

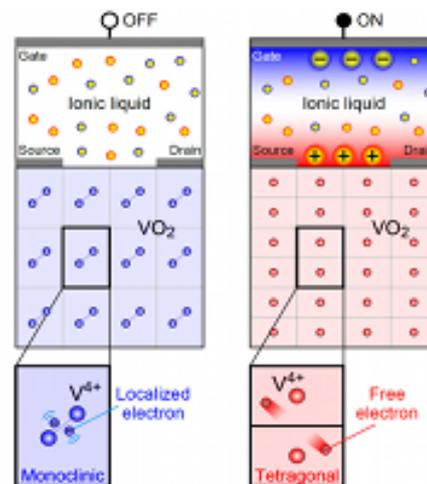
July 26, 2012

Switching the state of matter

New transistor harnessing strong electron correlations enables electrical switching of the state of matter

Sixty years after the transistor began a technological revolution that transformed nearly every aspect of our daily lives, a new transistor brings innovations that may help to do so again. Developed at RIKEN, the device uses the electrostatic accumulation of electrical charge on the surface of a strongly-correlated material to trigger bulk switching of electronic state. Functional at room temperature and triggered by a potential of only 1 V, the switching mechanism provides a novel building block for ultra low power devices, non-volatile memory and optical switches based on a new device concept.

After shrinking for many decades, conventional electronics is approaching quantum scaling limits, motivating the search for alternative technologies to take its place. Among these, strongly-correlated materials, whose electrons interact with each other to produce unusual and often useful properties, have attracted growing attention. One of these properties is triggered in phase transitions: applying a small external voltage can induce a very large change in electric resistance, a mechanism akin to a switch that has many potential applications.



VO₂-based electric-double-layer transistor in OFF and ON states

Now, researchers at the RIKEN Advanced Science Institute have created the world's first transistor that harnesses this unique property. Described in a paper in *Nature*, the device uses an electric-double layer to tune the charge density on the surface of vanadium dioxide (VO₂), a well-known classical strongly-correlated material. Thanks to the strong correlation of electrons and electron-lattice coupling in VO₂, this surface charge in turn drives localized electrons within the bulk to delocalize, greatly magnifying the change of electronic phase. A

potential of only 1 V, they show, is enough to switch the material from an insulator to a metal and trigger an astounding thousand-fold drop in resistance.

The electronic phase, however, is not the only thing that changes in this insulator-to-metal transition: using synchrotron radiation from RIKEN's SPring-8 facility in Harima, the research group analyzed the crystal structure of the VO_2 , showing that it, too, undergoes a transformation, from monoclinic to tetragonal structure. Electric-field induced bulk transformation of this kind is impossible using conventional semiconductor-based electronics and suggests a wide range of potential applications.

First released over sixty years ago to little fanfare, the transistor has had a dramatic impact on our daily lives, powering the electronic devices we use every day. The new switching mechanism takes this first discovery to a new level, demonstrating that a very small electric potential is enough to control macroscopic electronic states and offering a new route to controlling the state of matter.

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Reference

M. Nakano, K. Shibuya, D. Okuyama, T. Hatano, S. Ono, M. Kawasaki, Y. Iwasa and Y. Tokura. "Collective bulk carrier delocalization driven by electrostatic surface charge accumulation." *Nature*, 2012, DOI: [10.1038/nature11296](https://doi.org/10.1038/nature11296)

About RIKEN

RIKEN is Japan's flagship research institute devoted to basic and applied research. Over 2500 papers by RIKEN researchers are published every year in reputable scientific and technical journals, covering topics ranging across a broad spectrum of disciplines including physics, chemistry, biology, medical science and engineering. RIKEN's advanced research environment and strong emphasis on interdisciplinary collaboration has earned itself an unparalleled reputation for scientific excellence in Japan and around the world.

About the RIKEN Advanced Science Institute

The RIKEN Advanced Science Institute (ASI) is an interdisciplinary research institute devoted to fostering creative, curiosity-driven basic research and sowing the seeds for innovative new projects. With more than 700 full-time researchers, the ASI acts as RIKEN's research core, supporting inter-institutional and international collaboration and integrating diverse scientific fields including physics, chemistry, engineering, biology and medical science.

