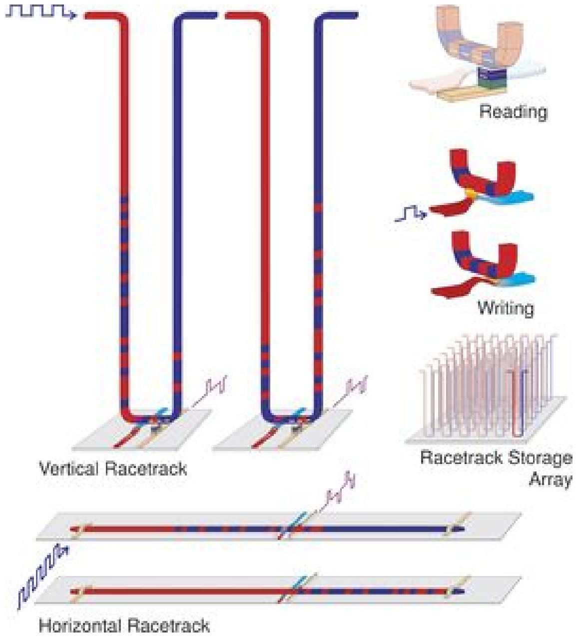
Researchers Move Closer To New Class of Memory



IBM scientists unveiled a major breakthrough in their effort to build a new class of memory, nicknamed "racetrack." A diagram of the nanowire shows how an electric current is used to slide -- or "race" – tiny magnetic patterns around the nanowire "track," where the device can read and write data in less than a nanosecond. The racetrack memory would stand billions of nanowires, like the one diagrammed here, around the edge of a chip, and potentially allow for hundreds of times the amount of storage in the same space as today&acutes memory. The expected benefits of racetrack memory over today’s memory technologies include operating at a greater speed, consuming much less power, and being practically indestructible, potentially unleashing applications that nobody has even imagined yet. Credit: IBM

Computer memory that combines the high performance and reliability of flash with the low cost and high capacity of the hard disk drive could be closer than you think, thanks to a team of IBM scientists.

In two papers published in the April 11 issue of *Science*, IBM Fellow Stuart Parkin and colleagues at the IBM Almaden Research Center in San Jose describe both the fundamentals of a technology dubbed "racetrack" memory as well as a milestone in that technology. This milestone could lead to electronic devices capable of storing far more data in the same amount of space than is possible today, with lightning-fast boot times, far lower cost and unprecedented stability and durability.

Within the next ten years, racetrack memory, so named because the data "races" around the wire "track," could lead to solid state electronic devices – with no moving parts, and therefore more durable – capable of holding far more data in the same amount of space than is possible today. For example, this technology could enable a handheld device such as an mp3 player to store around 500,000 songs or around 3,500 movies – 100 times more than is possible today – with far lower cost and power consumption. The devices would not only store vastly more information in the same space, but also require much less power and generate much less heat, and be practically unbreakable; the result: massive amounts of personal storage that could run on a single battery for weeks at a time and last for decades.

"It has been an exciting adventure to have been involved with research into metal spintronics since its inception almost 20 years ago with our work on spin-valve structures," said Dr. Parkin. "The combination of extraordinarily interesting physics and spintronic materials engineering, one atomic layer at a time, continues to be highly challenging and very rewarding. The promise of racetrack memory - for example, the ability to carry massive amounts of information in your pocket - could unleash creativity leading to devices and applications that nobody has imagined yet."

IBM is no stranger to creating entirely new markets that spring from exploratory research such as this. Just a few of the many game-changers invented at IBM Research include the memory chip, the hard disk drive and the relational database.

Currently, there are two main ways to store digital information: solid state random access flash memory, commonly used in devices such as mobile phones, music players and digital cameras, and the magnetic hard disk drive, commonly used in desktop and laptop computers and some handheld devices. While both classes of storage devices are evolving at a very rapid pace, the cost of storing a single data bit in a hard disk drive remains approximately 100 times cheaper than in flash memory. While the low cost of the hard disk drive is very attractive, these devices are intrinsically slower and, with many moving parts, have mechanical reliability issues not present in flash technologies.

