Transistor made from vanadium dioxide could function as smart window for blocking infrared light

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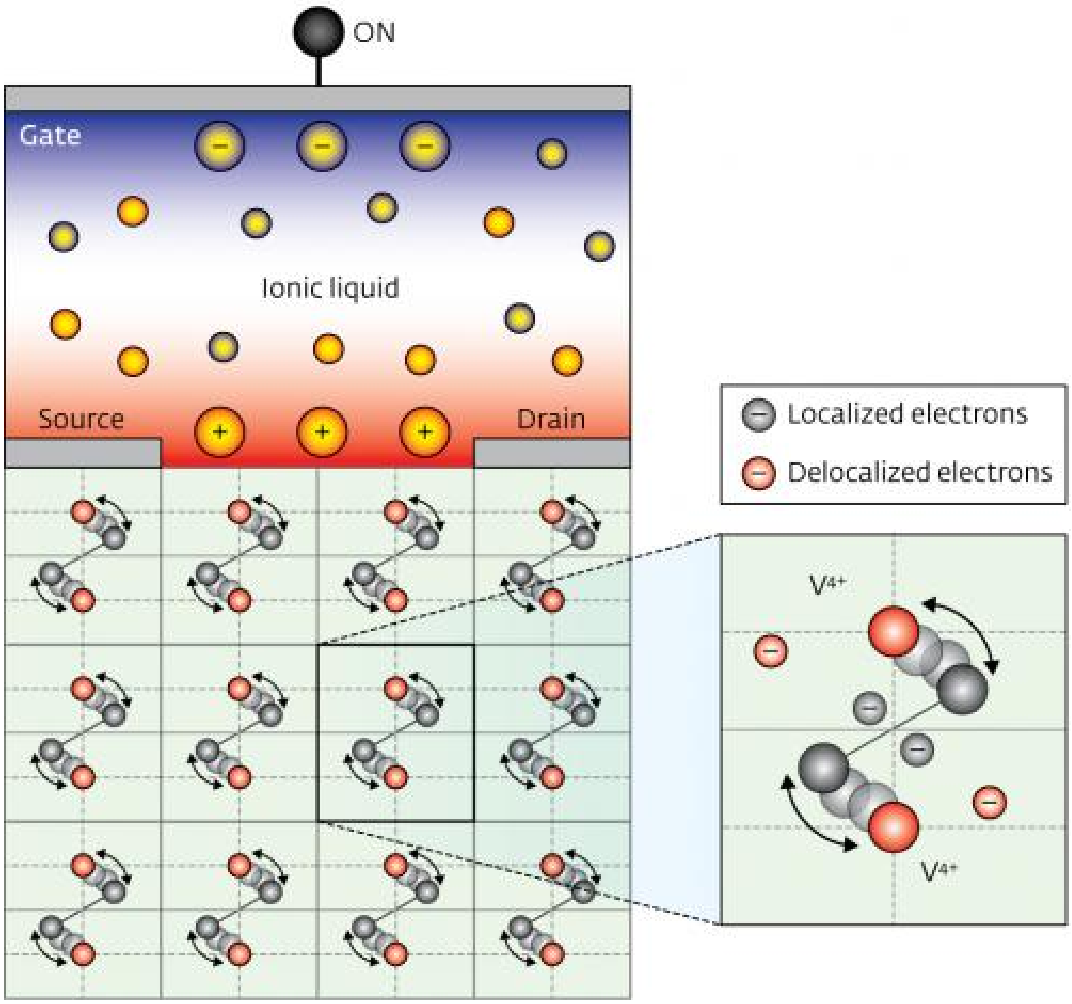

Figure 1:Below 47 °C, the vanadium ions in a film of VO2 pair up into a different crystal structure and the electrons no longer conduct freely. The transition can be reversed with a positive voltage, applied at the top of the film. The voltage induces electrons to move to the region near the surface, which

restores the high-temperature structure and metallic behavior throughout the entire film.

The transistor is the ultimate on-off switch. When a voltage is applied to the surface of a semiconductor, current flows; when the voltage is reversed, current is blocked. Researchers have tried for decades to replicate these effects in transition metal oxides by using a voltage to convert the material from an insulator to a metal, but the induced change only occurs within a few atomic layers of the surface.

Now, Masaki Nakano and colleagues at the RIKEN Advanced Science Institute in Wako have discovered that applying a voltage to a vanadium dioxide (VO_2) film several tens of nanometers thick converts the entire film from an insulator to a metal. The findings point to the specific material properties needed to make such devices work. They may also lead to new types of 'smart' technology.

The electronic properties of transition metal oxides can be tuned by changing their chemical composition or temperature. For example, VO_2 is an insulator at room temperature, but heating it or replacing a small fraction of the vanadium atoms with tungsten (an electron donor) causes a phase transition where the vanadium ions, which are paired up at low temperature, unfasten into a different crystal structure in which electrons are mobile. In principle, applying a positive voltage to the surface of an insulating VO_2 film can accomplish the same effect by inducing electrons to the surface, making this region metallic.

Researchers have assumed that this charging effect would be limited to a few atomic layers just below the surface because the excess of electrons cancels out the applied electric field (an effect called screening). But Nakano and his colleagues found that the excess electrons were enough to 'trigger' the crystal structure change associated with metallic behavior (Fig. 1). "The surface lattice distortion propagates through the entire film, followed by an electronic phase transition inside the bulk region," he says. The voltage-induced transition decreases VO_2's resistance by a factor of 100.

The team is actively seeking other materials like VO_2, as well as technological applications. One is a heat switch. Since temperature determines if VO_2 is a metal or an insulator, it also determines the frequency of light the material absorbs. VO_2-coated glass could therefore act as a 'smart window', passing or blocking infrared light depending on the temperature outside. "Normally, this switching temperature is fixed," says Nakano. "Our device adds electrical switching functionality to a smart window, which is very promising for energy-saving applications."

More information: 1.Nakano, M., Shibuya, K., Okuyama, D., Hatano, T., Ono, S., Kawasaki, M., Iwasa, Y. & Tokura, Y. Collective bulk carrier delocalization driven by electrostatic surface charge accumulation. *Nature* 487, 459–462 (2012). www.nature.com/nature/journal/ … abs/nature11296.html

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