Characterization of transport properties of VO_2 thin films across the metal-insulator transition

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Abstract

Vanadium dioxide is one of the most widely studied strongly correlated electron material that undergoes a first-order metal-insulator transition (MIT) at ~68 °C from a low-temperature insulating (monoclinic) phase to a high-temperature metallic (rutile) phase. It is being actively investigated due to its potential in switching device applications as well as the scientific interest utilizing this materials properties. Here we present a comprehensive study of the electrical properties and characteristics across the MIT in high-quality VO_2 thin-films grown by pulsed laser deposition on a c-plane sapphire substrate. The results are important to further understanding of the physical properties of this correlated oxide, as well as future device applications in electronics that exploit the phase transitions in this material.

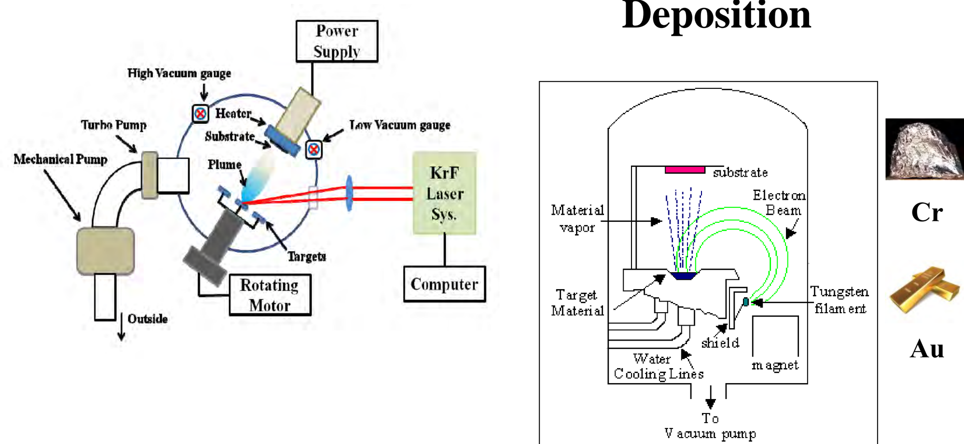
Introduction

Why Vanadium Dioxide (VO_2)?

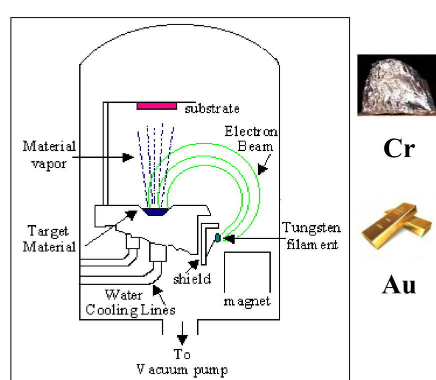
- Exhibits a first-order Metal-Insulator Transition (MIT) at ~ 68 °C (or ~341 K)
- Abrupt change in electrical and optical properties (proposed for electrical switching devices, smart windows, etc.)
- However, reliable transport data for high quality VO2 thin films is scarce

Methods

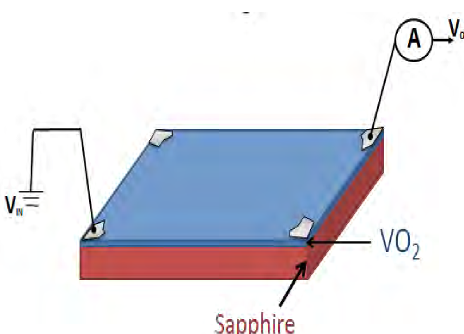
Pulsed Laser Deposition



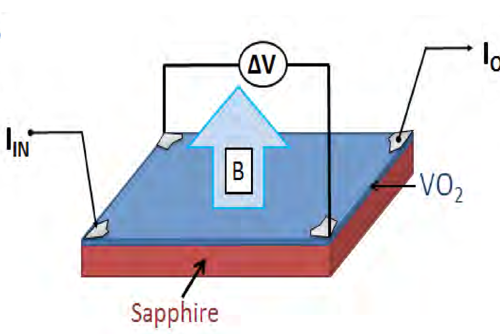
Electron Beam Deposition



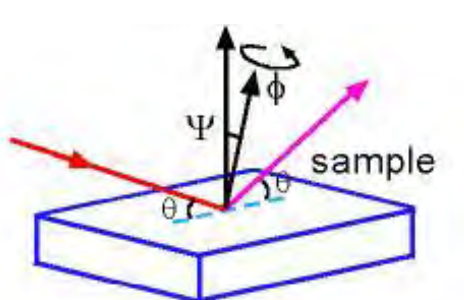
Resistance Measurement -Two Probe Method



