

Applied MDLx™ Ginestra™ Simulation Software

Solutions and Key Features

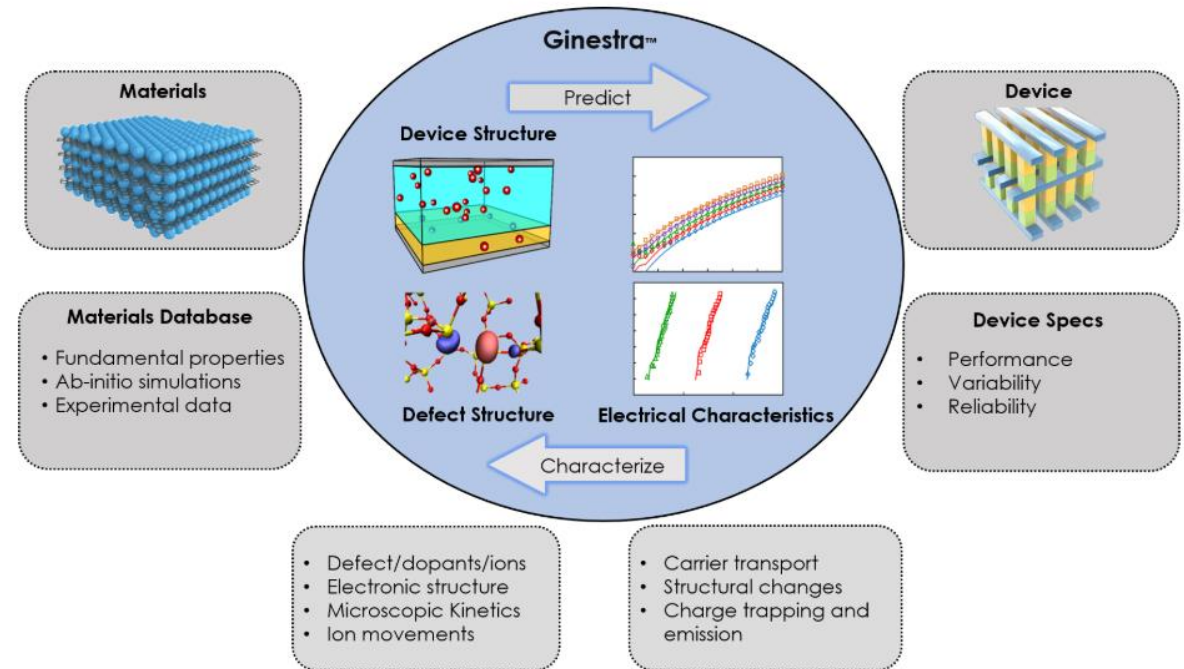


Ginestra™ Solutions

Ginestra is an innovative software platform that enables design and optimization of devices from materials based on performance, reliability and variability requirements

Features:

- Simulate electrical behavior for various material-device structure combinations
- Based on first principles treatment of carrier transport in different materials
- Accurate modeling of electrical properties at nanoscale and macroscale including defects and interfaces
- Transient, pulse and DC electrical characteristics together with long term reliability estimates

