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Atomic Resolution Studies of Metal-Insulator Transition in VO_2 Nanowires

Hasti Asayesh-Ardakani[1], Anmin Nie[1], Peter M. Marley[2], Adam Stabile[3], Ketaki Sarkar[4], Sarbajit Banerjee[2], Sambandamurthy Ganapathy[3], Zheng Yang[4], Robert F. Klie[5] and Reza Shahbazian-Yassar[1]

[1]Department of Mechanical Engineering, Michigan Technological University, Houghton, MI 49933-1295, USA
[2]Department of Chemistry and [3]Department of Physics, University at Buffalo, State University of New York, Buffalo, New York 14260-3000, USA
[4] Department of Electrical and Computer Engineering and [5]Department of Physics, University of Illinois at Chicago, Chicago, IL60607-7059, USA

There has been long-standing interest in Metal-Insulator Transition (MIT) in VO_2 because of their possible applications in data processing systems and memory devices. Phase transition in VO_2 can be triggered by any thermal, electrical, optical and strain excitations. The transition in VO_2 associated by structural phase transition from the monoclinic (M), insulating phase, to rutile (R), metallic phase. Coexistence of multiple domains and phases were reported at some conditions where a pure phase was expected [1]. Recent efforts focus on controlling of phase transition and domain structures which results in different material properties and play a critical role in device applications [2].

The present work investigates mechanical and thermal triggering of MIT in individual single-crystalline nanowires of VO_2. Experiments were performed inside the chamber of a transmission electron microscope (TEM) and a scanning transmission electron microscopy (STEM) using in-situ scanning tunneling microscopy (STM) holder and a double tilt heating holder.

The atomic arrangement of V and O is studied at different temperatures (below and above the transition temperature which is ~ 340˚K). The structural phase transition and the intermediate steps of the phase transition in single-crystalline VO_2 nanowires is inspected by analyzing atomic resolution images (annular bright filed(ABF) and high angle annular dark field images(HAADF)), corresponding fast Fourier transform(FFT) and electron energy loss spectra(EELS). The ABF and HAADF images and low loss EELS spectrum of VO_2 at 25˚C are shown in Figure 1a, 1b and 1f respectively. The solid sphere model of monoclinic VO_2 in [101] zone axis and its reciprocal lattice structure are shown in Figure 1c and 1d which are counterpart with the FFT of ABF and HAADF.

Further, we study the effect of strain in the MIT and how the strain induced in nanocrystalline structure results in multiphase structure. The multiphase structure is observed as abrupt jumps in the electrically driven MIT, suggesting different electrical properties for intermediate phases. The multiphase and strain induced studies are done by geometric phase analysis of high resolution images.

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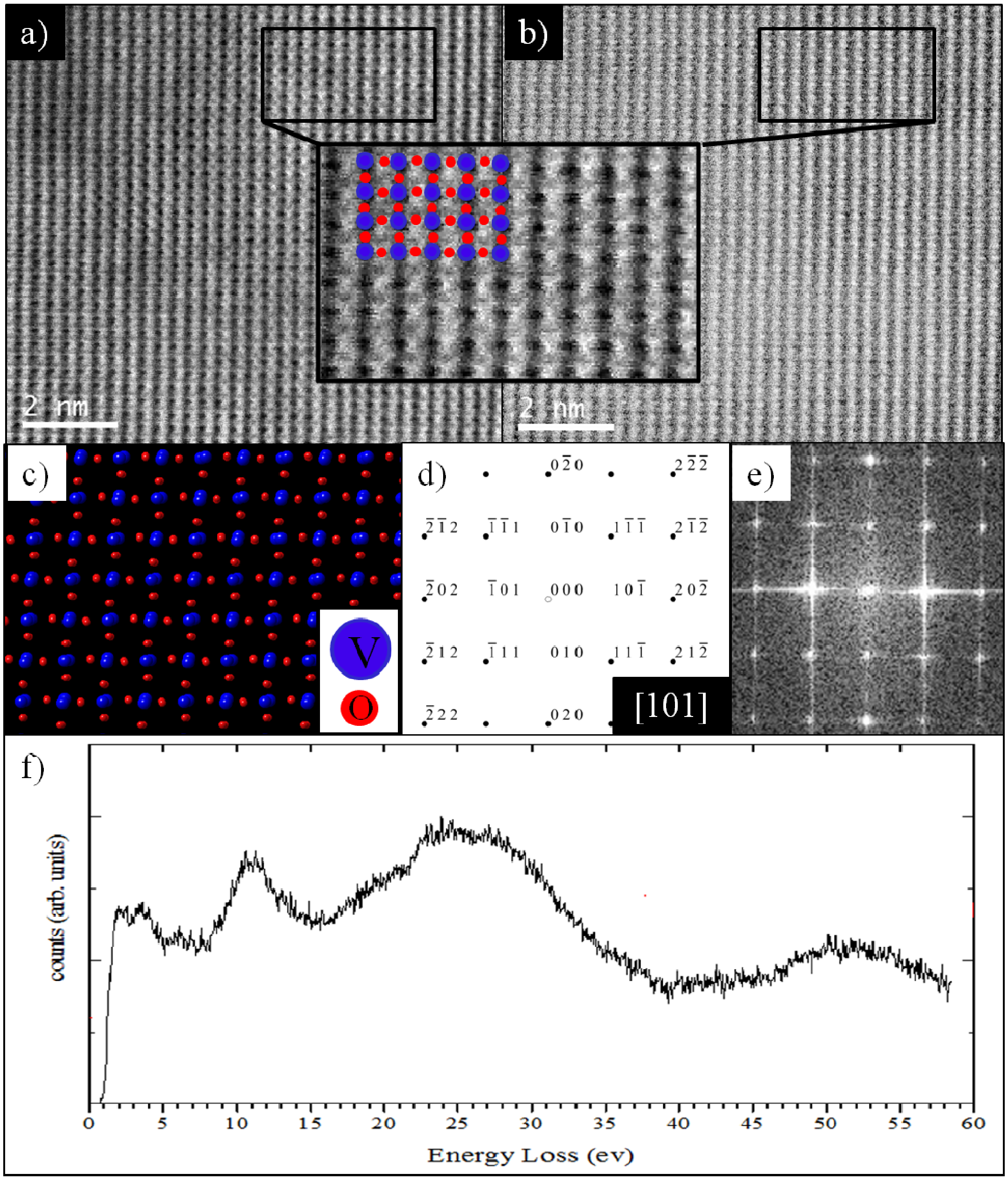

Figure 1. a) ABF and b) HAADF images of monoclinic VO_2 in [101] zone axis at 25˚C. c) solid sphere model of monoclinic VO_2 in [101] zone axis and d)reciprocal lattice structure based on the model. e) FFTof ABF and HAADF images. f) low loss EELS spectrum at 25˚C.

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