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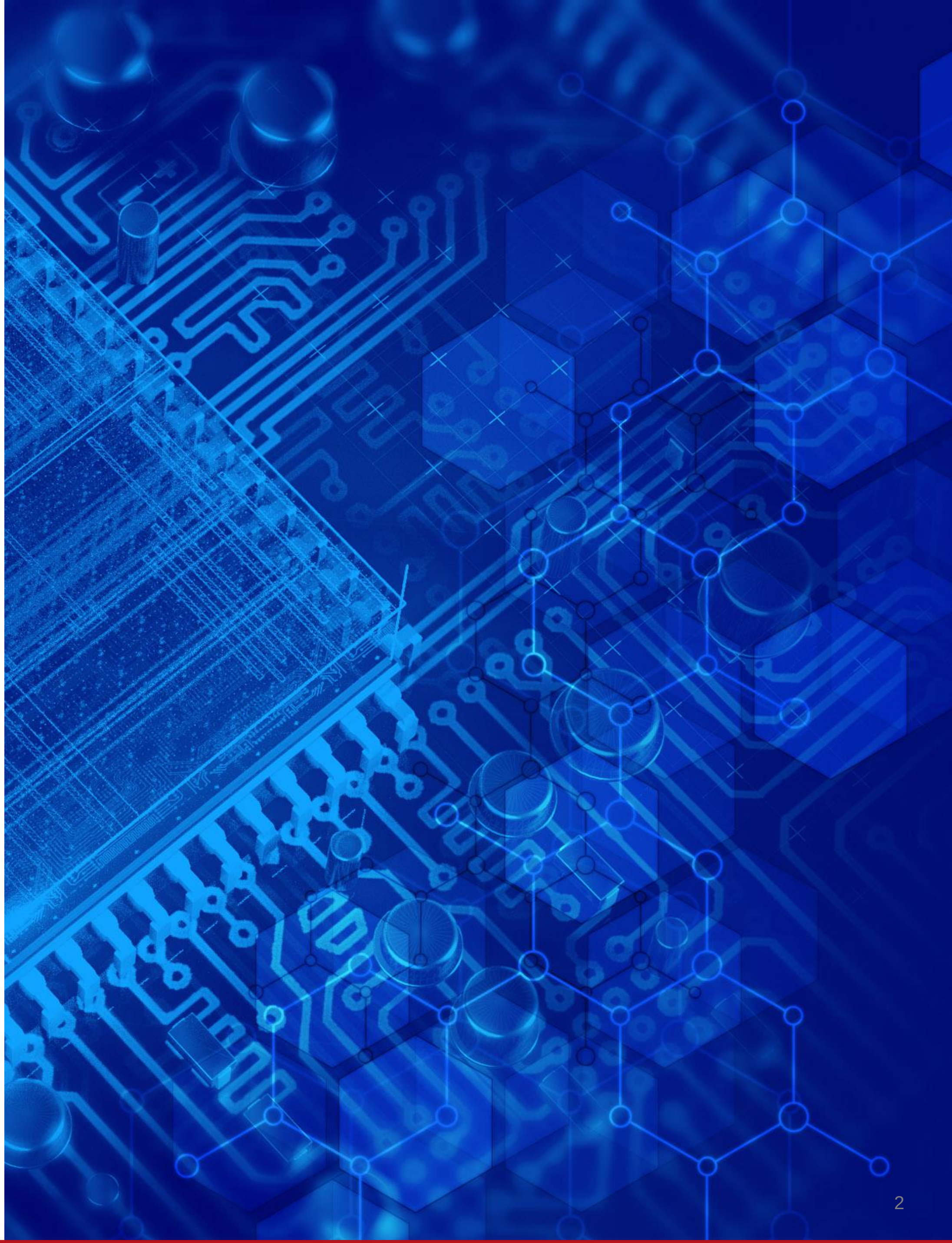
Silvaco TCAD

Leader in Power Device Technology Development

Silvaco TCAD for Silicon and Silicon Carbide Technology

Process Simulation
Device Simulation
Examples



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Victory Process for Si and SiC Power Devices

