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IBM Attempts to Reinvent Memory
A new type of memory using nanowires could be simpler, cheaper, denser, faster, and more reliable.
By Kevin Bullis

A new nanowire-based memory device being developed by researchers at IBM could combine the best qualities of the various types of memory used today, driving down costs and improving performance. If the experimental memory pans out--and the work is still in the very early stages of development--it could serve as a universal memory, substituting for the different types now used.

Stuart Parkin, an experimental physicist at IBM's Almaden Research Center, in San Jose, CA, says that the memory, which would pack a hundred bits of data on a single nanowire, could potentially store 10 to 100 times more data than flash--the type of memory used in digital cameras and other small portable devices--while operating at much faster speeds. And because it's solid-state memory, it would be far sturdier than magnetic hard drives, which require mechanical devices to read and write data. "In principle, we could be cheaper than flash would be, denser than flash would be, and orders of magnitude faster," Parkin says. "And there's no wear-out mechanism, so it's totally reliable."

All of this should be possible, Parkin says, as a result of applying new insights into the nanoscale behavior of magnetic materials and the electronic currents in these materials that open the way to storing many bits of data on a single nanowire. Parkin has demonstrated the basic elements of the new type of memory, but has not yet built a complete prototype.

Although it is early in development, the research has attracted attention because of Parkin's track record for making major breakthroughs in magnetic memory. His earlier discoveries and inventions have led to a thousand-fold increase in the storage density of magnetic hard drives, paving the way for the massive data-storage centers crucial to today's Internet, as well as making possible the immense storage capacity of portable devices such as iPods. The new memory devices would combine advantages of the three types of memory used widely today--hard drives, flash drives, and dynamic random access memory (DRAM)--while avoiding many of their disadvantages. Like hard drives, which are the cheapest form of memory, Parkin's proposed devices would store bits of data in a magnetic medium. But unlike hard drives, they would not require a mobile head and spinning disks to read and write these bits. Indeed, there would be no mechanical parts, making Parkin's memory much more robust than a hard drive: there would be no danger of the read-write head crashing into the magnetic media and destroying data.

Parkin's memory would also have advantages over conventional solid-state memory such as DRAM and flash. Unlike DRAM, the new memory would not require a continuous supply of energy to store data. Flash memory also has this advantage over DRAM: it can store data without power. But it's slow. The new memory could be orders of magnitude faster than flash, even rivaling the speed of DRAM, Parkin says.

The devices could also be more compact and cheaper than conventional solid-state memory. They would resemble such memory in that they would use millions of tightly packed read-write devices arrayed in a grid on a memory chip, rather than the few read-write heads used in hard drives. But unlike conventional solid-state memory, in which each read-write device can store between one and four bits, each would be paired with a nanowire that can store between 10 and 100 bits. These bits would be quickly shuttled along the length of the nanowire, propelled by electronic pulses, then read or written at one point along the nanowire.

Using fewer read-write heads per bit is a more compact arrangement than conventional solid-state memory. This is particularly the case if the nanowires are oriented perpendicularly to the surface of the chip, such that they grow vertically from the surface, or are deposited in wells carved into the chip. In this case, 100 bits might be stored in the same area as one bit in a conventional device. This arrangement is key to making memory denser and also less expensive.

Critical to the technology is finding a way to shuttle bits along the length of a nanowire. In Parkin's memory, bits of information would be stored by creating or removing magnetic boundaries called domain walls within magnetic nanowires. These domain-wall bits create distinctive magnetic fields that can be read with conventional devices. Researchers have long known that these walls can be moved using magnetic fields, but the walls would move in the same direction, annihilating each other. The key to making the device work was the discovery that electronic currents in magnetic materials can move these walls along a nanowire, and move them all in the same direction. That makes it possible to shift bits around to be read by single reading and writing devices.

Before such memory devices will be on store shelves, there are a couple of problems that need to be solved. First, the current required to move the domain walls is far too high to be practical. Parkin says that he's making progress on this front, having discovered that the current can be reduced by adjusting the frequency of short bursts. He's also working with new materials that may require less current.

A second challenge is getting a better understanding of the behavior of domain walls. For example, it's not clear how defects in a nanowire can affect their behavior, or how closely the domain walls can be spaced. The answers to these questions may determine just how much more dense the memory will be, says Stuart Wolf, a professor of materials science and engineering at the University of Virginia. Wolf also notes that it will be difficult to reach the speeds of DRAM, since there will be some delay involved in shuttling domain walls along a nanowire.

The researchers will probably start with a simple version of the technology, in which the nanowires are arranged horizontally on a chip, rather than vertically. This will still allow the memory chips to be about as dense as flash memory, but with far faster performance and greater reliability than flash. If that's successful, it would justify spending more money on even more compact devices using vertical nanowires, Parkin says.