Resistive Switching Memory Model using NovaTCAD

-Based on Monte Carlo Simulation of O2 diffusions
Resistive switching physical processes

- Temperature activated O2 generation and recombination.
- Temperature activated hopping of O2 at interstitial sites.
- Poole-Frenkel de-trapping model for off state leakage current.
- Absorption and release of O2 by electrodes.
- Physical based probabilities with field and temperature dependence.
- O2 site represented by a circuit node in Crosslight MiniSpice model.
- MiniSpice special resistor models: models based on sinh() function and quantum point contact.
- MiniSpice included in NovaTCAD as Mixmode device simulation.
Resistive switching Monte-Carlo approach

Vo generation rate, with $E_a$ as activation energy, delta-phi as barrier lowered by field

$$P_a = f \exp\left(-\frac{E_a - \Delta \phi_1}{k_B T_{loc}}\right)$$

Interstitial O2 hopping rate with $E_h$ as activation energy.

$$P_h = f \exp\left(-\frac{E_h - \Delta \phi_2}{k_B T_{loc}}\right)$$

Demo Structure

(a) Diagram showing the structure with layers labeled: AlCu, TiN, Ti, HfO₂, TiN, Gate, Source, Drain.

(b) Image showing layers identified as TiN, Ti, HfO₂, TiN.
A: Initial
B: set_half_up
C: set_up
D: set_half_down
E: set_down
F: reset_half_up
G: reset_up
H: reset_half_down
I: reset_down
At lattice_initial Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_set_half_up Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_set_up Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_set_half_down Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_set_down Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_reset_half_up Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_reset_up Blue=O2 site; Green=O2 Vac; Red=Inters
At lattice_reset_half_down Blue=O₂ site; Green=O₂ Vac; Red=Inters
Use of CSUPREM for TCAD mesh
Max. Vector (A) = 0.7221E-05
Summary

- Monte Carlo method integrated with NovaTCAD mixmode.
- Basic set and reset characteristics demonstrated.
- Suitable for TCAD design as well as for research.