Flash memory, however, has its own drawbacks – while it is fast to read data, it is slow to write data, and it, too, has a finite lifespan. Flash, can be reused only a few thousands of times because it eventually breaks because it is slightly damaged by each use or "rewrite."

Since racetrack memory has no moving parts, and, rather than storing data as ensemble of electronic charge, uses the "spin" of the electron to store data, it has no wear-out mechanism and so can be rewritten endlessly without any wear and tear.

A closer look at racetrack

For nearly fifty years, scientists have explored the possibility of storing information in magnetic domain walls, which are the boundaries between magnetic regions or "domains" in magnetic materials. Until now, manipulating domain walls was expensive, complex, and used significant power to generate the fields necessary to do so. In the paper describing their milestone, "Current Controlled Magnetic Domain-Wall Nanowire Shift Register," Dr. Parkin and his team describe how this long-standing obstacle can be overcome by taking advantage of the interaction of spin polarized current with magnetization in the domain walls; this results in a spin transfer torque on the domain wall, causing it to move. The use of spin momentum transfer considerably simplifies the memory device since the current is passed directly across the domain wall without the need for any additional field generators.

In the review paper that describes the fundamentals of racetrack, "Magnetic Domain-Wall Racetrack Memory," Dr. Parkin and colleagues describe the use of magnetic domains to store information in columns of magnetic material (the "racetracks") arranged perpendicularly or horizontally on the surface of a silicon wafer. Magnetic domain walls are then formed within the columns delineating regions magnetized in opposite directions (e.g. up or down) along a racetrack. Each domain has a "head" (positive or north pole) and a "tail" (negative or south pole). Successive domain walls along the racetrack alternate between "head to head" and "tail to tail" configurations. The spacing between consecutive domain walls (that is, the bit length) is controlled by pinning sites fabricated along the racetrack.

In their paper, the scientists describe their use of horizontal permalloy nanowires to demonstrate the successive creation, motion and detection of domain walls by using sequences of properly timed nanosecond long spin-polarized current pulses. The cycle time for the writing and shifting of the domain walls is a few tens of nanoseconds. These results illustrate the basic concept of a magnetic shift register relying on the phenomenon of spin momentum transfer to move series of closely spaced domain walls – an entirely new take on the decades-old concept of storing information in movable domain walls.

Ultimately, the researchers expect the racetrack to move into the third dimension (3D) with the construction of a novel 3D racetrack memory device, a paradigm shift from traditional two-dimensional arrays of transistors and magnetic bits found in silicon-based microelectronic devices and hard disk drives. By moving into the third dimension, racetrack memory stands to open new possibilities for developing less expensive, faster devices because it is not dependant on miniaturization as dictated by Moore’s Law.

Racetrack memory: in the fast lane

Dr. Parkin’s advances with racetrack memory build on his prior accomplishments in memory technologies including the spin valve, and Magnetic Tunnel Junctions (MTJs) and breakthroughs in magnetic RAM (MRAM).

Racetrack memory encompasses the most recent advances in this realm, the field of metal spintronics. The spin-valve read head enabled a thousand-fold increase in the storage capacity of the hard disk drive in the past decade; the MTJ is in the process of supplanting the spin-valve because of its higher signal. MTJs also form the basis of modern MRAM, in which the magnetic moment of one electrode is used to store a data bit. Whereas MRAM uses a single MTJ element to store and read one bit, and hard disk drives use a single spin-valve or MTJ sensing element to read the approximately 100 GB of data in a modern drive, racetrack memory uses one sensing device to read 10 to 100 bits.

Further understanding of the interaction of spin polarized current with magnetic moments is essential. "For example, this might allow a reduction in the current density needed to manipulate or move domain walls," said Dr. Parkin. "This would drop the power needed for racetrack further, and enable even lower power devices. We expect that our exploration of a wide variety of materials and structures will provide new insight into domain wall dynamics driven by current, making possible domain wall based memory and even logic devices that were previously inconceivable. It will not only change the way we look at storage, but the way we look at processing information. We're moving into a world that is more data-centric than computing-centric."

Source: IBM