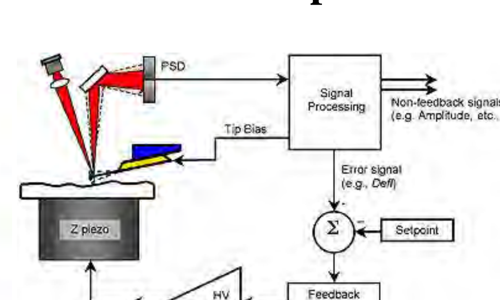
Hall Measurements -Van der Pauw Method



X-Ray Diffraction



Atomic Force Microscope



Pulsed Laser Deposition (PLD)
- KrF Excimer Laser λ=248 nm
- Vacuum Chamber: 10^{-6} Torr
- Oxygen Pressure = 10 mTorr
- Growth Temperature: 530 °C
- Duration: 1 hour (~120 nm)
- Substrate: C-plane sapphire

Electron Beam Deposition (EBD)
- Chamber Vacuum: 4×10^{-6}Torr
- Metal: 15 nm Cr, 210 nm Au

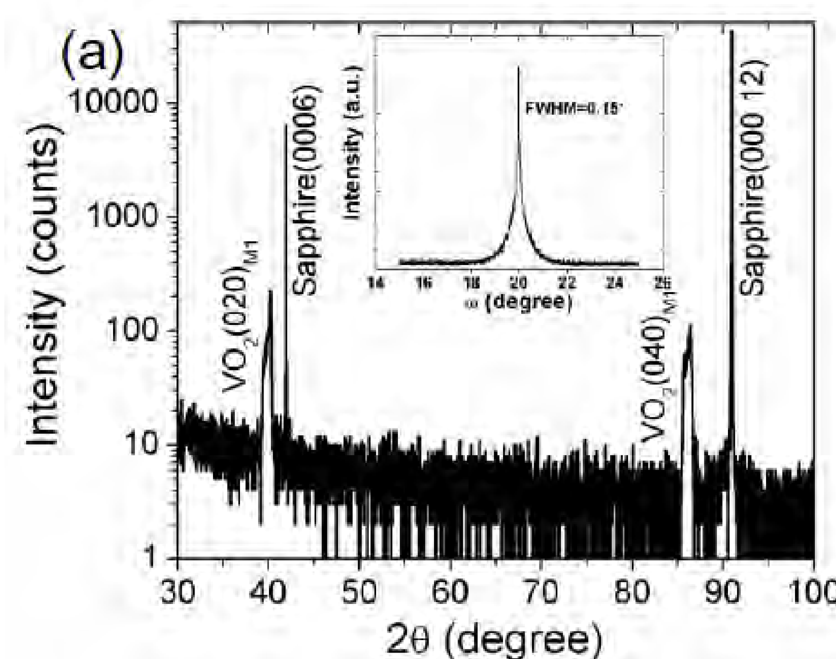
Resistance Measurement
- Two Probe Method
- Bias Voltage = 0.100 V
- Temp. Ramp Rate: 8 °C/min
- Temp. Range: 30 - 110 °C

