New logic: the attraction of magnetic computation

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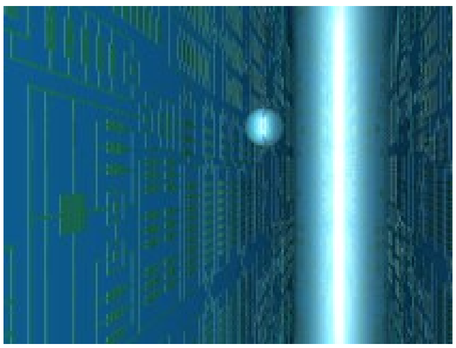

Spinning into control with next-generation microchip-making. © Jennyhorne - Dreamstime.com

European researchers are the first to demonstrate functional components that exploit the magnetic properties of electrons to perform logic operations. Compatible with existing microtechnology, the new approach heralds the next era of faster, smaller and more efficient electronics.

In the 1960s, Henry Moore observed that it took around 18 months for silicon chip manufacturers to shrink their technology and fit twice as many transistors into the same area of silicon.

But Moore's Law is beginning to lose its hold. According to the International Technology Roadmap for Semiconductors (ITRS), devices based on silicon-only technology will soon reach the limits of miniaturisation and power efficiency.

Chip designers and manufacturers are looking for new materials and techniques that will drive forward a new era of electronic devices and applications. An EU-funded project called MAGLOG has demonstrated for the first time the possibility of producing processors from ferromagnetic materials that are faster, smaller and more efficient than conventional silicon chips.

More than 150 years ago, Lord Kelvin found that the electrical resistance of iron changed when it was in an external magnet field, and that the change depended on the direction of the field.

This magnetoresistance effect was very small, but in 1988 Peter Grünberg and Albert Fert – joint Nobel Prize for Physics winners in 2007 – independently developed materials which exhibited much larger magnetoresistance. Their work spawned a new field of science, magnetoelectronics, or spintronics, which promises significant advances in IT and computing.

Magnetoelectronics exploit the magnetic properties or spin of electrons as well as their charge. In the presence of a magnetic field the electrons may point 'left' or 'right', which can represent bits of data, such as the binary digits 0 and 1.

MAGLOG brought together leaders in the field of magnetoelectronics to adapt the technology not just for data storage and memory, but also for computation. The project partners describe it as "memory that can think".

The input signals at each magnetic logic gate change the magnetisation of physical structures within the cell. The magnetic field affects the electrical resistance of the structures which can be measured with a readout of ‘True’ or ‘False’, or in binary a 1 or 0.

“The main goal of MAGLOG was to show that magnetic logic gates could be produced on a conventional complementary metal-oxide-semiconductor (CMOS) platform,” says the project coordinator Guenter Reiss. “For successful commercialisation, it is critical that this novel method of data processing can be integrated into conventional chip technologies.”

Swift thinking

One production approach uses lithography to etch structures within the ferromagnetic material to produce zones where the magnetic orientation of the material ‘flips’.

This switching between two states depends on input signals and thereby enables logical operations to be performed. Cells fabricated in this way use no silicon and require no multilayer processing – they can be manufactured at very low cost on flexible materials.

Another successful production approach for magnetic logic gates remains confined to high-performance computing applications that require low power consumption, for instance battery operated devices such as mobile phones.

This form of magnetic logic gate uses structures called magnetic tunnelling junctions. Each junction is manufactured from alternating layers of ferromagnetic materials and insulators. This type of gate is programmable – it is possible to change the operator within the logic gate, for example switching an ‘and’ gate to an ‘or’ function.

“The industry is crying out for reconfigurable computing to make microprocessors more efficient,” says Reiss. “We have one of the best demonstrations of reprogramming logic gates ‘on the fly’ and could enhance the performance of a central processing unit by a factor of 10 to 100.”

Magnetic logic has other advantages over conventional microprocessors. First, such processors are ‘non-volatile’, meaning that they retain their output state even when the current is switched off.

“When you switch it on again, you are exactly where you were when the power went off,” says Reiss. “This could greatly reduce or avoid the need for booting up, which can take a long time, especially with small devices that have to load a lot of information from memory.”

Magnetoelectronic components generally consume less power than their conventional counterparts, but the non-volatility can help chips cut their consumption to the bare minimum by temporarily shutting down zones that are not in use.

Attractive market

The project was originally funded for three years to build a very simple demonstrator. The team received a six-month extension for further research into the manufacture of working logic gates integrated on a CMOS wafer.

Although MAGLOG has now ended, the partners continue to work together to bring about the birth of this next-generation microprocessor technology.

Ingenia Technology, a spin-off company from project partner Imperial College, is investigating applications for domain wall structures, such as intelligent smart cards. The cards would be able to perform a degree of data processing within the smart card's chip. This in-built ‘intelligence’ provides the card with an additional layer of security.

The partners also hope to enter the market for the application-specific integrated circuits (ASIC) typically found in mobile phones. These are chips designed for a specific application and often customised for individual customers, making them expensive.

The programmability of magnetic tunnelling junction logic gates could also allow chip designers to manufacture generic chips that are then customised through logic gate programming.

“From a generic ASIC chip you could configure it with its unique identity,” says Reiss. “We know of a project in Japan and IBM are working on this, but this is a market with huge potential. There's a tremendous need for smaller chip dimensions and less power consumption, and we think that chips with magnetic logic are the answer.”

MAGLOG received funding from the EU's Sixth Framework Programme for research.

Source: ICT Results