# Correlated Nano-Oxides for Electronic Phase Change Electronics

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Strongly correlated oxide is one of the interesting emerging memory materials owing to their huge electronic phase transition [1]. Among them, Vanadium dioxide ($VO_2$) shows orders-of-magnitude changes in resistance at the metal-insulator transition (MIT) around 340 K, and have been attracting attention not only for long time concerning the physical mechanism inherent in MIT but also for the memory device application [2]. In this correlated electron systems, it is known that different types of electronic/spin phases of a few hundreds of nanometers in size often coexist randomly during the phase transition. This electronic inhomogeneity plays an essential role to dominate the physical properties [3,4], and the control of their behavior is quite powerful approach to make the device performance to be gigantic. We report manipulation of MIT characteristics, especially electrical switching behavior, by artificial control of the spatial domain configuration through the control of the size and shape of $VO_2$ micro/nano-structures [5].

$VO_2$ thin films were deposited on $TiO_2$ (001) substrates using a pulsed laser deposition technique. Micro-sized films with a variety of aspect ratios (combinations of various length (L) and width (W)) were prepared by photolithography. Figure 1(a) - (c) shows optical micro-scope images for (a) a random configuration of two-dimensional (2D) metallic domains observed in conventional $VO_2$ thin films with hundreds of micrometer size on $TiO_2$ (001) substrates, (b) a one-dimensional series do-main configuration in high aspect ratio (L/W = 1.25) micro-scaled films, and (c) a parallel domain configuration in low aspect ratio (L/W = 0.30) micro-scaled films. Notably, this indicates that the aspect ratio of geometric patterns generate different types of domain configuration.

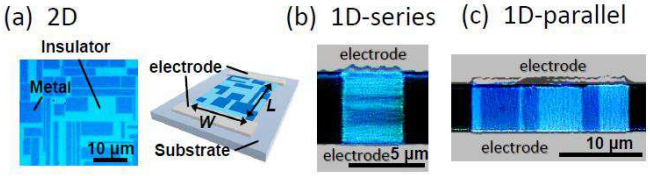


Figure 1. Optical microscope images and schematic illustration of metal and insulator domain configurations in (a) random 2D, (b) 1D series and (c) 1D parallel connections.

It is seen that the domain configurations have a crucial impact on the determination of the electrical transport properties. The apparent transition temperature drastically shifts from 294 K in the 1D parallel domain configuration to 312 K in the 1D series configuration (see Fig.2). A very steep and abrupt resistive drop occurs at 294 K in the parallel domain configuration. The optical microscope image revealed that the first giant metallic domain, which became a current path between electrodes, was generated at this temperature point (294.4 K). In the series configuration case, in contrast, the resistive behavior shows a step-like drop at every metallic domain increment, and a drastic resistive drop appears only when a bottleneck insulating domain transfers to a metallic phase. Thus, metallic domain configuration influences the transport property, and the size and aspect ratio of thin films are beneficial parameters for its general control.

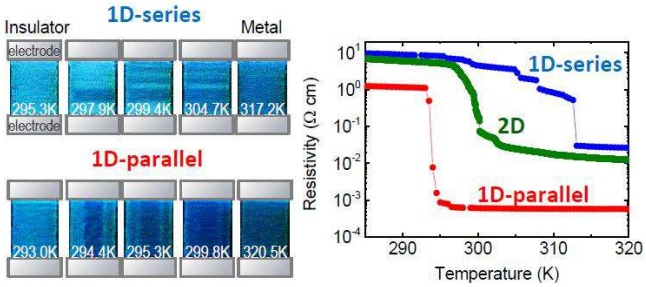


**Figure 2.** Optical microscope images obtained at 293 to 320 K during heating of the 1D series connection (upper) and 1D parallel connection (lower). The right figure shows temperature dependence of resistivity for 1D series, 1D parallel, and 2D domain configurations.

Furthermore, much smaller $VO_2$ nanowires with 200nm width on $Al_2O_3$ (0001) substrate prepared by nanoimprint lithography, and it exhibited steep MIT driven by temperature and voltage (Fig.3). The random network resistor simulation revealed that trapping of 50nm scale metallic domains within nanowire is essential mechanism.

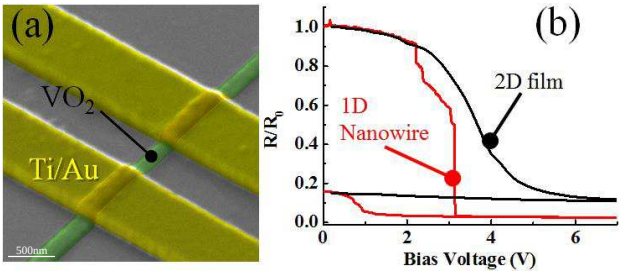


Figure 3. (a) SEM image for $VO_2$ nano-wire device. (b) Bias voltage dependence of resistivity for 1D nano-wire device and 2D film device.

In summary, this confined-spatial electronic conduction yields new aspects different from those observed in conventional film samples, and is expected to allow designable electronic functionality in future devices. These results will illustrate design of device performance and scaling limit of novel nonvolatile Emerging Memories based on correlated oxides.

References

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