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Defect Transport Studies in TaOx – Understanding Conduction Mechanisms in Memristors

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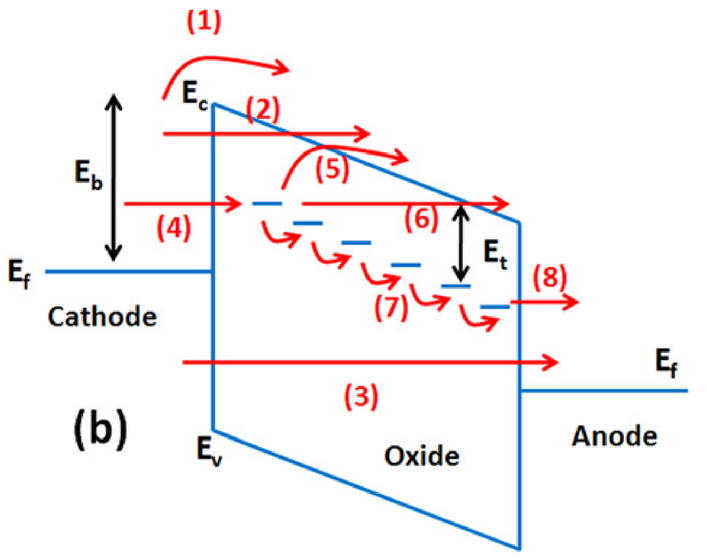
Conduction in Insulators

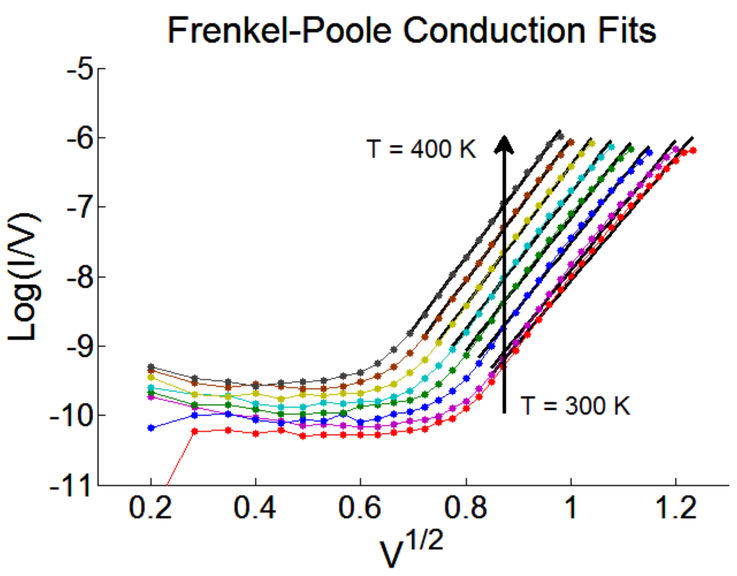


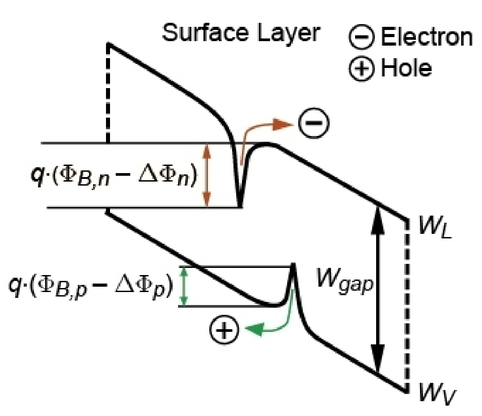
What process is dominant in TaOx?

How does it change with oxygen stoichiometry?

