

Effect of substrate and growth method on vanadium dioxide thin films by RF magnetron sputtering

A. S. Christensen,¹ A. B. Posadas,¹ B. Zutter,² P. Finnegan,³ S. Bhullar,² A. A. Talin,² A. A. Demkov¹

¹ The University of Texas at Austin, Austin, TX 78712

² Sandia National Laboratories, Livermore, CA 94550

³ Sandia National Laboratories, Albuquerque, NM 87123

Interest in vanadium dioxide (VO_2) comes from its ability to undergo a metal-to-insulator transition (MIT) from monoclinic, semiconducting M1 phase to the metallic, rutile R phase. This transition occurs at a temperature of 340 K [2] and is generally characterized by a rapid change in electrical conductivity. This makes VO_2 attractive for many electronic and optical switching applications [1,3-4]. Research on VO_2 thin film deposition has run the gamut in terms of the substrates and deposition methods used, but the use of bulk yttria-stabilized zirconia (YSZ) substrates and RF sputtering in combination or CMOS compatible fabrication has not been emphasized.

In this talk, we demonstrate that the growth of VO_2 (M1) thin films and the magnitude of the MIT (on/off ratio) are strongly impacted by choice of substrate and deposition method, and these choices are not trivial. This is achieved by comparing reactive RF sputtering deposition and oxidation of a polycrystalline vanadium metal film sputtered on (100)- and (111)-oriented YSZ substrates. The dioxide stoichiometry of these films is confirmed by x-ray photoelectron spectroscopy (XPS) and Raman spectroscopy. X-ray diffraction (XRD) reveals that direct reactive sputtering on both substrate orientations yields VO_2 (B), a metastable phase epitaxially stabilized by lattice matching. The metal sputtering and subsequent oxidation process (Fig. 1a) on (100)-oriented YSZ results in (010)-oriented VO_2 (M1) exhibiting an MIT on the order of 10^3 confirmed by temperature dependent conductance measurements (Fig. 1b) in CMOS compatible devices. With the same metal sputtering and subsequent oxidation process on (111)-oriented YSZ, we achieve slightly overoxidized films with similar magnitude of MIT.

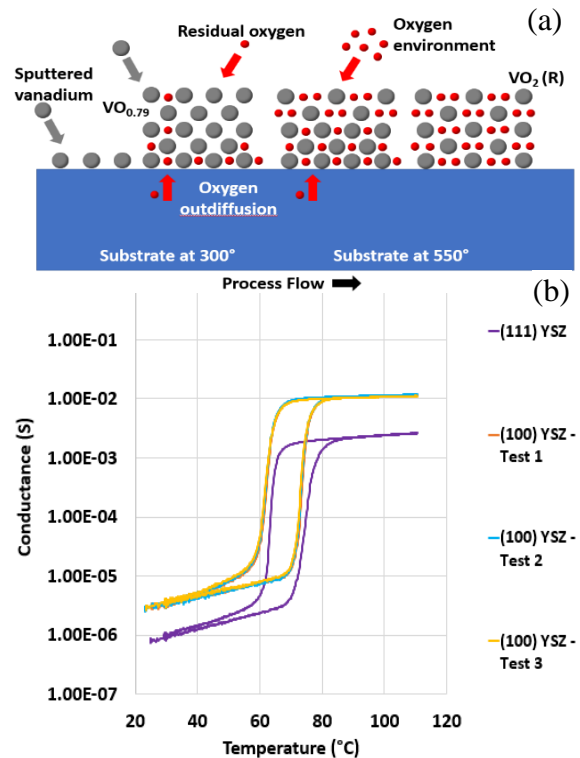


Figure 1. a) Vanadium metal sputtering + oxidation process schematic. b) Temperature dependent conductance measurements.

[1] Zhou, Y; Ramanathan, S. *Proceedings of the IEEE*, 103(8), 1289 (2015)

[2] Morin, F. J. *Phys. Rev. Lett.*, 3(1), 34 (1959)

[3] McInerney, J. G. *Proceedings of SPIE*, Cambridge, MA, United States, January 1, 1987; Vol. 836, 234

[4] Lysenko, S.; Rua, A. J.; et al. *Appl. Surf. Sci.*, 252(15), 5512 (2006)

