

Nuclear spins control current in plastic LED: Step toward quantum computing, spintronic memory, better displays

September 18 2014



An organic light-emitting diode, or OLED, glows orange when electrical current flows through it. University of Utah physicists used this kind of OLED -- basically a plastic LED instead of a conventional silicon semiconductor LED -- to show that they could read the subatomic 'spins' in the center or nuclei of hydrogen isotopes and use those spins to control current to the OLED. It is a step toward 'spintronic' devices such as faster computers, better data storage and more efficient OLEDs for TV, computer and cell phone displays. Credit: Andy Brimhall, University of Utah

University of Utah physicists read the subatomic "spins" in the centers of nuclei of hydrogen isotopes, and used the data to control current that powered light in a cheap, plastic LED – at room temperature and without strong magnetic fields.

The study – published in Friday's issue of the journal *Science* – brings physics a step closer to practical machines that work "spintronically" as well as electronically: superfast quantum computers, more compact data storage devices and plastic or organic light-emitting diodes, or OLEDs, more efficient than those used today in display screens for cell phones, computers and televisions.

"We have shown we can use [room-temperature](#), plastic electronic devices that allow us to see the orientation of the tiniest magnets in nature – the spins in the smallest [atomic nuclei](#)," says physics professor Christoph Boehme, one of the study's principal authors. "This is a step that may lead to new ways to store information, produce better displays and make faster computers."

The experiment is a much more practical version of a study Boehme and colleagues published in *Science* in 2010, when they were able to read nuclear spins from phosphorus atoms in a conventional silicon semiconductor. But they could only do so when the apparatus was chilled to minus 453.9 degrees Fahrenheit (nearly absolute zero), was bombarded with intense microwaves and exposed to superstrong magnetic fields.

In the new experiments, the physicists were able to read the nuclear spins of two isotopes of hydrogen: a single proton and deuterium, which is a proton, neutron and electron. The isotopes were embedded in an inexpensive plastic polymer or organic semiconductor named MEH-PPV, an OLED that glows orange when current flows.

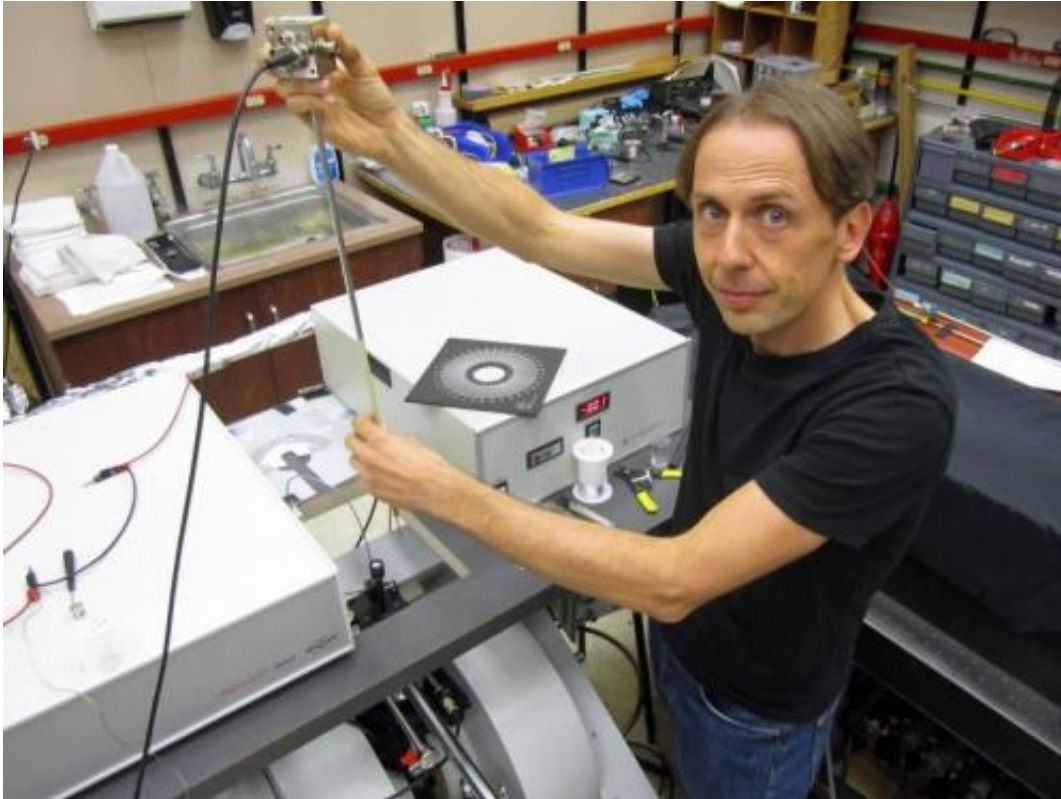
The researchers flipped the spins of the hydrogen nuclei to control electrical current flowing through the OLED, making the current stronger or weaker. They did it at room temperature and without powerful light bombardment or magnetic fields – in other words, at normal operating conditions for most [electronic devices](#), Boehme says.

"This experiment is remarkable because the magnetic forces created by the nuclei are millions of times smaller than the electrostatic forces that usually drive currents," yet they were able to control currents, he says.