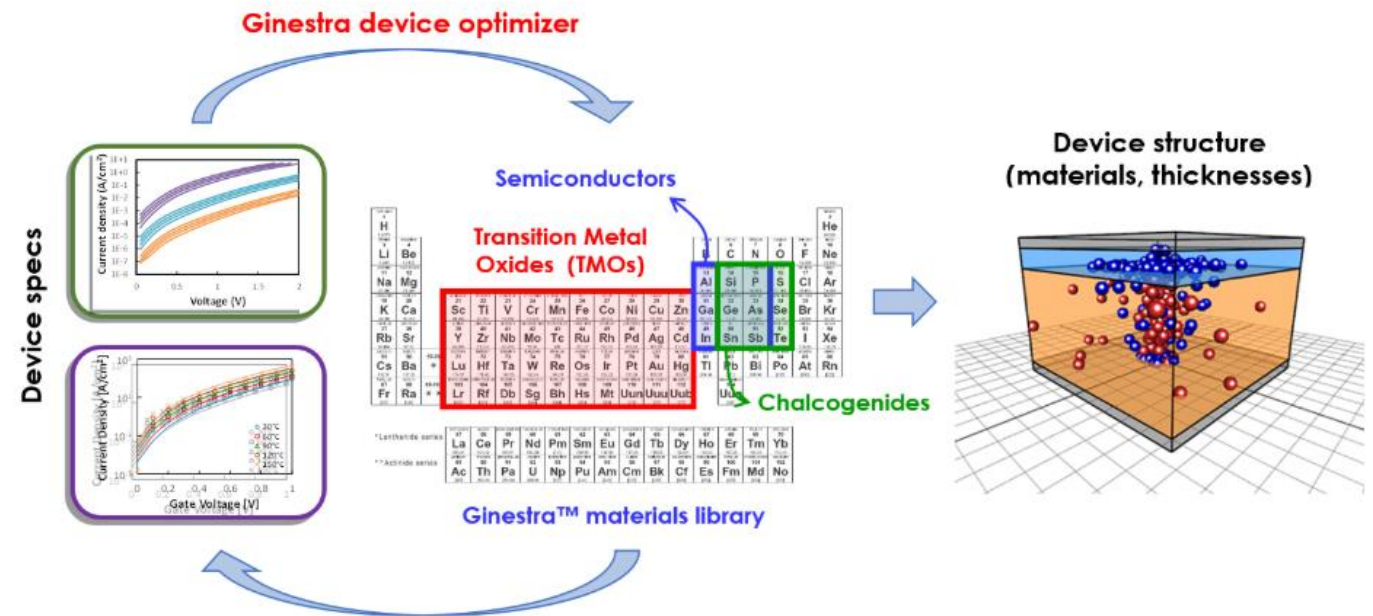


Memories and Novel Devices

Ginestra enables Novel Device Design by leveraging material properties

Features:

- Design novel devices or optimize existing technologies with the automatic Ginestra optimization tool
- Simultaneous optimization of multiple Figures of Merit for specific functionalities
- Comprehensive electrical tests covering all aspects of Performance, Variability, and Reliability

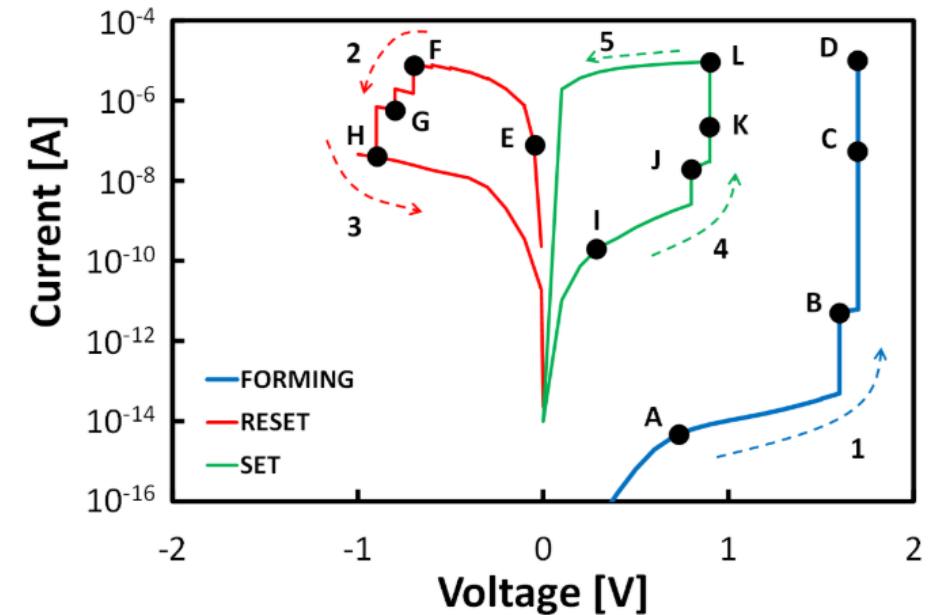


Design of novel devices by identifying materials combinations and device geometries for optimum device performance

