE NANOWIRE

Researchers are perfecting ways to produce gate-all-around devices

THE END OF Moore's Law has been predicted again and again. And again and again, new technologies, most recently FinFETs, have dispelled these fears. Engineers may already have come up with the technology that will fend off the next set of naysayers: nanowire FETs (field-effect transistors).

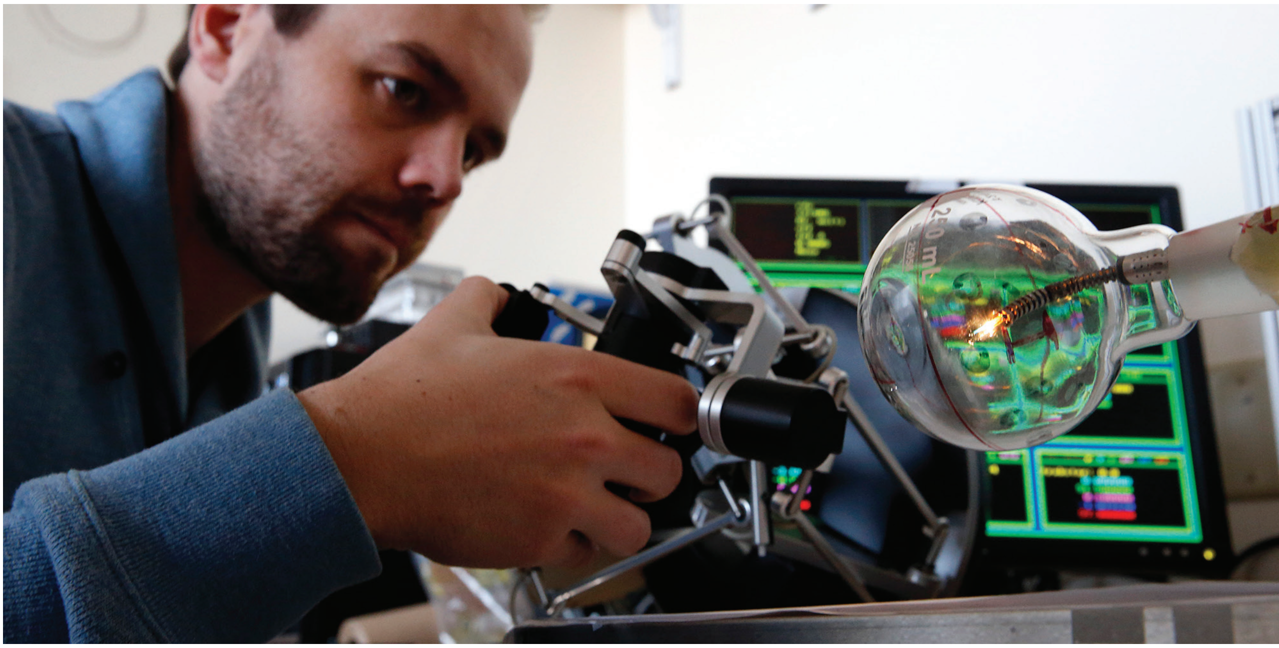
In these nanodevices, current flows through the nanowire or is pinched off under the control of the voltage on the gate electrode, which surrounds the nanowire. Hence, nanowire FETs' other name: "gate-all-around" transistors. However, because of their small size, single nanowires can't carry enough current to make an efficient transistor.

The solution, recent research shows, is to make a transistor that consists of a small forest of nanowires that are under the control of the same gate and so act as a single transistor. For example, researchers at Hokkaido University and from the Japan Science and Technology Agency reported last year in *Nature* a gate-all-around nanowire transistor consisting of 10 vertical indium gallium arsenide nanowires grown on a silicon substrate. Although the device's electrical properties were good, the gate length—a critical dimension—was 200 nanometers, much too large for the tiny transistors needed to power the microprocessors of the 2020s. »



Gate-All-Around Transistors
In a new design, the transistor channel is made up of an array of vertical nanowires. The gate surrounds all the nanowires, which improves its ability to control the flow of current. Platinum-based source and drain contacts sit at the top and bottom of the nanowires.

ILLUSTRATION BY Emily Cooper



BLADDER-BOT Vanderbilt University engineers have invented a 5.5-millimeter-wide robot designed to snake through the urethra to find and remove bladder tumors.

Now two researchers working in France, Guilhem Larrieu of the Laboratory for Analysis and Architecture of Systems, in Toulouse, and Xiang-Lei Han of the Institute for Electronics, Microelectronics, and Nanotechnology, in Lille, report the creation of a nanowire transistor that could be scaled down to do the job. It consists of an array of 225 doped-silicon nanowires, each 30 nm wide and 200 nm tall, vertically linking the two platinum contact planes that form the source and drain of the transistor. Besides their narrowness, what's new is the gate: A single 14-nm-thick chromium layer surrounds each nanowire midway up its length.

That thickness, the gate length, is the key. "The advantage of an all-around gate allows the creation of shorter gates, without loss of control on the current through the channel," explains Larrieu. "We demonstrated the first vertical nanowire transistor with such a short gate." An all-around gate will be a must if gate lengths are to get smaller than 10 nm, he says. In that scheme, "the size of the gate depends only on the thickness of the deposited layer; there is no complicated lithography involved," he adds.

The nanowires were of an unusual construction. Unlike with most vertical nanowire transistor prototypes, in which the nanowires are grown upward from a substrate, the French duo created their nanowires by starting out with a block of doped silicon and then etching away material to leave nanopillars. In between the pillars, they deposited an insulating layer to about half the pillars' height. Then they deposited the 14 nm of chromium and filled the remaining space with another insulating layer. "We tried to make the process completely compatible with current technology used in electronics. No new machines will have to be invented," says Larrieu. The researchers have plans to try to go below 10-nm gate length, and also to use indium gallium arsenide nanowires because of the better electron mobility.

Kelin Kuhn, director of advanced device technology at Intel's Hillsboro, Ore., location, agrees that all-around gate structures have some key advantages. Of all the CMOS-style advanced devices, they're generally expected to provide the best gate control for very short channels, she says.

Davide Sacchetto, a researcher at the École Polytechnique Fédérale de Lausanne, agrees: "The fabrication of the gate is interesting, and you get a small gate length." However, the advantage is lost if the nanowires are too long—200 nm in this case—and the channel is only a small part of the total length of the nanowire, he says. "Even a difference of 5 nm would make a huge difference in the drain current."

According to Judy Hoyt, a researcher at the Microsystems Technology Laboratories at MIT, gate-all-around technology is now under study at a number of university labs worldwide. But as the nanowire transistors are more complex than the FinFETs, will this effort allow Moore's Law to live longer and fit even more transistors on a chip? "The jury is still out," says Hoyt. It depends on what the fabrication process and the structure will be, she says. "You really have to get the physics right, and that is what all these efforts are based on." —ALEXANDER HELLEMANS

JOE HOWELL/VANDERBILT UNIVERSITY

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