Imaging the nanoscale phase separation in V_2O_3 with scanning microwave impedance microscopy

Weiyan Lin[1], Yoav Kalchheim[2], Ivan K. Schuller[2], Xiaodong Zhou[3] & Jian Shen[1,3]

[1]State Key Laboratory of Surface Physics and Department of Physics, Fudan University, Shanghai 200433, China

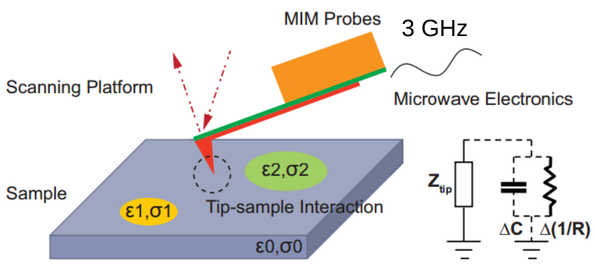
[2]Department of Physics and Center for Advanced Nanoscience, University of California, San Diego, La Jolla, California 92093, USA

[3]Institute for Nanoelectronic Devices and Quantum Computing, Fudan University, Shanghai 200433, China

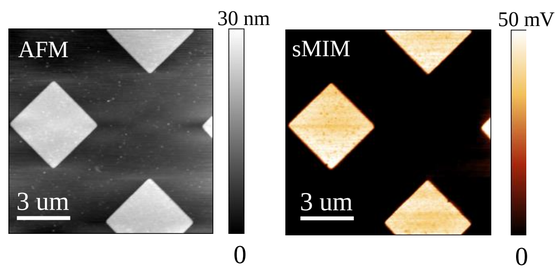
Introduction

➢ Scanning Microwave Impedance Microscopy (sMIM)

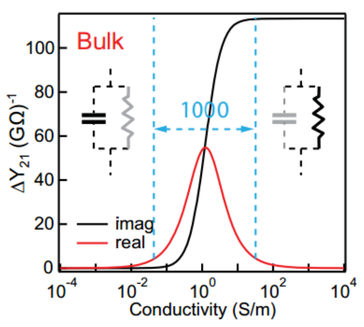
- AFM-based near field scanning probe working at microwave frequency
- Probe the local conductivity/dielectric variation through AC microwave impedance measurement
- High spatial resolution (~50 nm) with subsurface sensing capability



Block diagram of sMIM [1]

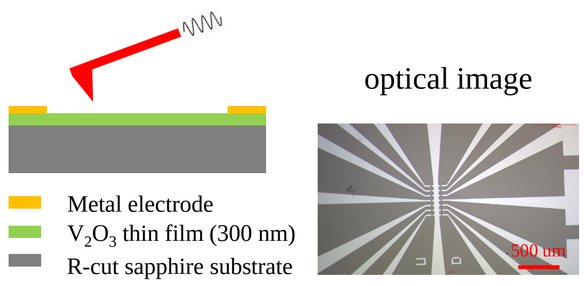


Al dot on SiO_2



sMIM response curve [1]