Designing Resistive RAM Using Ginestra

Features:

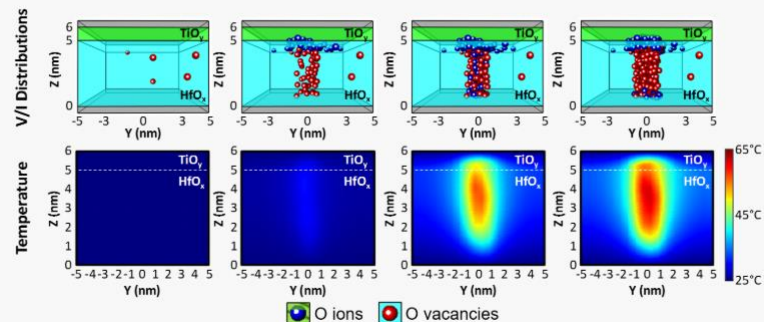
- Simulation of a full FORMING-RESET-SET cycle
- **FORMING**: Field-Induced Temperature-Driven positive feedback
 - ▶ Field and Temperature-Driven diffusion of atomic species
- **RESET**: Partial oxidation of the Conductive Filament due to Field-Driven diffusion of oxygen ions
- **SET**: Field-Induced breakdown of the oxide barrier
 - ▶ Oxygen diffusion recreates the oxygen reservoir



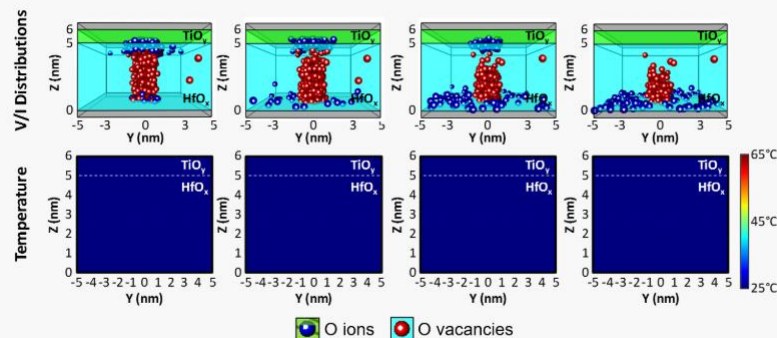
Resistive RAM Simulations

FORMING: Field-Induced Temperature-Driven positive feedback

- ✓ Field and Temperature-Driven diffusion of atomic species

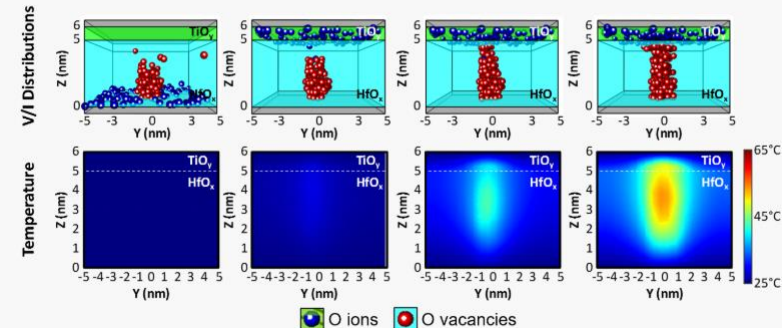


RESET: Partial oxidation of the Conductive Filament due to Field-Driven diffusion of oxygen ions