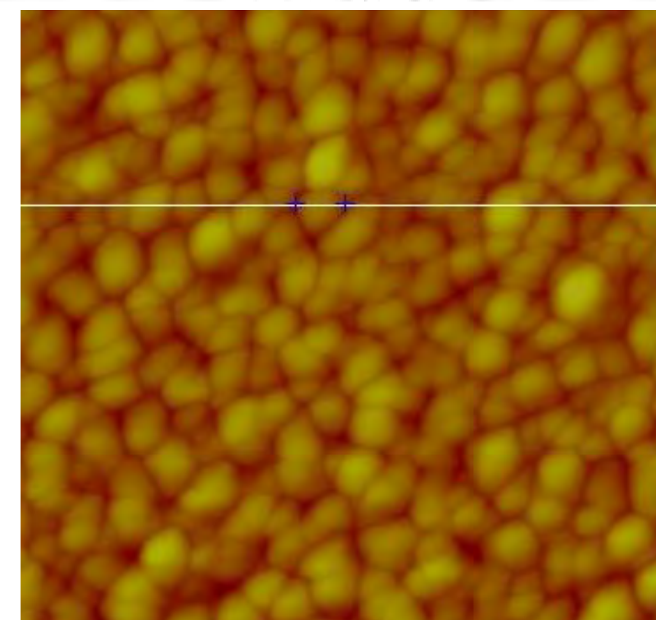
Hall Measurements
- Van der Pauw 4 Probe Tech.
- Magnetic Field: 0.6 T
- Temp Range: 30 – 110 °C

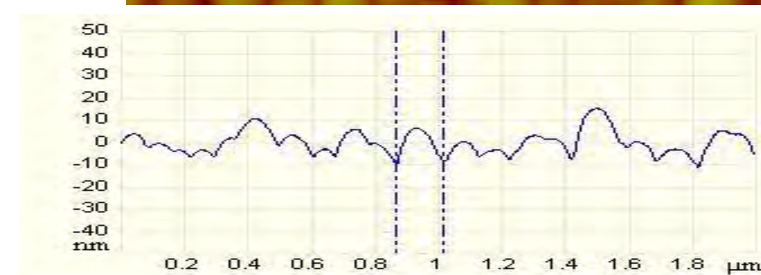
X-Ray Diffraction (XRD)
- Crystallography of film

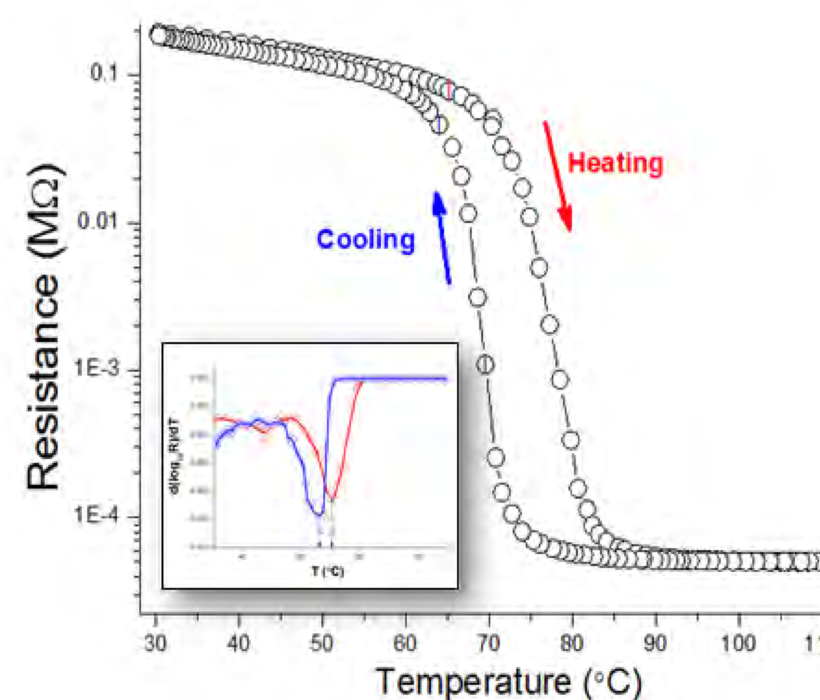
Atomic Force Microscopy (AFM)
- Study surface morphology
- Measure in-plane grain size

