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MILESTONE 20

Information in a spin

The success of the digital age, and the prosperity of the world economy, owes much to the development of the silicon chip and the idea that information can be represented, manipulated and transmitted in the form of electronic charge. The power and speed of computers has doubled approximately every two years for more than half a century, but within the next decade such exponential progress in silicon-based computing is expected to end — with potentially serious consequences. In 1990, Supriyo Datta and Biswajit Das proposed a device that uses electronic spin rather than charge to process information — an idea that has the potential to go beyond the fundamental limitations of silicon electronics.

The practical use of spin in the context of electronics originated from the discovery of giant magnetoresistance (Milestone 18). When an electric current flows from a magnetized material, such as a ferromagnetic metal contact, to a non-magnetic material, the charges that carry this flow become polarized so that their spins point predominantly in one direction. If this spin current is injected from the non-magnetic material into a second ferromagnetic contact, it will experience a resistance that depends on the relative orientation of the magnetic field of the contact. Such behaviour forms the basis of operation of the 'spin valve' — a device that detects the orientation of a magnetic field, facilitating substantial improvements in the storage capacity of modern computer hard disks.

Yet the spin valve is little more than a passive sensor that converts information stored magnetically into a charge-based signal that can be read by conventional electronics. By contrast, the device described by Datta and Das acts as a switch, similar in concept to the transistors of a silicon chip. Known as a Datta–Das spin field-effect transistor or spin-FET, the device would exploit the fact that in certain semiconducting materials with strong spin–orbit coupling — that is, the coupling between the orbital angular momentum of its electronic states and the spin of the electrons that fill these states — an applied electric field can rotate the direction of an injected spin current.

Although no one has yet succeeded in building a Datta–Das spin-FET, owing to several outstanding technical challenges, its proposal planted the idea that spin could be used in its own right as a means to carry and manipulate information — and gave birth to the new field of 'spintronics'.

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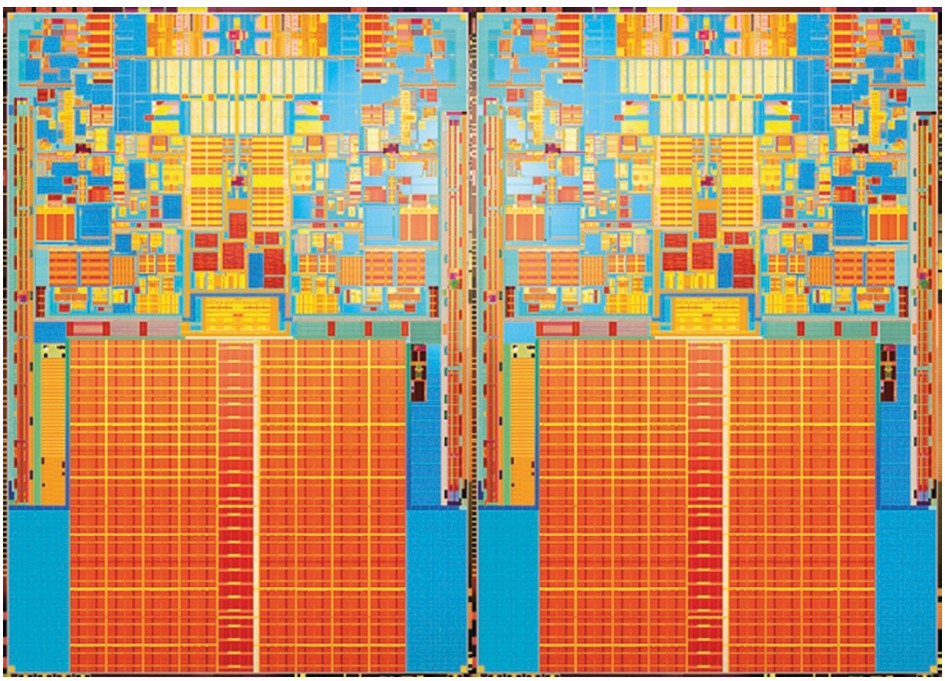
Nature Physics



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