1. Schottky/Thermionic emission
2. Fowler-Nordheim tunneling
3. Direct tunneling
4. Tunneling to traps
5. Trap emission to conduction band (Frenkel-Poole)
6. F-N tunneling to conduction band
7. Trap-to-trap tunneling

Transport Measurements Suggest Frenkel-Poole





Frenkel-Poole conduction provided the best quality fits with most physically reasonable parameters

$$J \propto E \exp\left(\frac{-q\left(\phi_B - \sqrt{qE/(\pi\epsilon)}\right)}{k_B T}\right)$$

Two Approaches to Stoichiometry Control

Reactive Annealing

Activate reactive "primer" layer to reduce stoichiometric layer

This has been reported as an effective method to produce high quality suboxide HfOx devices

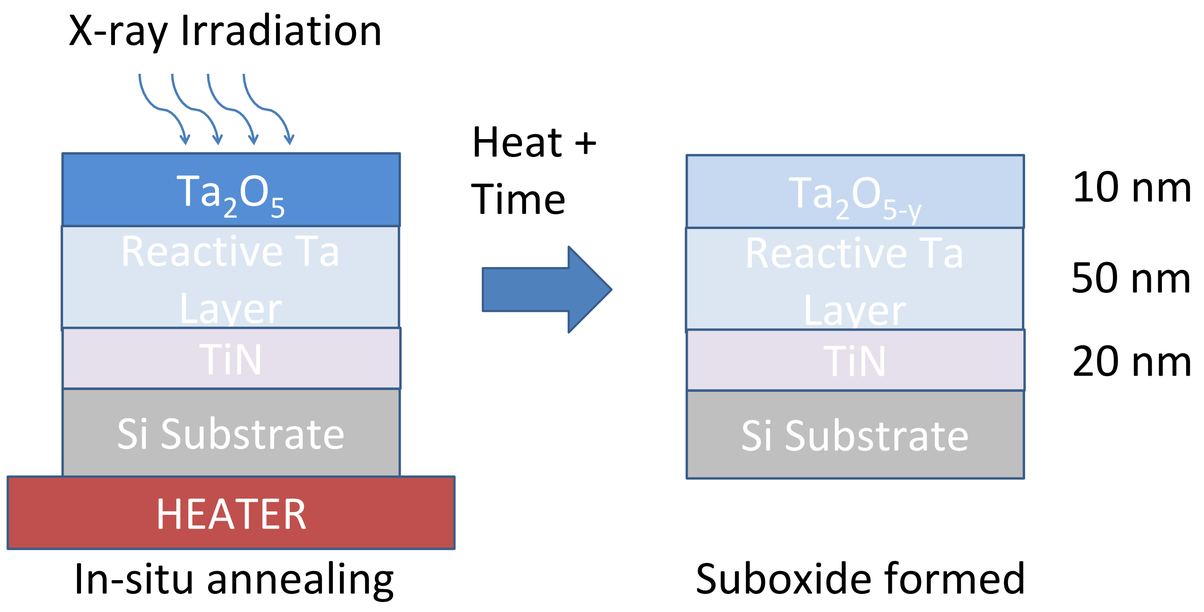
Deposition Control

Reactive Ion Sputtering

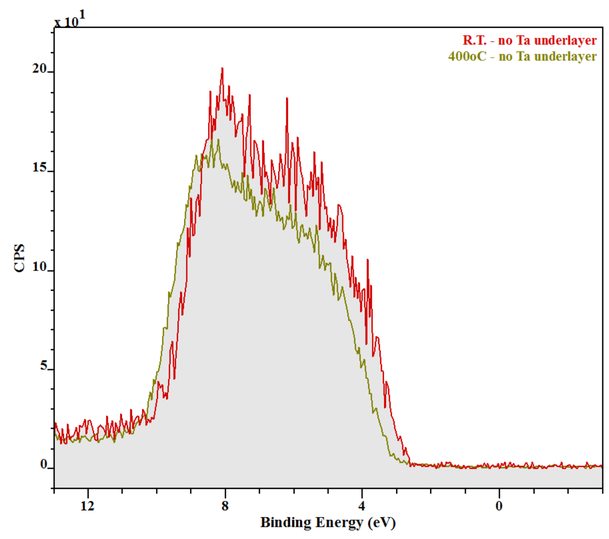
Ion Assisted Deposition

