Scientists watch a next-generation ferroelectric memory bit switch in real time

November 17 2011

For the first time, engineering researchers have been able to watch in real time the nanoscale process of a ferroelectric memory bit switching between the 0 and 1 states.

Ferroelectric materials have the potential to replace current memory designs, offering greater storage capacity than magnetic hard drives and faster write speed and longer lifetimes than flash memory. Replacing dynamic random access memory—the short-term memory that allows your computer to operate—with ferroelectric memory can significantly decrease energy usage in computers. Ferroelectric memory doesn't require power to retain data.

A paper on the research is published in the Nov. 18, 2011, edition of *Science*.

"This is a direct visualization of the operation of ferroelectric memory," said principal investigator Xiaoqing Pan, a professor in the Department of Materials Science and Engineering and director of the U-M Electron Microbeam Analysis Laboratory.

"By following ferroelectric switching at this scale in real time, we've been able to observe new and unexpected phenomena. This work will help us understand how these systems work so one can make better memory devices that are faster, smaller and more reliable."

The researchers were able to see that the switching process of ferroelectric memory begins at a different site in the material than they initially believed. And this switching can be sparked with a lot less power than they had hypothesized.

"In this system, electric fields are naturally formed at the ferroelectric/electrode interfaces and this lowers the barrier for switching—for free. That means you can write information with much lower power consumption," Pan said.

Pan is leading the development of special hybrid materials that contain both ferroelectric and magnetic components and could lead to next-generation magnetoelectric memory devices. This new study reports the behavior of one such material. An advantage of using these hybrid materials in memories is that they combine the advantages of both electric and magnetic memory classes: the ease of writing ferroelectric memory and the ease of reading magnetic memory. The interactions between ferroelectric and magnetic orders allow these hybrid materials to be integrated into other novel designs such as spintronics, which harness the intrinsic "up" or "down" spin of electrons.

Researchers from Cornell University, Penn State University, the University of Washington, the University of Wisconsin and Peking University also contributed to the work. The paper is called "Domain Dynamics during Ferroelectric Switching." The research is funded by the U.S. Department of Energy and the National Science Foundation.

Ferroelectrics, discovered about 90 years ago, are characterized by a spontaneous electric polarization that can be reoriented between different orientations by an applied electric field. This ability to form and manipulate the regions (domains) with different polarization orientations at the nanometer scale is key to the utility of ferroelectric materials for devices such as nonvolatile memories. The ferroelectric switching occurs through the nucleation and growth of favorably oriented domains and is strongly influenced by defects and interfaces with electrical contacts in devices. It is critical for memory devices to understand how the ferroelectric domain forms, grows and interacts with defects and interfaces.

Provided by University of Michigan