A new spin on silicon

August 2 2005

'Orbitronics' could keep silicon-based computing going after today's technology reaches its limits

For about 40 years, the semiconductor industry has been able to continually shrink the electronic components on silicon chips, packing ever more performance into computers. Now, fundamental physical limits to current technology have the industry scouring the research world for an alternative. In a paper published in the Aug. 1 online edition of Physical Review Letters (PRL), Stanford University physicists present "orbitronics," an alternative to conventional electronics that could someday allow engineers to skirt a daunting limit while still using cheap, familiar silicon.

"The miniaturization of the present-day chips is limited by power dissipation," says Shoucheng Zhang, a professor of physics, applied physics and, by courtesy, electrical engineering, who co-authored the PRL study. "Up to 40 percent of the power in circuits is being lost in heat leakage," which he says will eventually make miniaturization a forbidding task.

Spintronics

In recent years, the search for an alternative to conventional semiconductors has resulted in the discovery of a nanotechnology called "spintronics," which uses a property of electrons called "spin" to produce a novel kind of current that integrated circuits can process as information. Spin refers to how an electron rotates on its axis, similar to the rotation of the Earth. In 2003, Zhang and colleagues at the University of Tokyo showed that producing and manipulating a current of aligned electron spins with an electric field would not involve any losses to heat-a technique they called spintronics.

Zhang now co-directs the IBM-Stanford Spintronic Science and Applications Center, along with Stanford electrical engineering Professor James Harris and IBM research fellow Stuart Parkin. The center, established in 2004, is investigating many applications of spintronics, including room-temperature superconductors and quantum computers.

Playing the angles

For all its potential, a drawback of spintronics is that it doesn't work very well with lighter atoms, such as silicon, which the microelectronics industry prefers. Enter Zhang's new research. In the PRL paper, he and graduate students B. Andrei Bernevig and Taylor L. Hughes show how, in theory, silicon could be used in a related technology they dubbed orbitronics. By using orbitronics, Zhang says, computer chip makers could get the benefits of spintronics without having to abandon silicon.

Both orbitronics and spintronics involve a physical quantity called "angular momentum," a property of any mass that moves around a fixed position, be it a tetherball or an electron.

Like an electric current, which is the flow of negatively charged electrons in a conventional integrated circuit, an orbital current would consist of a flow of electrons with their angular momenta aligned in an orbitronic circuit. "If you push electrons forward with an electric field, then an orbital current will be generated perpendicular to this electric current," Zhang says. "It will not carry charge, but will carry orbital angular momentum perpendicular to the direction in which the electrons are moving."

Therefore, he explains, with orbitronics, silicon would still be able to provide a useful current with no losses to heat at room temperature. Some alternative technologies require cold temperatures that are difficult and expensive to maintain, he adds.

From theory to application

The authors point out that orbitronics still has a long way to go to become an applied technology in the semiconductor industry. "This is so new," Zhang acknowledges. "When something is first discovered it is hard to say. There are many difficulties in the practical world."

Harris agrees, noting that spintronics will likely still take decades to become a mature commercial technology. "It's not going to happen immediately, even if we are incredibly successful," he says.

But if orbitronics turns out to indeed be an economically feasible technology to manufacture, it will be a boon to the industry to stick with silicon, Zhang says. "There is a huge, huge investment in processing silicon," he says. "We don't want to switch overnight to a new material."

Source: Stanford University

Citation: A new spin on silicon (2005, August 2) retrieved 27 April 2024 from https://phys.org/news/2005-08-silicon.html