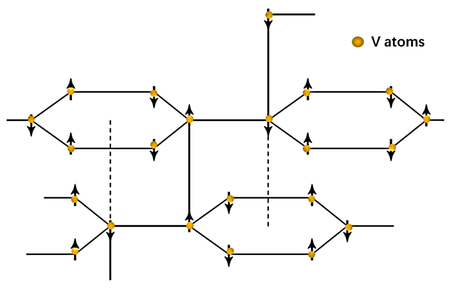
➢ Our sample



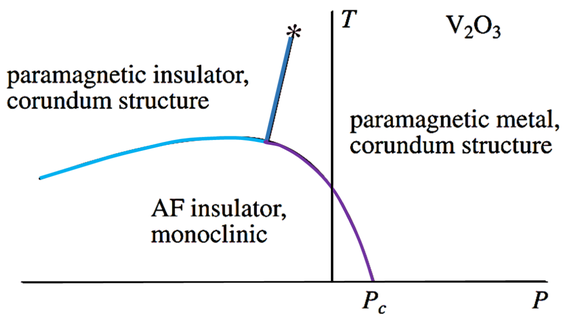
V_2O_3 on Al_2O_3

The metal-insulator transition of V_2O_3

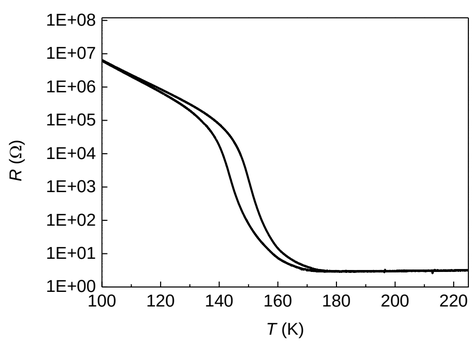
- Canonical system with metal- insulator transition (MIT)
- 1st order MIT accompanied by a structural transition
- MIT mechanism: the structure driven Peierls transition? or Mott transition?



Schematic picture of crystal and magnetic structure of V_2O_3 [2]

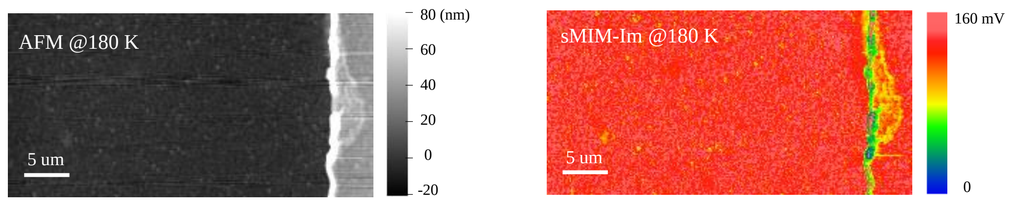


Phase diagram of V_2O_3 [2]

