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H.P. Unveils New Memory Technology

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A team of Hewlett-Packard scientists reported Wednesday in the science journal Nature that they have designed a simple circuit element they believe will enable tiny powerful computers that could imitate biological functions.

The device, called a memristor, could make it possible to build extremely dense computer memory chips that use far less power than today's DRAM memory chips, which are rapidly reaching the limit in how much smaller they can be made.

The memristor, an electrical resistor with memory properties, may also make it possible to fashion advanced logic circuits, like a class of reprogrammable chips known as field programmable gate arrays, that are today widely used for rapid prototyping of new circuits and for custom-made chips that need to be manufactured quickly.

Potentially even more tantalizing is the memristors' ability to store and retrieve a vast array of intermediate values, not just the binary 1s and 0s as conventional chips do. This makes them function like biological synapses, which would be ideal for many artificial intelligence applications ranging from machine vision to understanding speech.

The H.P. researchers said that the discovery of the memory properties in tiny, extremely thin spots of titanium dioxide, came from a frustrating, decade-long hunt for a new class of organic molecules to serve as nano-sized switches. Researchers in both industry and academia have hoped they would be able to fashion switches as small as the size of a single molecule to someday replace transistors once the semiconductor industry's shrinking of electronic circuits made with photolithographic techniques reached a technological limit.

Independent researchers said that it seemed likely that the memristor might relatively quickly be applied in computer memories, but that other applications might be more challenging. Typically, technology advances are not adopted unless they offer dramatic cost or performance advantages over the technologies they are replacing.

"Whether it will be useful for other large scale applications is unclear at this point," said Wolfgang Porod, director for the Center of Nano Science and Technology at the University of Notre Dame.

The material offers a new approach that is radically different than another type of solid state storage called “phase-change memory” that is now being pursued by I.B.M., Intel and other companies. In a phase-change memory heat is used to shift a glassy material from an amorphous to a crystalline state and back again. The switching speed of these systems is both slower and requires more power, according to the H.P. scientists.

The memristor technology should be fairly quickly commercialized, said R. Stanley Williams, director of the quantum science research group at H.P. “This is on a fast track,” he said.

The memristor was predicted in 1971 by a Berkeley electrical engineer, Leon Chua. There have been hints of an unexplained behavior in the literature for some time, Mr. Chua said in a phone interview on Tuesday.

However, he noted that he had not worked on his idea for several decades and that he was taken by surprise when he was contacted by the H.P. researchers several months ago. The advance clearly points the way to a prediction made in 1959 by the physicist, Richard Feynman, that “there’s plenty of room at the bottom,” referring to the possibility of building atomic-scale systems.

“I can see all kinds of new technologies and I’m thrilled,” he said.

The original theoretical work done by Mr. Chua was laid out in a 1971 paper titled “Memristor — The Missing Circuit Element.” The paper argued that basic electronic theory required that in addition to the three basic circuit elements — resistors, capacitors, and inductors — a fourth element should exist.

The H.P. research team titled their paper, “The Missing Memristor Found.”

The H.P. team has successfully created working circuits based on memristors that are as small as 15 nanometers (the diameter of an atom is roughly about a tenth of a nanometer.) Ultimately, it will be possible to make memristors as small as about four nanometers, Mr. Williams said. In contrast the smallest components in today’s semiconductors are 45 nanometers, and the industry currently does not see away to shrink those devices below about 20 nanometers.

Because the idea of a memristor was invented almost 40 years ago by Mr. Chua, it is in the public domain, however the H.P. scientists have applied for patents covering their successful implementation of a working version of the device.

One of the most exciting aspects of the new devices is that they may consume dramatically less power compared with today’s microprocessors and memory devices, which must be continually refreshed electrically to maintain their state. In contrast, circuits made from memristors will require power only to switch and will hold their state for at least several years once they have been set in a particular state. Moreover, they can be made in the same kinds of semiconductor factories that the chip industry now uses without specialized equipment.

The most significant limitation that the H.P. researchers said the new technology faces is that the memristors function about 10 times more slowly than today's DRAM memory cells.

The discovery was made when the H.P. researchers and a cooperating team of scientists at U.C.L.A. got widely different results in a technical experiment involving organic materials. Ultimately the H.P. team was able to prove that the dramatic changes in resistance they were seeing were coming from a contaminant, and not from the organic molecules.

"I'll take serendipity, but it took us a long time to figure this out," Mr. Williams said.

The researchers were eventually able to determine that the change in resistance came from the movement of oxygen atoms in the material in response to an electrical charge. Moreover, the changes were so significant that it was simple to detect the state of the device even at near-atomic scale.

After beginning to explore the properties of titanium dioxide, Mr. Williams said his group was at first baffled by the effect and were unable to produce it reliably. However, through experimentation they gained a solid theoretical understanding of the phenomenon. Currently they are building the devices from a sandwich of a pure layer of titanium dioxide and a second layer of the same material doped with a proprietary material.