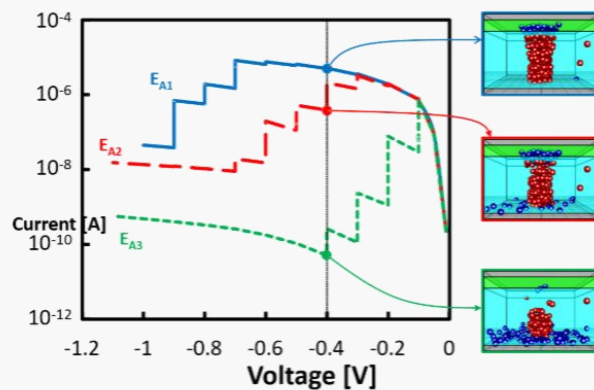
SET: Field-Induced breakdown of the oxide barrier

- ✓ Oxygen diffusion recreates the oxygen reservoir

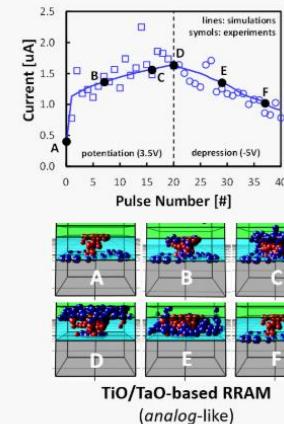
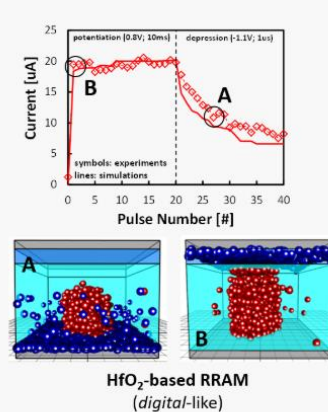


Identification of material properties affecting device performance

- ✓ Oxygen diffusion properties control RESET voltage



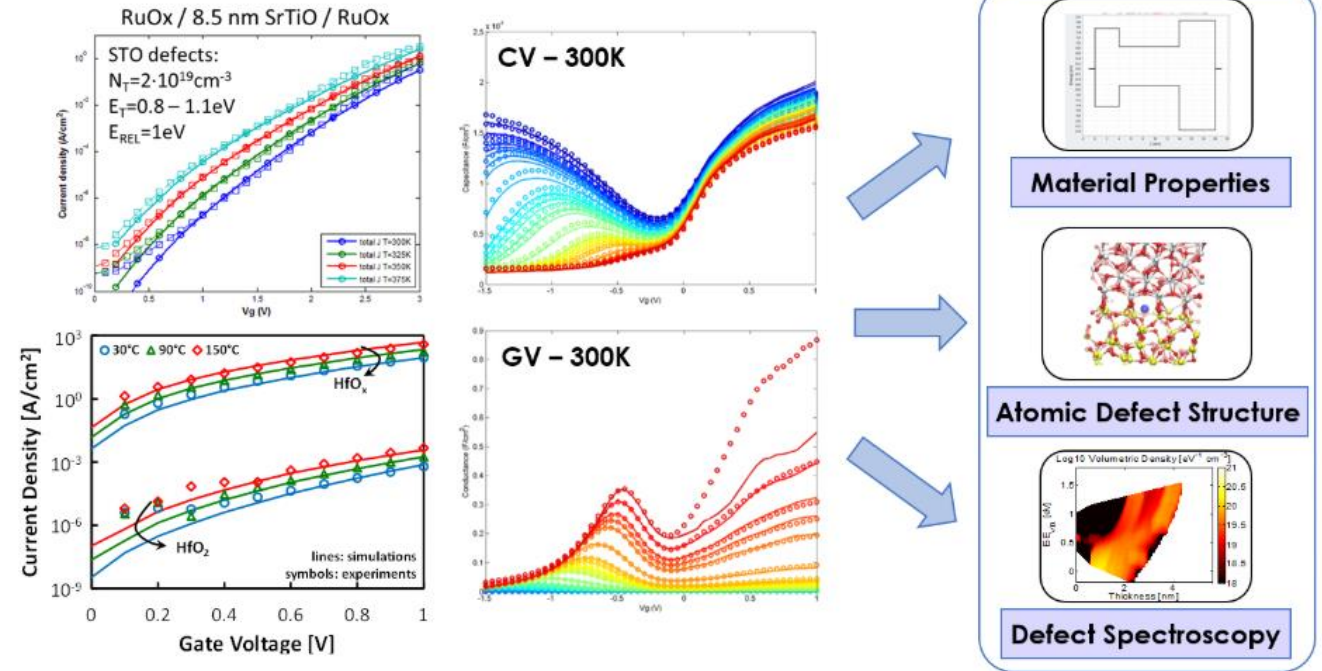
From digital to analog switching: Link between material, conductive filament properties and device electrical behavior