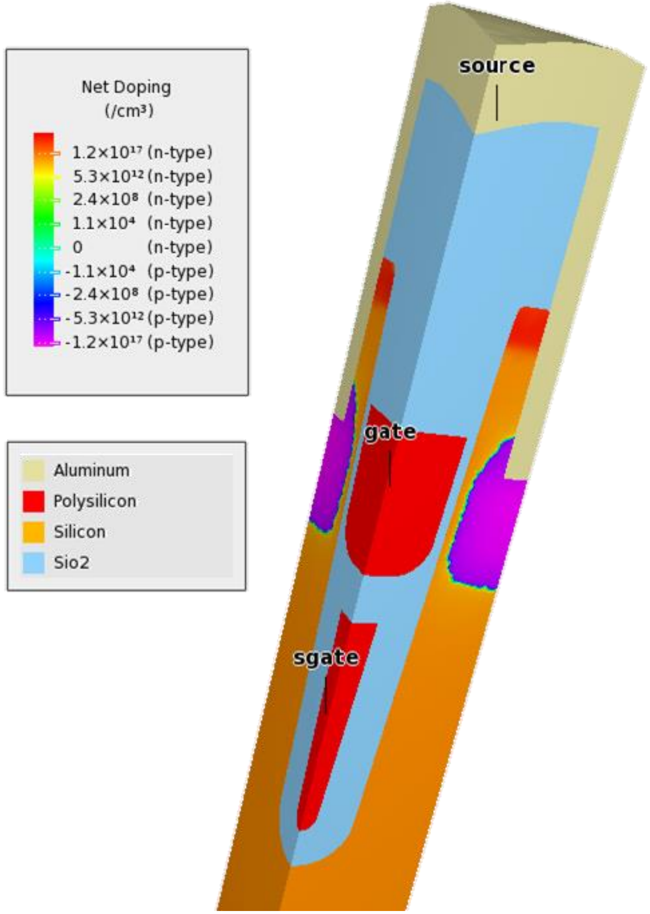
Virtualize your process flow. Optimize the next generation power devices through virtual fabrication

Full 2D/3D TCAD Process Solution

- Build, debug, calibrate in fast 2D
- Easy transition to realistic 3D for full 3D technology design
- Seamless integration into Device Simulation

Process simulation for Si and SiC

- Etch & Deposition
- Implantation
- Dopant Activation
- Oxidation
- Open Model Library and Material database
  - Allows for user customizability

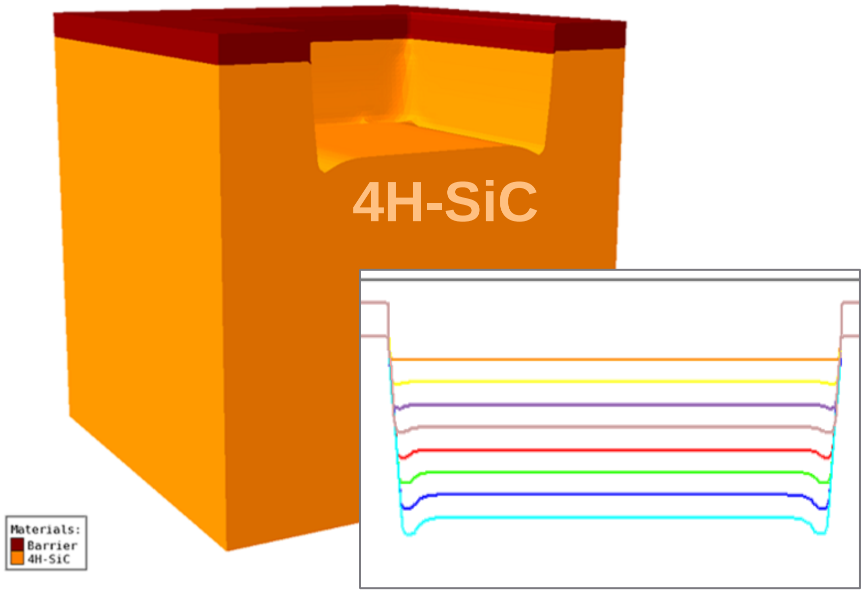


Silicon Split Gate Trench UMOSFET from Victory Process

Etch and Deposition for Next Generation Devices

New power devices utilize multiple etch and deposition steps to produce trenches, spacers, and dielectric layers. Capturing material geometry faithfully ensures TCAD simulation matches the fab.

- **GDSII driven TCAD,** connecting fab to TCAD
    - Import layout to use as masks for any process step
- **Simple geometric models** for fast simulating etch & deposition steps
    - Define etch/deposition thicknesses and a geometric model
- **Detailed physical models** for deeper understanding of your process steps
    - Define deposition/etch rates for each material
    - Sticking factors, flux parameters
    - Useful for understand visibility effects



