Building "bottom-up" circuits using nanowires

By John Timmer | Last updated a day ago

The circuitry we rely on today comes from what could be considered a top-down approach, with the wiring completely laid out before it's etched into silicon. With the advent of nanotechnology, however, researchers have been able to control the assembly of material that is as small as some of the circuitry in current chips. That raises the prospect of assembling circuitry from the bottom up, starting with small functional units and assembling them into more complex hardware. A paper released by *Nature* today provides a demonstration of a functional nanowire device built from these simple starting units.

In many ways, the starting units are interesting in their own right. Their functionality relies on wires made of germanium coated in silicon, each about 10 nanometers in diameter. These nanowires have a useful property: when exposed to an external charge, the amount of charge that they can carry changes. When close to a positively charged material, the density of charge carriers in the wire goes down, and the total current it can carry drops accordingly.

The devices described in the paper layer additional wires across the germanium-silicon ones; charges can be trapped in these wires, influencing the behavior of the underlying nanowires. This charge trapping is nonvolatile but reversible; in other words, you can switch one of the nanowires on or off by altering the charge stored in its neighborhood. This makes it possible to turn the nanowires into a standard field-effect transistor (the authors term them NWFETs for "nanowire field-effect transistors").

It's also possible to link these transistors together. By taking the output of one nanowire and pumping it into the control wire of another, the state of one wire can control the state of another. This simple property is sufficient to enable the NWFETs to perform basic logic functions.

There are lots of ways to make a basic logic gate, so that probably wouldn't have been enough to get the work into *Nature* on its own. But the authors designed the NWFETs so that they could be assembled into an array of linked gates. "We have developed a scalable system architecture in which both the locations and the interconnections of transistors are decided after fabrication," they write. By stacking two next to each other and adding the appropriate wiring, they turned the pair into a bit-adding device that kept track of the carry-over.

Since the individual FETs are reprogrammable, they then reconfigured their device as a bit subtracting device, where the outputs became the difference and borrowed bit. They got this to work as a multiplexer and demultiplexer circuit, and a type of storage unit called a D-latch. All of the states were stable, produced the right output, and provided easy-to-detect voltage differences at the output end. This complex logic is more sophisticated than anything done previously with nanowires, carbon nanotubes, or memristors. None of the previous efforts had the advantage of reprogrammability, either.

These new devices aren't about to replace the top-down approach when it comes to large chips. Even though the wires are smaller than anything Intel has in production, the associated hardware necessary to link them up into functional units requires a significant amount of die space, although the authors suggest that this portion of their production hardware could be up to 1,000 times smaller than in the demonstration device. Still, the performance and reprogrammability appear very useful, and the authors certainly don't rule out general use in the future.

For now, however, they suggest that these devices might be useful for performing simple control functions in other nanoscale hardware, where even the simplest of existing microcontrollers would dwarf whatever it's meant to control.

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