Material Characterization

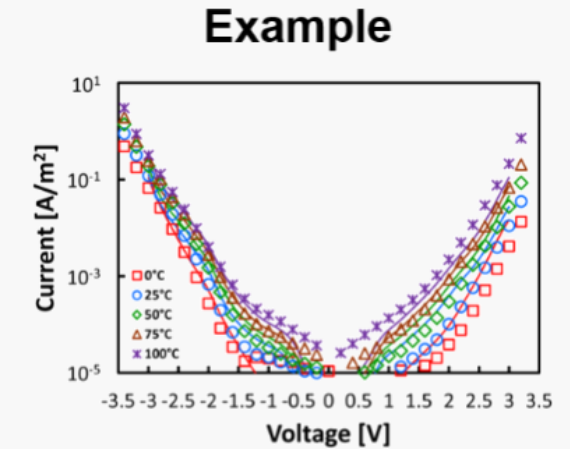
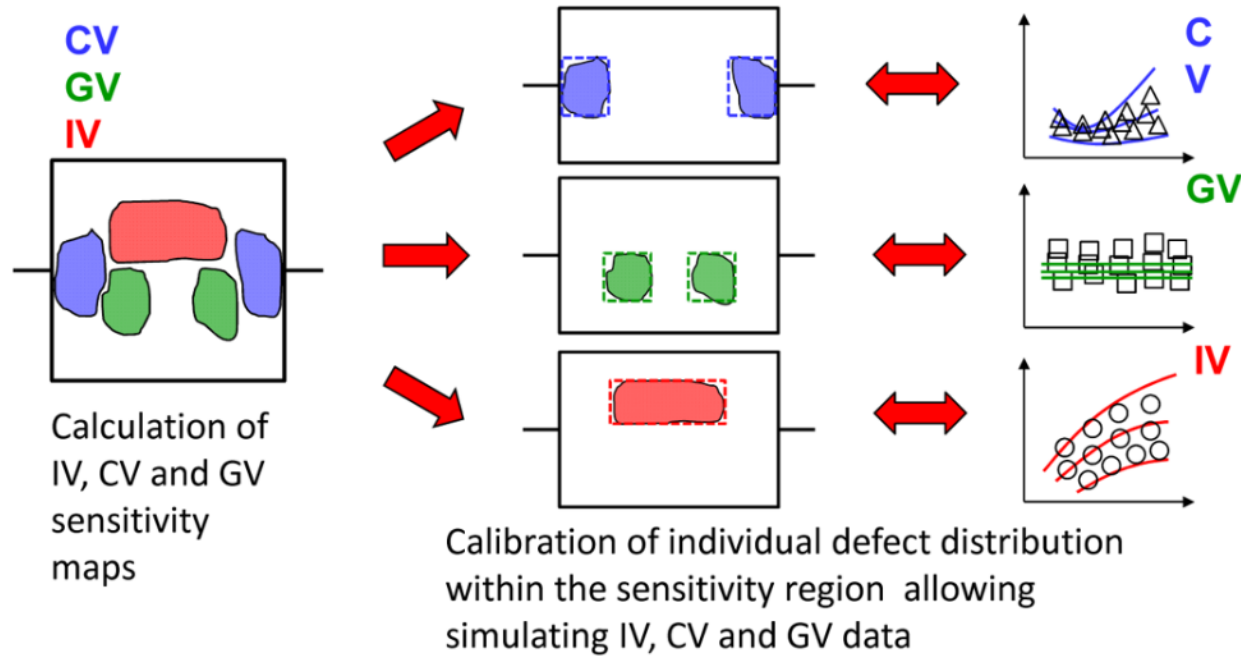
Features:

- Automatic extraction of key materials properties from electrical measurements (IV, CV, GV, BTI, TSCIS)
- Full characterization of defect energy and space distribution
- Identification of atomic defect species affecting device electrical characteristics

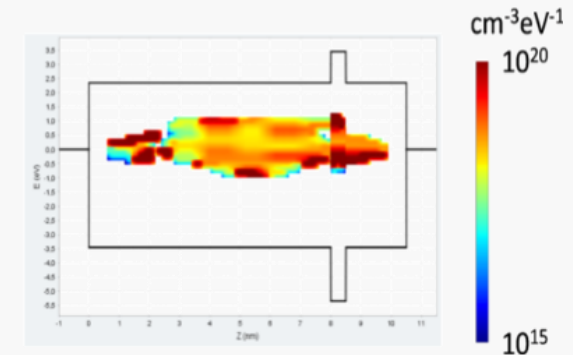


Fast characterization of material and defects properties from automatic interpretation of multiple electrical measurements

Defect Spectroscopy



Simulation fit of experimental I-V curves of MIM stack



Extracted Defect Density Profile for stack

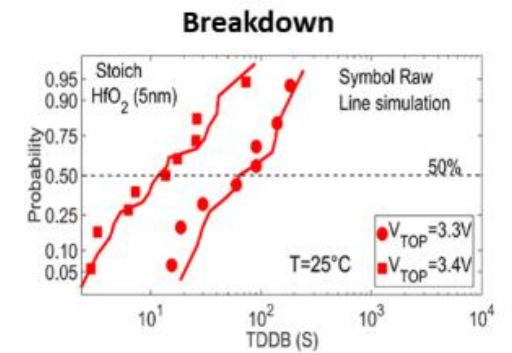
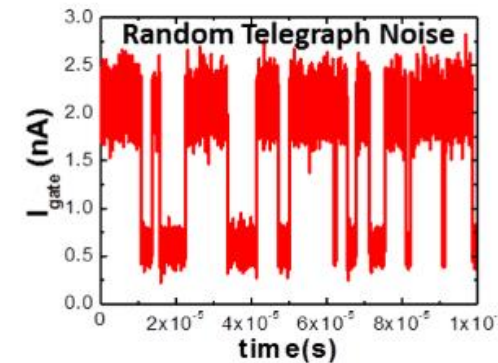
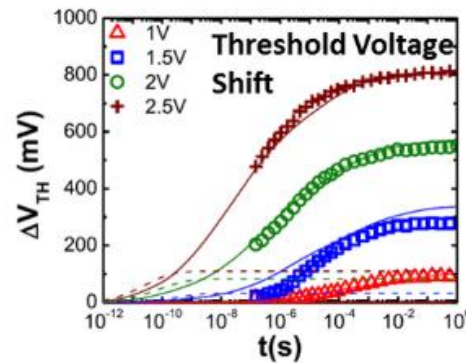
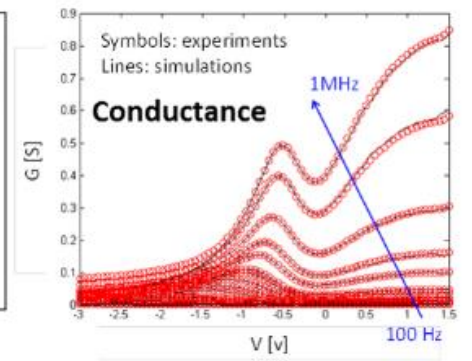
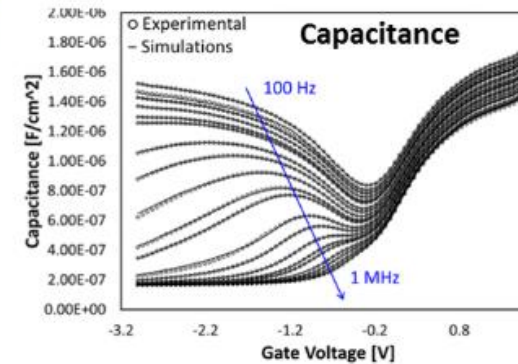
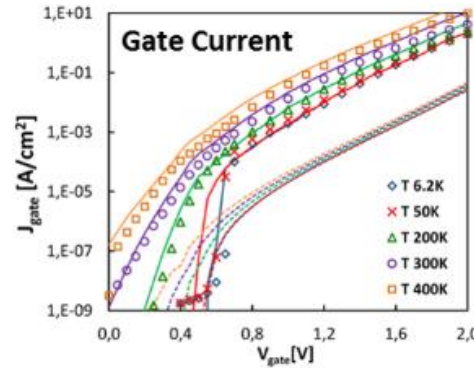
Method for extracting defect density depth profiles using a combination of electrical measurements

