A 'Spin-Voltaic' Effect May Enable Silicon Spintronics

October 18 2006

Can conventional semiconductors learn new tricks? Igor Zutic is betting that they can. Zutic, a University at Buffalo theoretical physicist and the recipient of a prestigious National Science Foundation CAREER Award, is finding ways to introduce spintronic properties and a phenomenon called spin injection into silicon.

"For information processing and advanced logic operations, it would be particularly desirable to integrate seamlessly magnetic materials with silicon," said Zutic, Ph.D., assistant professor of physics in the UB College of Arts and Sciences. "Rather than displace all that we've learned about silicon through the decades, my work tries to build on it."

Zutic's proposal for spin injection and detection in silicon was published in July in *Physical Review Letters* with collaborators Jaroslav Fabian of the University of Regensburg and Steven Erwin at the Naval Research Laboratory.

Now, the October issue of *Nature Materials* is publishing Zutic's "News & Views" article on related experimental efforts to grow junctions of ferromagnetic metals and silicon.

Modern information technology uses the charge of electrons to process information and the spin of electrons to store data.

While charge-based electronics is centered around semiconductor silicon chips, magnetic data storage (as in computer hard drives) relies on magnetic metals. The two spin directions, "up" or "down," provide a way to encode ones and zeroes for storing data, Zutic explained.

Research efforts that attempt to combine these two technologies, called spin electronics or spintronics, promise low power/high speed computers, which could be turned on instantly and require no boot-up time.

In addition to being abundant and inexpensive, Zutic explained, silicon also has very favorable spin properties, which could enable improved performance in proposed spin transistors.

But in contrast to extensive studies with several conventional semiconductors, such as gallium arsenide and indium arsenide, which can be made magnetic by adding magnetic impurities or by growing them next to standard ferromagnets, no such advances have yet been realized with silicon.

Currently, even basic spintronic elements, such as reliable spin injection -- ensuring that electrons injected into silicon maintain their spin -- and spin detection have yet to be demonstrated in silicon.

The difficulty is that silicon has an indirect band gap, Zutic said, which means that silicon cannot emit light efficiently.

"Circularly polarized light is the smoking gun that confirms the presence of injected spin," he said. "That means, unfortunately, that neat tricks of injecting or detecting spin optically, often used at UB, are not directly applicable to silicon."

Zutic published an extensive discussion of these challenges in a paper in *Reviews of Modern Physics* in 2004 that since has received more than 500 citations.

It may now be possible to overcome this hurdle, he said, with a phenomenon he has named the spin-voltaic effect, a spin analog of the photovoltaic effect used in solar cells to convert light into electric energy.

"In the spin-voltaic effect, an injected spin produces an electrical signal due to its proximity with a magnetic region," he said, "a signal that could be measurable even in an indirect band gap material like silicon. Reversing the direction of injected spin could lead to switching the direction of electrical current, which can flow even if no electrical voltage has been applied.

"The spin-voltaic effect also can play an important role in providing dynamically tunable current amplification in a novel class of spin transistors, a building block for future spin-logic applications," he said.

Recent work by Zutic's collaborators at the Tokyo Institute of Technology has demonstrated for the first time the spin-voltaic effect in direct band-gap semiconductors.

During a visit to Japan in August, Zutic continued his collaboration with this group on efforts to detect this effect in silicon. Scientists at the University of Tohoku in Sendai in Japan are planning to conduct similar experiments.

Source: University at Buffalo

Citation: A 'Spin-Voltaic' Effect May Enable Silicon Spintronics (2006, October 18) retrieved 19 April 2024 from
https://phys.org/news/2006-10-spin-voltaic-effect-enable-silicon-spintronics.html

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