Harnessing nuclear spins can increase the efficiency "of electronic materials out of which so much technology is made," Boehme adds. "It also raises the question whether this effect can be used for technological applications such as computer chips that use nuclear spins as memory and our method as a way to read the spins."

The U.S. Department of Energy funded the new study, and the physicists used facilities of the University of Utah's Materials Research Science and Engineering Center, funded by the National Science Foundation.

Boehme conducted the study with fellow University of Utah physicists: first author and postdoctoral fellow Hans Malissa; research professor and co-senior author John Lupton, who also is on the faculty of the University of Regensburg, Germany; distinguished professor Z. Vally Vardeny; professor Brian Saam; graduate students Marzieh Kavand and David Waters; and postdoctoral fellow Kipp van Schooten. Another co-author was Paul Burn of Australia's University of Queensland.



University of Utah physicist Christoph Boehme works in his laboratory on an apparatus used in a new study that brings physics a step closer to 'spintronic' devices such as superfast computers, more compact data storage devices and more efficient organic LEDs or OLEDs than those used today for display screens in cell phones, computers and televisions. The study, published in the Sept. 19 issue of the journal *Science*, showed the physicists could read the subatomic 'spins' in hydrogen nuclei and use the data to control current that powers light in a cheap, plastic LED, or OLED, under practical operating conditions. Credit: Lee J. Siegel, University of Utah

Spintronics: Storing Data in Atomic Nuclei

Electronic devices use electrical current or electrons, which are negatively charged particles orbiting the nuclei or centers of atoms. Modern computers store data electronically: data are stored as binary "bits" in which zero is represented by "off," or no electrical charge, and

one is represented by "on" or the presence of electrical charge.

In spintronics, data are stored by the spins of either electrons or, preferably, atomic nuclei. Spin often is compared with a tiny bar magnet like a compass needle, either pointing up or down – representing one or zero – in an electron or an atom's nucleus. Nuclear spin orientations live longer, so are better for storing data.

The 2010 study by Boehme and colleagues showed that nuclear spins of phosphorus in a silicon semiconductor could control electrical current, but at impractically low temperatures and strong magnetic fields. They had to use the magnetic fields to align spins of phosphorus electrons in the same direction, and then use intense light to transfer the same alignment to the spins of phosphorus nuclei. Then they bombarded the semiconductor with radio waves to reverse the nuclear spins and control the current.

Boehme says scientists previously have claimed that current in plastic semiconductors – known formally as pi-conjugated polymers – can be controlled by the nuclear spins in hydrogen. Until the new study, "nobody has ever shown it directly" at room temperature by turning nuclear spins to change an electrical current, he adds.

The New Study

In the new experiments, the physicists used magnetic resonance to reverse the nuclear spins in hydrogen isotopes embedded in the OLED, and then were able to detect how the reversed spins caused a change in the electrical current through the OLED.

In the first two experiments, Boehme says, the physicists made nuclear spins in a proton and deuterium wiggle in characteristic ways, and were able to read corresponding wiggles in the resulting electrical current. In a

third experiment, they flipped the spins back and forth at a rate they wanted instead of at the characteristic frequencies.

"It worked," Boehme says. "This shows you can turn a nuclear spin when you want, and only then the current turns around. We can control a current by controlling nuclear spins."

The researchers measured the current change directly, but not resulting changes in the OLED's light output – changes so small they aren't detectable with the naked eye.

In both the 2010 and the new studies, the physicists did not read the spins of individual nuclei, but the collective spins of more than 1 million nuclei at a time. The ultimate goal is to be able to read the spins of nuclei individually.

"If you want to store information, the highest storage density would be to store information in single nuclear spins," Boehme says. Since the 2010 study, other physicists have achieved that in phosphorus nuclei, he adds.

Benefits of Spintronics

By storing information using both spins and electrical charge, spintronic devices should have greater storage capacity and process data more quickly – although researchers still have years to go to figure out how to connect and process spintronically stored information in futuristic computers, conventional and quantum.

"We don't know if its five years, 50 years or never," Boehme says.

Yet he says spintronics already resulted in today's terabyte-sized computer hard drives, which use spintronic "read heads" so small that data can be stored more densely.

In 2012, Boehme and colleagues showed the same spintronic OLED in the new study works as a "dirt cheap" [magnetic field](#) sensor at room temperature without being compromised by degradation. Such sensors may enable more accurate spacecraft navigation systems, he says.

Because nuclear spin-controlled [electrical current](#) regulates output of light by the OLED, it provides a way to study how to make OLEDs more efficient. OLEDs convert far more electricity into light than incandescent light bulbs, which turn most incoming electricity into heat. But there is much more room for improved efficiency.

"Hopefully, OLEDs will become better – use less electricity and produce more light – because we learned here how nuclear spins' orientation influences how well the OLED works," Boehme says. "Any sort of efficiency limitation can only be overcome if the mechanism that imposes this limitation is understood."

More information: "Room-temperature coupling between electrical current and nuclear spins in OLEDs" *Science*, 2014:

[www.sciencemag.org/lookup/doi/ ... 1126/science.1255624](http://www.sciencemag.org/lookup/doi/.../1126/science.1255624)

Provided by University of Utah

Citation: Nuclear spins control current in plastic LED: Step toward quantum computing, spintronic memory, better displays (2014, September 18) retrieved 27 April 2024 from <https://phys.org/news/2014-09-nuclear-current-plastic-quantum-spintronic.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.