THE NEXT HIGH-PERFORMANCE TRANSISTOR

A potential FinFET successor is made from stacks of lateral nanowires

Five years ago, Intel introduced today’s high-performance transistor to the world. Dubbed the FinFET, the device takes its name from its appearance: The transistor’s current-carrying channel sticks up vertically in the shape of a fin, and the gate that controls it drapes over the sides. The result is a much tighter control over the flow of current, which in modern microprocessors can fairly easily sneak across the transistor when it’s supposed to be shut off.

But well before the FinFET exploded onto the scene in 2011, engineers and device physicists had already been looking at the possibility of taking that transistor geometry to its logical conclusion, with a gate that completely surrounds the current-carrying channel. Shifting to such a “gate-all-around” geometry would, in theory, allow chip companies to produce shorter transistors that don’t leak copious amounts of current, improving speed or power consumption in the process.

Now, Hans Mertens and colleagues from the nanoelectronics research firm Imec, based in Leuven, Belgium, have constructed gate-all-around transistors from dense stacks of 8-nanometer-wide nanowires on a conventional silicon surface. Although engineering hurdles remain, the coming years could see further improvements to this basic approach—and perhaps its introduction into mass manufacturing.

Gate-all-around devices can be made by orienting a nanowire made of semiconducting material in one of two ways: laterally, as today’s transistor channels are arranged, or vertically, so that the nanowire stands on end, perpendicular to the plane of the chip.

The Imec team, which presented its findings at the Symposium on VLSI Technology and Circuits, held in June in Honolulu, took the lateral approach. They began by growing alternating layers of silicon and a silicon germanium mix. The team then etched away parallel trenches, leaving behind fins containing these alternating layers—a bit like pillars of rock with different sedimentary strata. In a later step, the team etched away the remaining silicon germanium, leaving behind two silicon nanowires in each erstwhile fin.

To create a transistor, insulating material and then metal gates were added around each nanowire to form the gate structure. And for each vertical pair of nanowires, the source and drain regions—the places where current originates and winds up—

FIN EVOLUTION:
Transistors made with stacks of horizontal nanowires take a page from the fin-like devices used today. The gate material wraps around each channel to provide better control. Stacking the nanowires boosts current density.

SHORT STACK: Imec constructed transistors from stacks of horizontal silicon nanowires (cross section of array shown here).
If you follow discussions about the Internet of Things, you’ve probably heard this stunning prediction at least once: The world will have 50 billion Internet-connected devices by 2020. Ericsson’s former CEO, Hans Vestburg, was among the first to toss out that number, when he gave a 2010 presentation to shareholders. The following year, Dave Evans, who worked for Cisco at the time, published the same prediction in a white paper.

Today, that figure has arguably done more than any other statistic to set sky-high expectations for potential IoT growth and profits. Remarkably, those projections weren’t even close to the highest at that time. A 2012 IBM forecast predicted 1 trillion connected devices by 2015. “The numbers were getting kind of crazy,” recalls Bill Morelli, director of the IHS Markit division that handles IoT and digital security.

Both Ericsson and Evans have since lowered their expectations for 2020: Evans, a cofounder of Stringify, who now serves as its chief technology officer, says he expects to see 30 billion connected devices by then; Ericsson figures on 28 billion by 2021. Other firms have adopted similar tones: IHS Markit projects 30.7 billion IoT devices for 2020; Gartner expects 20.8 billion by that time (excluding smartphones, tablets, and computers); and International Data Corp. anticipates 28.1 billion (again, not counting those devices).

That’s likely because it’s the third quarter of 2016, and we’re nowhere near 1 trillion IoT devices—or even 50 billion for that matter. The true total is somewhere between Gartner’s estimate of 6.4 billion (excluding smartphones, tablets, and computers), and IHS Markit’s estimate of 17.6 billion (with all such devices included).

But the popular 50 billion figure continues to be widely cited. Even Evans is a bit surprised by its staying power. “I think people do tend to latch onto numbers that seem really hard to fathom,” he says. “Fifty billion is pretty staggering.”

Peter Middleton, a research director at Gartner...