Electrical Characterization

Ginestra simulates key device characteristics that encompass performance, variability and reliability

Features:

- Simulation of DC, pulsed and transient electrical characteristics
- Accurate over wide range of voltages, times and temperature



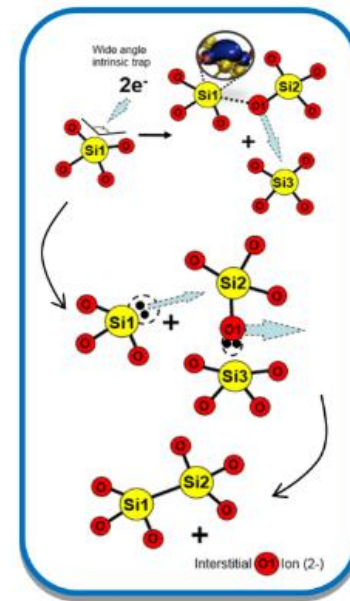
Accurate DC, AC and transient electrical characteristics determined by accounting for the effect of bulk atomic structure, interfaces and defects

Reliability and Variability

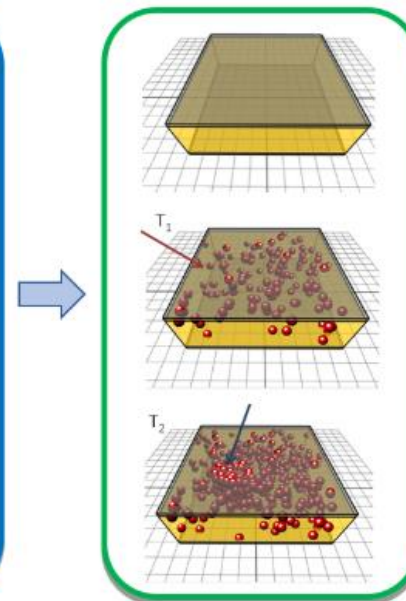
Ginestra allows visibility into long term reliability and performance degradation of devices under operating conditions

Features:

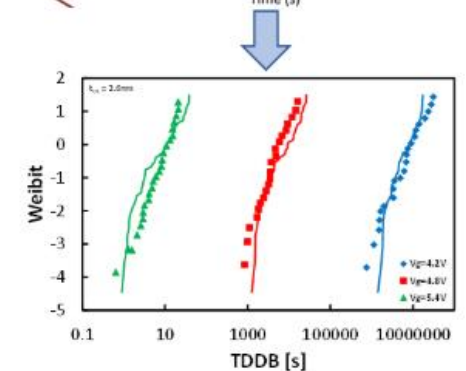
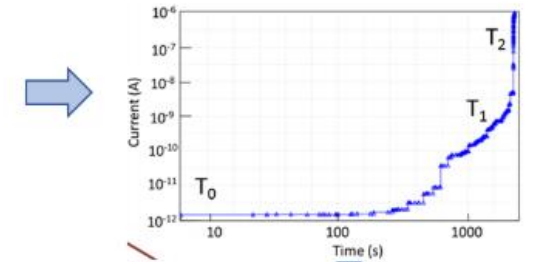
- Multiscale simulation of SILC, BD, BTI, RTN
- Use built-in module for statistical simulations to assess device variability
- Predict device lifetime for multiple different operating conditions and applications



Microscopic model of the defect formation process



Simulation of the degradation process at the device level



Statistical Breakdown simulations for reliability assessment and prediction

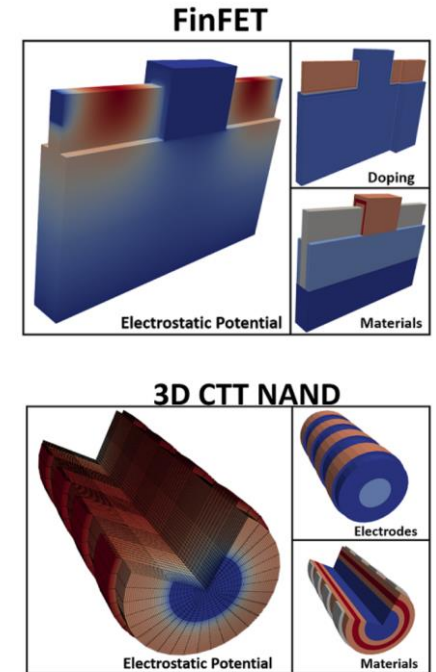
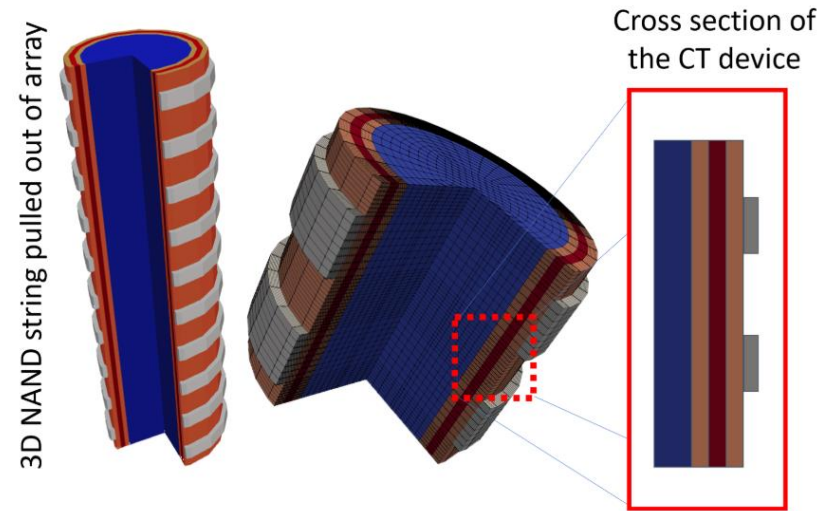
Models link microscopic material properties to electrical characteristics

Ginestra 3D

New FEM-based approach for arbitrary 3D geometries

Features:

- Finite Element and Finite Volume
- Highest accuracy through hexahedral mesh with local refinement capabilities
- Tunneling and quantization effects
- Individual defects considered
- 3D templates: FinFET, 3D CTT NAND, DRAM



Understand how defect-related issues affect performance, variability and reliability of state-of-the art logic and memory technologies