Supplementary Information

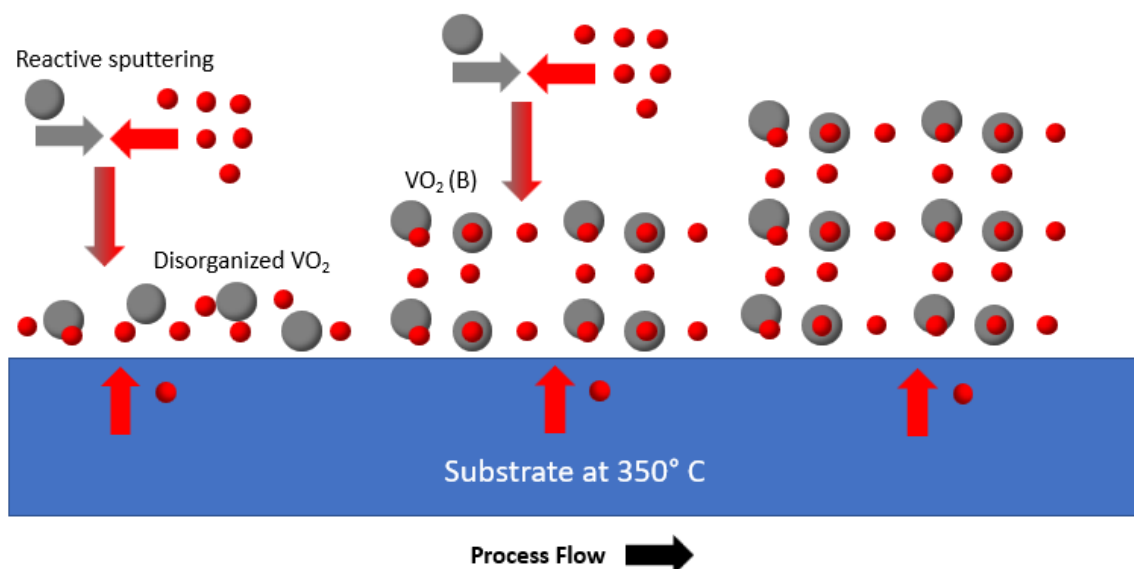


Figure 2. Schematic depicting the reactive sputtering process. Vanadium is sputtered from the target in an oxygen environment (reactive sputtering) and deposited on the substrate as disordered vanadium oxide. These molecules then organize into the epitaxially stabilized VO_2 (B). Slight overoxidation does occur due to substrate outdiffusion and the oxygen environment.

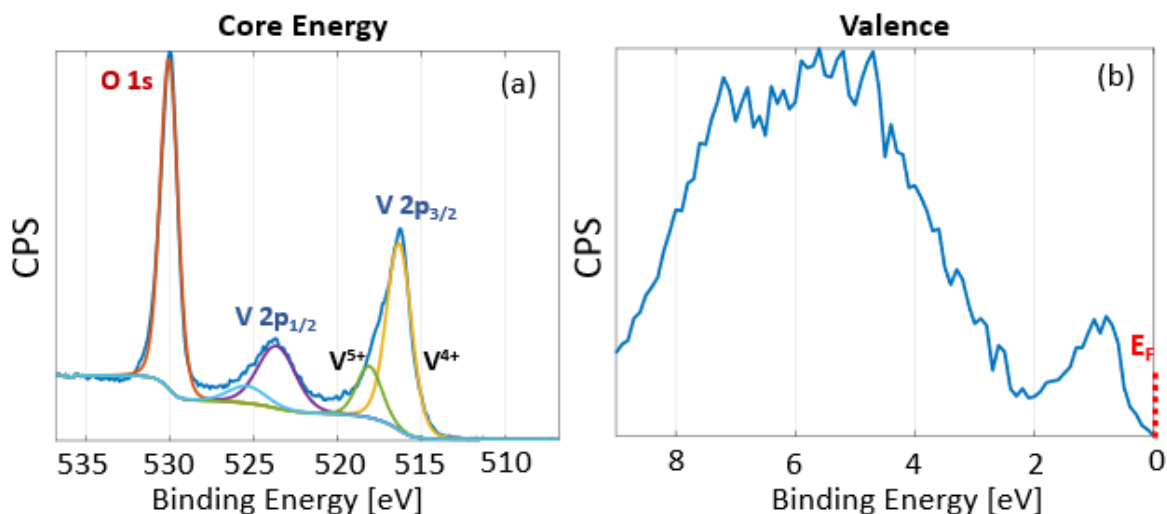


Figure 3. Photoemission spectra in (a) the energy range for oxygen and vanadium core levels and (b) the valence band for VO_2 formed by first depositing vanadium metal and then oxidizing this film in an oxygen environment on (100)-oriented YSZ. Characteristic features in (a) include a $\text{V } 2p_{3/2}$ peak centered near 516.25 eV and in (b) a symmetric $\text{V } 3d$ peak centered at 1.50 eV which has a height ratio of 0.26 relative to the $\text{O } 2p$ peak centered at 6 eV.