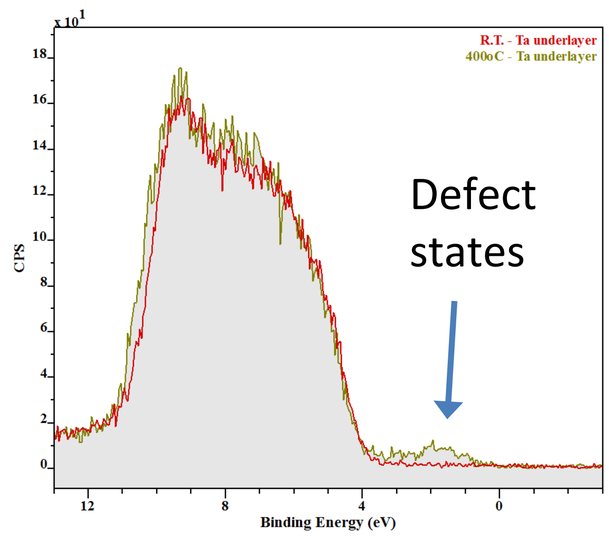
RBS of witness samples for calibration

XPS Measurement of In-Situ Annealed Samples



Defect States Develop in Gap During Anneal

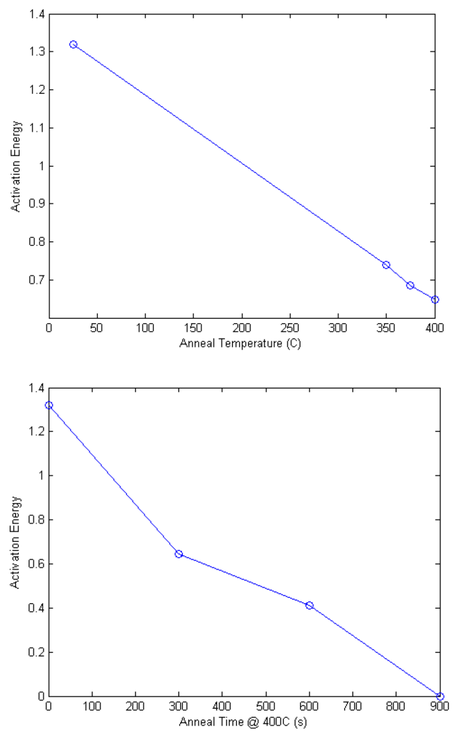


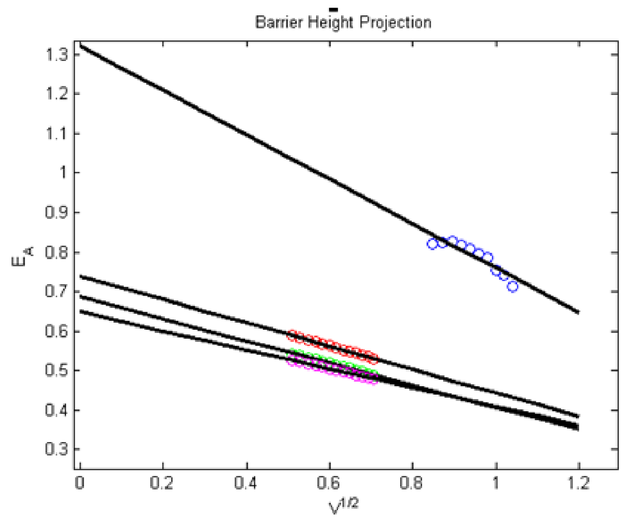


Control sample ensures that the surrounding vacuum does not create oxygen vacancies

Oxygen vacancies created by oxygen reacting with primer layer results in defect states in the band gap

Lowering Activation Energy





Anneal induced defect states are closer to band edge, lowering the effective hopping barrier

Summary

XPS of annealed samples demonstrate the development of intraband defect states

Transport measurements

Future Directions

Varying reactive layer thickness

Begin DLOS measurements

transport study with RIS and IAD samples of varying stoichiometry