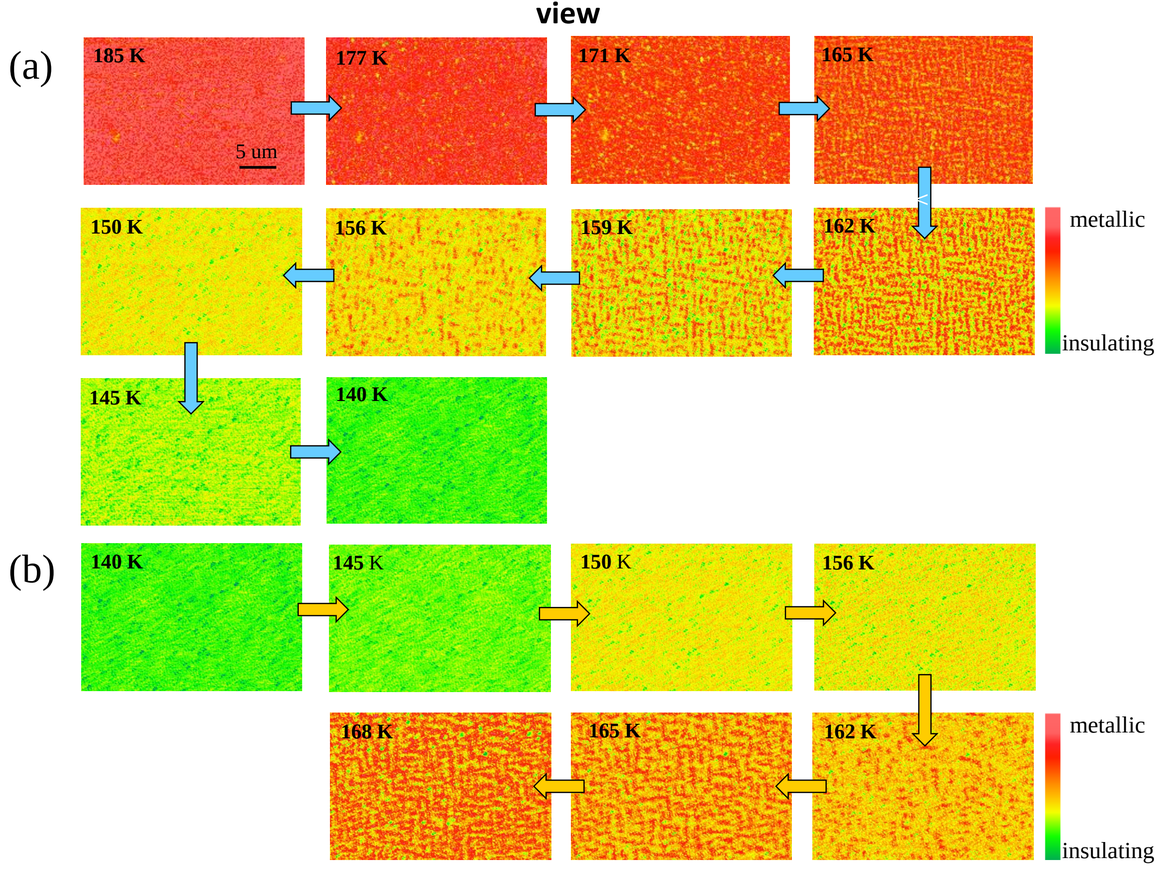


Macroscopic resistivity measurement on cooling and warming

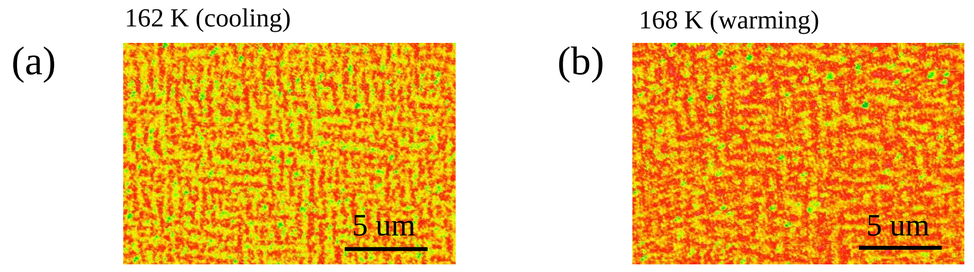
Nanoscale phase separation in V_2O_3



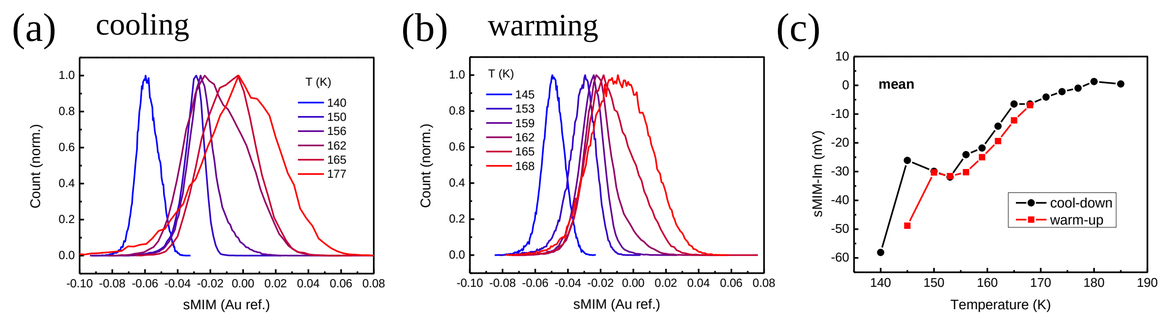
sMIM-Im signal normalized to an absolute reference by inclusion of a lithographically defined gold electrode within the imaging field of view



Temperature-dependent co-localized sMIM images (normalized) of nanoscale phase separation in V_2O_3 show bi-directional striped pattern



Nearly identical configuration of phase separation during (a) cooling and (b) warming indicates a strong phase pinning effect by substrate [3]



The measured sMIM signal level shows a continuous change with a thermal hysteresis consistent with the macroscopic resistivity measurement

Conclusions

1. **The MIT in V_2O_3 was probed microscopically with sMIM displaying a bi-directional striped pattern of phase separation at micrometer scale.**
2. **The measured sMIM signal level shows a continuous change with temperature including the thermal hysteresis, facilitating a direct comparison with macroscopic resistivity measurement.**
3. **Potential research application of sMIM to system with contrasting spatial conductivity, such as domain/domain walls in multiferroics and topological edge states in topological phases.**

References

[1] Worasom, K. PhD thesis. "Imaging nanoscale electronic inhomogeneity with microwave impedance microscopy", Stanford, 2013.

[2] Daniel I. Khomskii "Transition Metal Compounds" Cambridge University Press, 2014. Pp. 496. ISBN 9781107020177.

[3] A. S. Mcleod, *et al*. "Nanotextured phase coexistence in the correlated insulator V_2O_3" *Nature Physics* **13**, 80-89 (2017)