Emulation of SiC Microtrench formation with time evolution

Implantation Accuracy with Victory Process

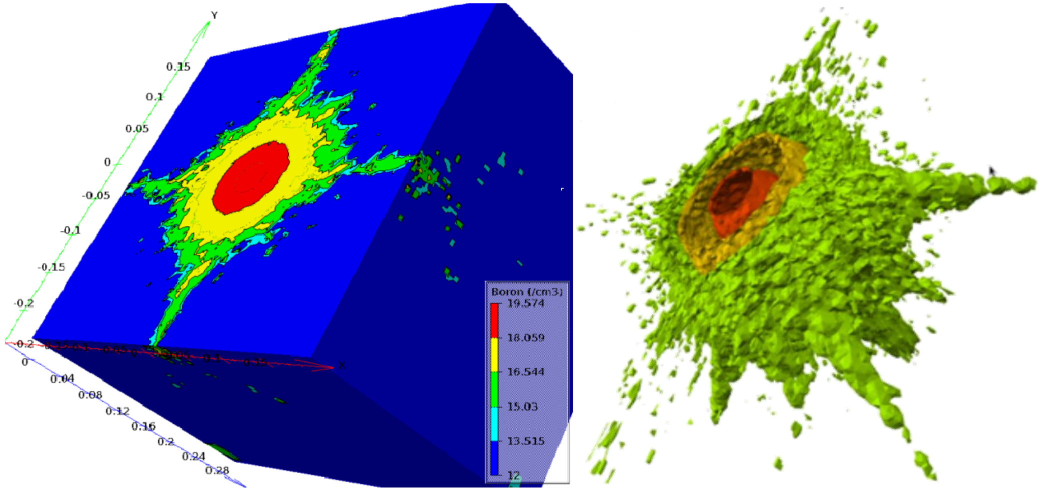
Fabrication processes include numerous implantations steps. Capturing physics-accurate implantation profiles allows optimization of process conditions for the best performing, high yield devices

Physical Implantation via Monte Carlo Implantation

- User-Definable Implant Properties
    - Substrate type/orientation, wafer miscut, angle, dose and energy
- Well calibrated stopping within crystal channels and random direction
    - Crystal Damage & Scattering due to damage accumulation

Empirical Methods to define doping in process

- Doping profiles by analytical distribution function
    - Quickly add Gaussian doping
- Doping profiles defined by external data files
    - Use SIMS profiles to build your TCAD process



Implant distribution at the Silicon surface shows pronounced lateral channeling

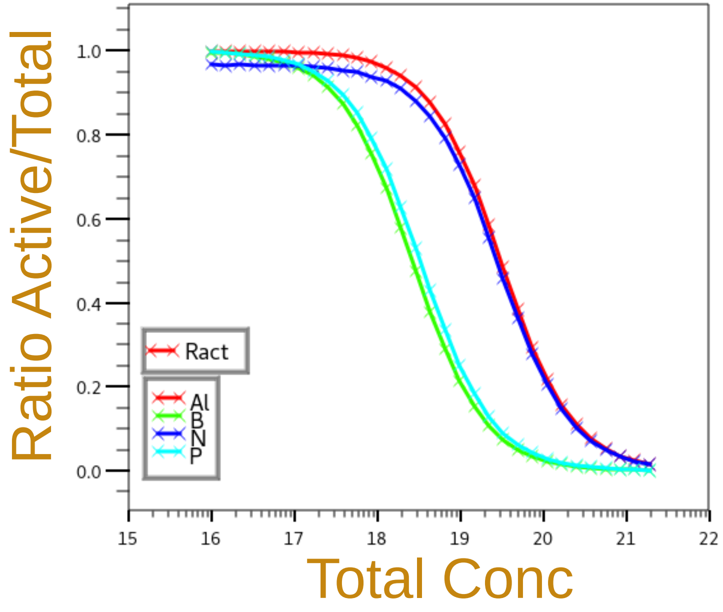
Electrical Activation During Fabrication

Incomplete activation of dopants can dictate device performance, especially in Silicon Carbide. Modeling electrical activation as part of process simulation captures dopant concentrations accurately

Dopant Activation Models calibrated for both Si & SiC

- Two major activation models: Empirical and Transient
  - **Empirical:** Instantaneous relationship between active and non-active concentrations
  - **Transient:** Adds transient partial differential equation to the empirical model

- **Table Method** for inserting user input data
  - Allows users to incorporate proprietary or new experimental activation data with ease



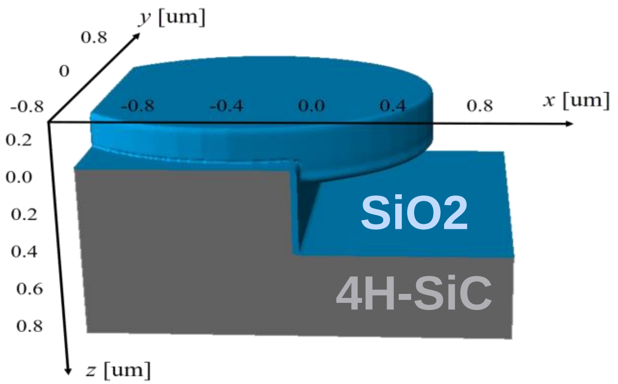
Activation Ratio vs Concentration for 4H-SiC at 1700C

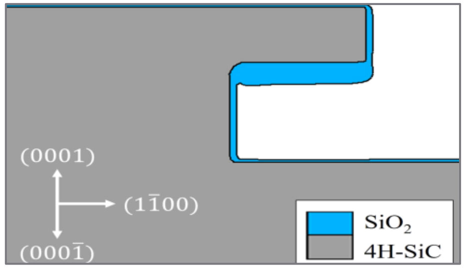
Robust Oxidation Simulation

Simulation of 3D oxidation is a challenging numerical problem. Victory Process is capable of efficiently and accuracy modeling key oxidation steps for Silicon and Silicon Carbide devices.