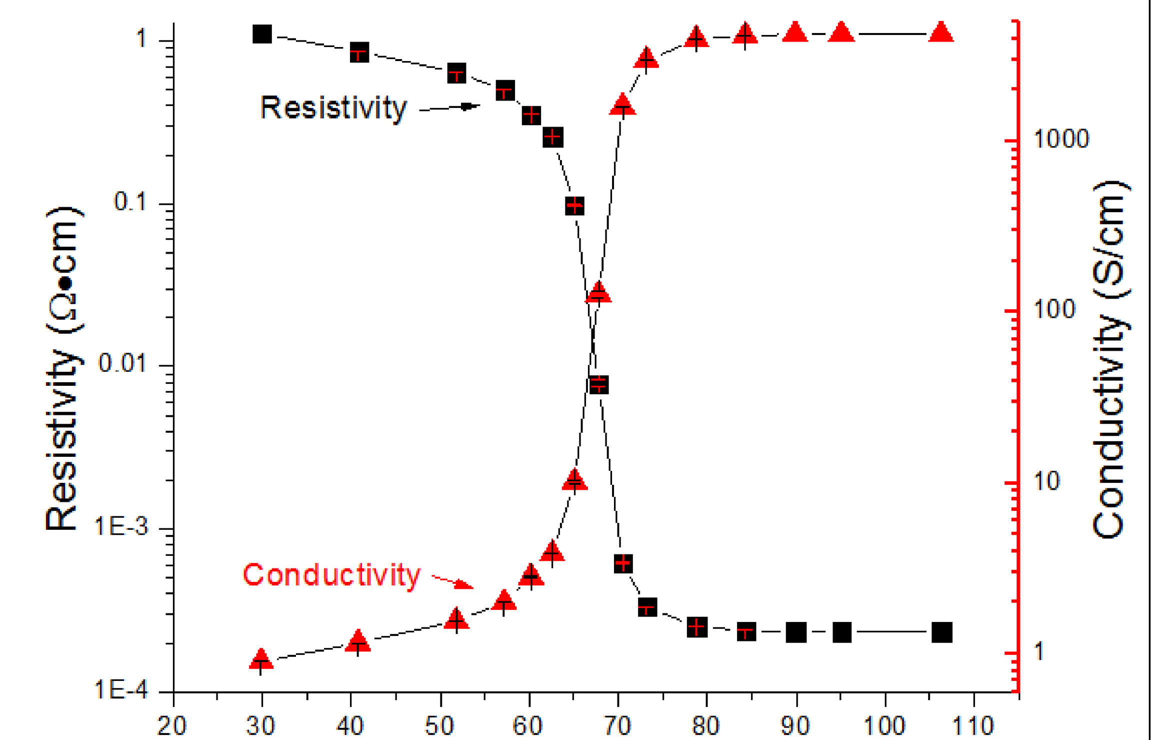
Results

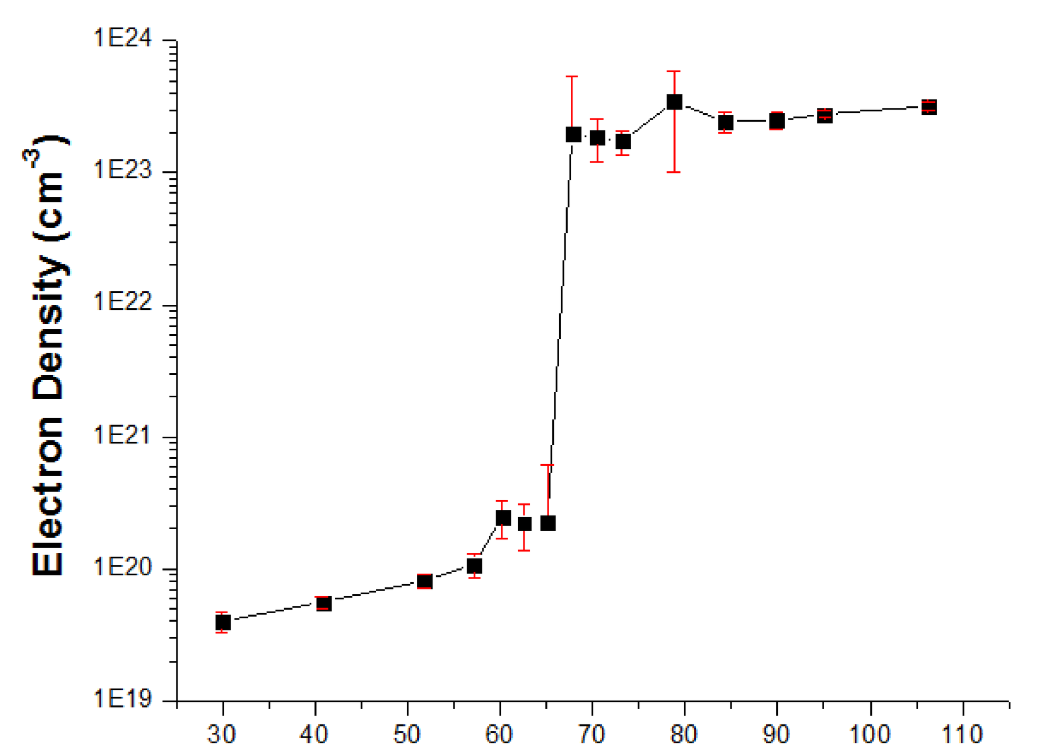


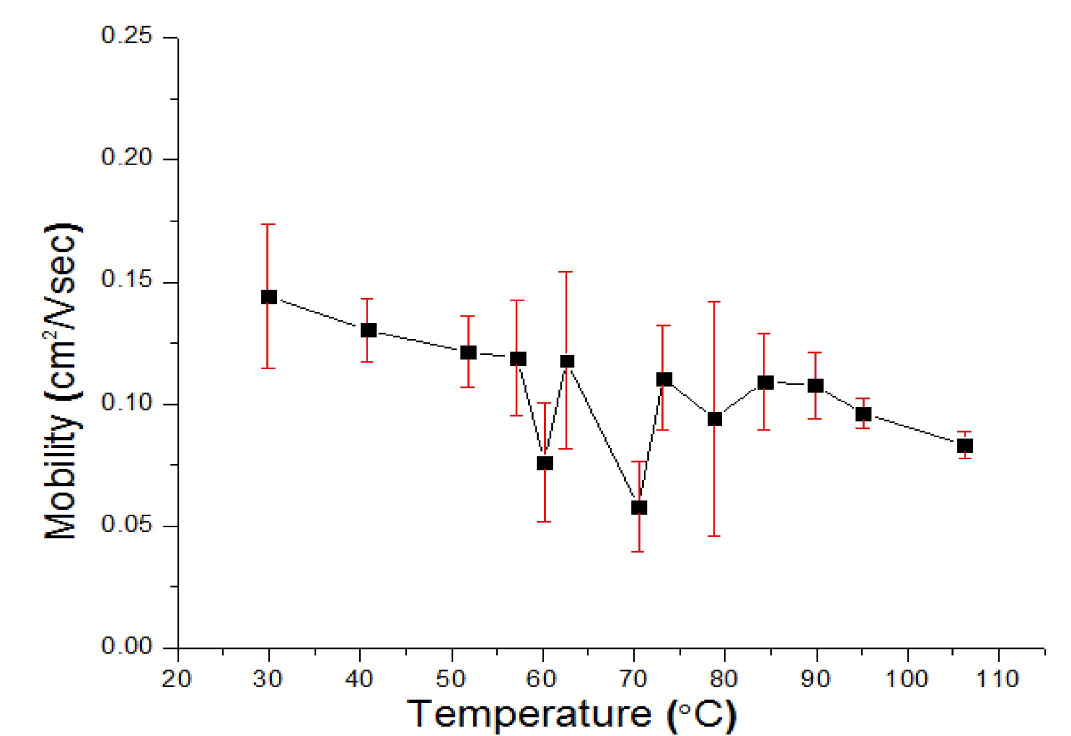












Conclusion

- Obtained a highly oriented ($[010]_{M1}$ direction) VO_2 polycrystalline thin film
- Abrupt phase change near 68 °C
- Over 3 orders of magnitude change in electron density, which almost entirely accounts for the change of the conductivity across its MIT
- The electron mobility decreases very slightly from ~ 0.15 cm^2/Vs to ~ 0.09 cm^2/Vs across the MIT

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Support Information

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National Science Foundation

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