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Discovery could help electronics industry enter new phase

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Electronic devices of the future could be smaller, faster, more powerful and consume less energy because of a discovery by researchers at the Department of Energy's Oak Ridge National Laboratory.

The key to the finding, published in Science, involves a method to measure intrinsic conducting properties of ferroelectric materials, which for decades have held tremendous promise but have eluded experimental proof. Now, however, ORNL Wigner Fellow Peter Maksymovych and co-authors Stephen Jesse, Art Baddorf and Sergei Kalinin at the Center for Nanophase Materials Sciences believe they may be on a path that will see barriers tumble.

"For years, the challenge has been to develop a nanoscale material that can act as a switch to store binary information," Maksymovych said. "We are excited by our discovery and the prospect of finally being able to exploit the long-conjectured bi-stable electrical conductivity of ferroelectric materials.

"Harnessing this functionality will ultimately enable smart and ultra-dense memory technology."

In the paper, the authors have demonstrated for the first time a giant intrinsic electroresistance in conventional ferroelectric films, where flipping of the spontaneous polarization increased conductance by up to 50,000 percent. Ferroelectric materials can retain their electrostatic polarization and are used for piezoactuators, memory devices and RFID (radio-frequency identification) cards.

"It is as if we open a tiny door in the polar surface for electrons to enter," Maksymovych said. "The size of this door is less than one-millionth of an inch, and it is very likely taking only one-billionth of a second to open."

As the paper illustrates, the key distinction of ferroelectric memory switches is that they can be tuned through thermodynamic properties of ferroelectrics.

"Among other benefits, we can use the tunability to minimize the power needed for recording and reading information and read-write voltages, a key requirement for any viable memory technology," Kalinin said.

Numerous previous works have demonstrated defect-mediated memory, but defects cannot easily be predicted, controlled, analyzed or reduced in size, Maksymovych said. Ferroelectric switching, however, surpasses all of these limitations and will offer unprecedented functionality. The authors believe that using phase transitions such as ferroelectric switching to implement memory and computing is the real fundamental distinction of future information technologies.

Making this research possible is a one-of-a-kind instrument that can simultaneously measure conducting and polar properties of oxide materials with nanometer-scale spatial resolution under a controlled vacuum environment. The instrument was developed and built by Baddorf and colleagues at the Center for Nanophase Materials Sciences. The materials used for this study were grown and provided by collaborators at the University of California at Berkeley.

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