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SCIENCE

IBM Scientists Find New Way to Shrink Transistors

By **JOHN MARKOFF** OCT. 1, 2015

In the semiconductor business, it is called the "red brick wall" — the limit of the industry's ability to shrink transistors beyond a certain size.

On Thursday, however, IBM scientists reported that they now believe they see a path around the wall. Writing in the journal Science, a team at the company's Thomas J. Watson Research Center said it has found a new way to make transistors from parallel rows of carbon nanotubes.

The advance is based on a new way to connect ultrathin metal wires to the nanotubes that will make it possible to continue shrinking the width of the wires without increasing electrical resistance.

One of the principal challenges facing chip makers is that resistance and heat increase as wires become smaller, and that limits the speed of chips, which contain transistors.

The advance would make it possible, probably sometime after the beginning of the next decade, to shrink the contact point between the two materials to just 40 atoms in width, the researchers said. Three years later, the number will shrink to just 28 atoms, they predicted.

The ability to reduce electrical resistance will not only make it possible to extend the process of shrinking transistors beyond long-held beliefs about physical limits. It may also be the key to once again increasing the speed of computer processors, which has been stalled for the last decade.

The report represents a big advance for an exotic semiconductor material that has long held great promise but has also proved maddeningly difficult for scientists to work with. Single-wall carbon nanotubes are strawlike structures that are a composed of a one-atom thick matrix of carbon atoms rolled into an infinitesimally small tube.

The challenge of carbon nanotubes in their typical state is that they form what scientists call a giant “hairball” of interwoven molecules.

However, researchers have found ways to align them closely and in regularly spaced rows and deposit them on silicon wafers with great precision. They then serve the crucial role of a semiconductor, allowing electrical current to be switched on and off in a computer circuit.

Until now, however, they have been just one of a range of new materials that have been seen as candidates to replace silicon, which has for more than half a century been the material of choice for chip makers.

“Of all the possible materials, this one is at the top of the list by a long shot,” said Dario Gil, vice president for science and technology at IBM Research.

At the same time, he acknowledged that challenges remained in perfecting carbon nanotube transistors, but he said that IBM was increasingly confident that they could be overcome.

“By way of analogy, in the past we have had to carve in marble to create a statue," Dr. Gil said, referring to the photolithographic etching process that is the standard industry manufacturing technique today. In the future, researchers are looking to materials that will "self-assemble."

"With carbon nanotubes, you begin with dust and you have to find a way to assemble it into a statue," he said.

Computer chips such as microprocessors are made up of vast interconnected arrays of transistors — tiny switches that can turn electrical flows on and off. Computer processors have become vastly more powerful because it has been possible to double the number of silicon transistors etched into silicon chips at two-year intervals for many decades. Today, modern microprocessors are composed of billions of switches capable of switching on and off in just billionths of a second.

However, during the last decade, the pace and power of semiconductor technology has begun to slow. The switching speed of computer chips stopped increasing because heat created by ultrafast processors was rising to the point where the chips would break.

More recently, for most of the industry, the cost of transistors has ceased to decline with each new generation. This has undercut the tremendous power of the technology to create new markets. And this year, Intel announced that the challenges and costs of bringing a new generation of technology to market had forced it to slow the every-two-year pace it had been on for more than a decade.

Now the industry has a new reason for optimism.

"Carbon nanotube field-effect transistors are excellent candidates for improving the performance and energy efficiency of future computing systems," said Subhasish Mitra, a Stanford University electrical engineer.

The IBM researchers said that, in simulations, they had been able to