Researchers Put 'Spin' in Silicon, Advance New Age of Electronics

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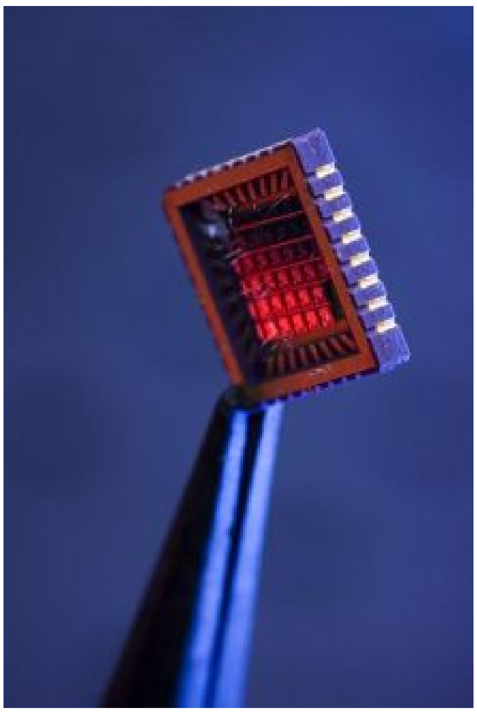

The world's first silicon spin-transport devices, fabricated and measured in Ian Appelbaum's lab at the University of Delaware. More than 25 individual silicon spin-transport devices are represented, one within each tiny wire grid, on this ceramic chip holder. Credit: Jon Cox, University of Delaware

Electrical engineers from the University of Delaware and Cambridge NanoTech have demonstrated for the first time how the spin properties of electrons in silicon--the world's most dominant semiconductor, used in electronics ranging from computers to cell phones--can be measured and controlled.

The discovery could dramatically advance the nascent field of spintronics, which focuses on harnessing the magnet-like "spin" property of electrons instead of solely their charge to create exponentially faster, more powerful electronics such as quantum computers.

The experiment, conducted in the laboratory of Ian Appelbaum, assistant professor of electrical and computer engineering at UD, with doctoral student Biqin Huang, and in collaboration with Douwe Monsma, co-founder of Cambridge NanoTech in Cambridge, Mass., is reported in the May 17 issue of the prestigious scientific journal *Nature*.

In commenting on the UD team's research findings in the "News and Views" section, which also was published in the *Nature* edition, Igor Zutic of the Department of Physics at the State University of New York at Buffalo, and Jaroslav Fabian, of the Institute of Theoretical Physics at the University of Regensburg in Germany, note, "Modern computers present serious challenges for conventional, silicon-based electronics. Ever-increasing demands on processor speed, memory storage and power consumption--the era of the laptop that can keep us warm in winter is fast upon us--are forcing researchers to explore unfamiliar territory in the quest for increased performance. In these endeavours, Appelbaum and colleagues report a possibly decisive development: the first demonstration of the transport and coherent manipulation of electron spin in silicon."

While manipulating electron charge is the basis of the present-day electronics industry, researchers in academia and industry over the past decade have been exploring the capability of electron spin to carry, process and store information. A major goal in spintronics is to reach the precise level of control over electron spin that modern electronics has executed over electron charge.

"An electron has intrinsic angular momentum called spin," Appelbaum noted. "The first step to making spintronic devices and circuits is to inject more spins of one direction than in the opposite direction into a semiconductor."

Silicon has been the workhorse material of the electronics industry, the transporter of electrical current in computer chips and transistors. Silicon also has been predicted to be a superior semiconductor for spintronics, yet demonstrating its ability to conduct the spin of electrons, referred to as "spin transport," has eluded scientists--until now.

To provide conclusive evidence of spin transport in silicon, Appelbaum and Huang fabricated small, silicon semiconductor devices using a custom-built, ultra-high vacuum chamber for silicon-wafer bonding.

After spin injection, electrons in the silicon were then subjected to a magnetic field, which caused their spin direction to "precess" or gyrate (much like gravity's effect on a rotating gyroscope), producing tell-tale oscillations in their measurement.

"The processes of precession and dephasing, or decay, are the most unambiguous hallmarks for spin transport. Our work is the first time anyone has shown this effect in silicon," Appelbaum said.

"It's an important problem to solve because silicon is the most important semiconductor for electronics," Appelbaum noted. "However, methods that worked for spin detection in other semiconductors failed in silicon."

Appelbaum said that pursuing the research was a risk worth taking. He credits Monsma with introducing him to hot-electron spin transport and applying it to the problem of spin detection in silicon several years ago when they were postdoctoral fellows together at Harvard University.

Originally, when Appelbaum entered college as an undergraduate at Rensselaer Polytechnic Institute, he thought he wanted to become a physician. But a professor there, Stephen Nettel, turned him on to physics and electrical engineering, and now Appelbaum is teaching his UD students using Nettel's textbook.

So while Appelbaum decided not to become a medical doctor, in some circles he might now be considered, literally, a "spin" doctor.

"We hope we're with spintronics where Bell Labs was with semiconductor electronics in 1948," Appelbaum said.

That year, Bell announced the invention of the transistor, which laid the foundation for modern electronics.

Source: University of Delaware

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