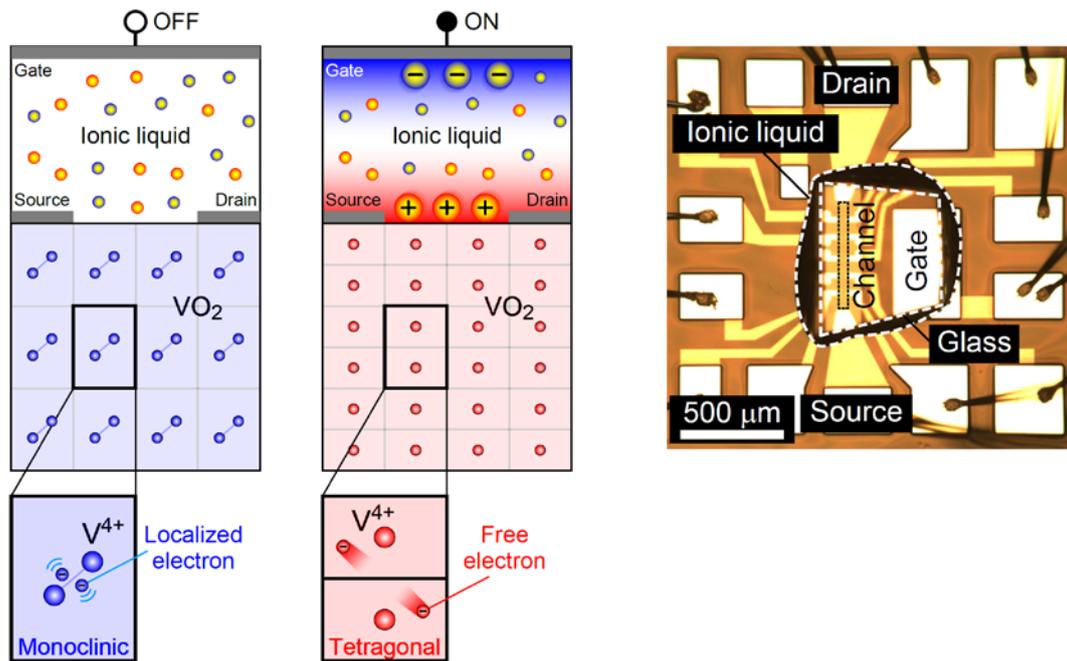


Figure 1: A schematic and an optical micrograph of a new transistor based on VO₂ enabling electrical switching of the state of matter.

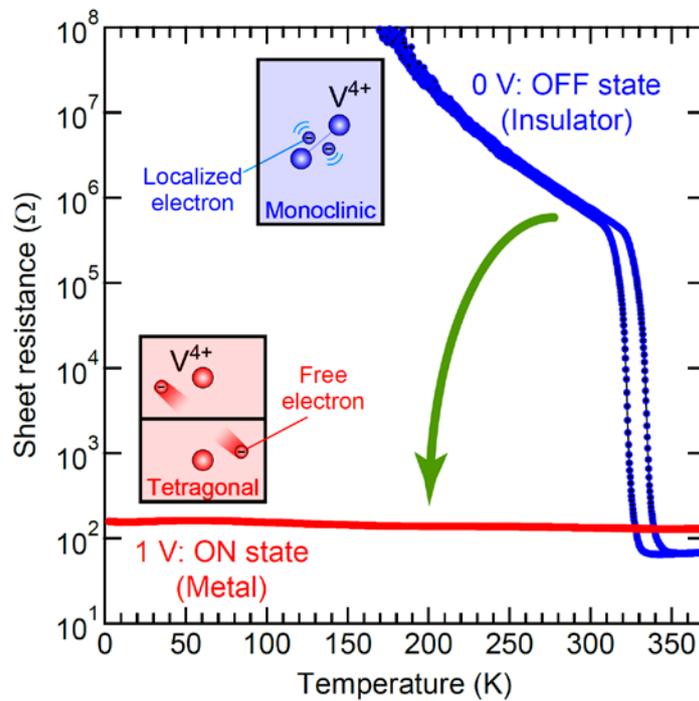


Figure 2: Temperature dependence of the sheet resistance of VO₂ in ON and OFF states. Just one volt is enough to switch ON and OFF states.