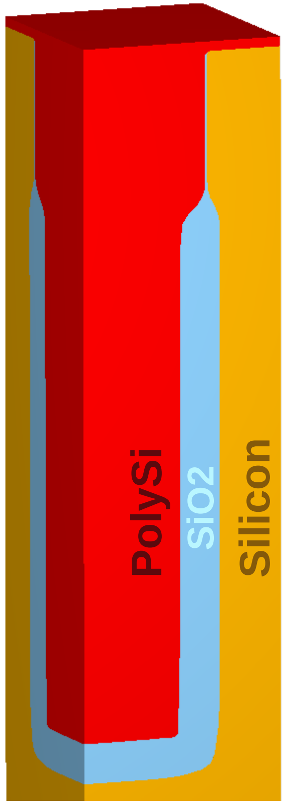
Oxidation Simulations available for Si & SiC

- Well calibrated for Silicon & Silicon Carbide
- Fully 3D Anisotropic Oxidation Model for 4H-SiC
    - Each crystal plane will have separate oxidation rates
    - Well calibrated to experimental results
    - Useful for understanding oxidation in trench devices





Anisotropic Oxidation Effects for 4H-SiC



LOCOS Oxidation for Silicon Power Device

Victory Device for Si and SiC Power Devices

Victory Device meets the breadth and depth of power device simulation needs

Simulate DC, AC and transient electrical simulation
- Understand how your device performs in any scenario

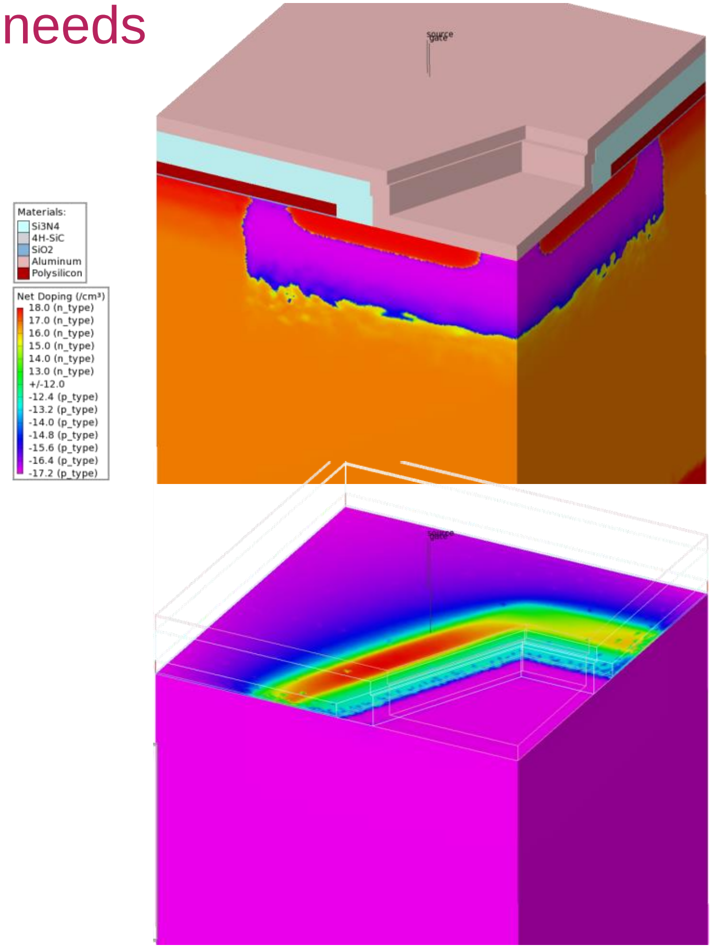
Self-Heating Simulation
- Gain insight into self-heating effects that influences electrical physics

Reliability and Radiation
- Simulate device degradation due to electrical stress, as well as radiation effects (TID, DD, SEB)

MixedMode circuit/device simulation
- Simulate TCAD devices within a SPICE circuit

User-customizable physical models & material parameters
- Calibrate any simulated device to your experimental data
- Novel wide bandgap materials can be simulated by adjusting the physical parameters

Advance numerical solvers and methods
- Multithreaded simulations and numerical extended precision available for the more difficult simulations



Anisotropic Mobility of SiC HexFET

Mobility Models for Accurate Simulation

Using the correct mobility models are essential for simulating your device properly

Mobility Models in Si

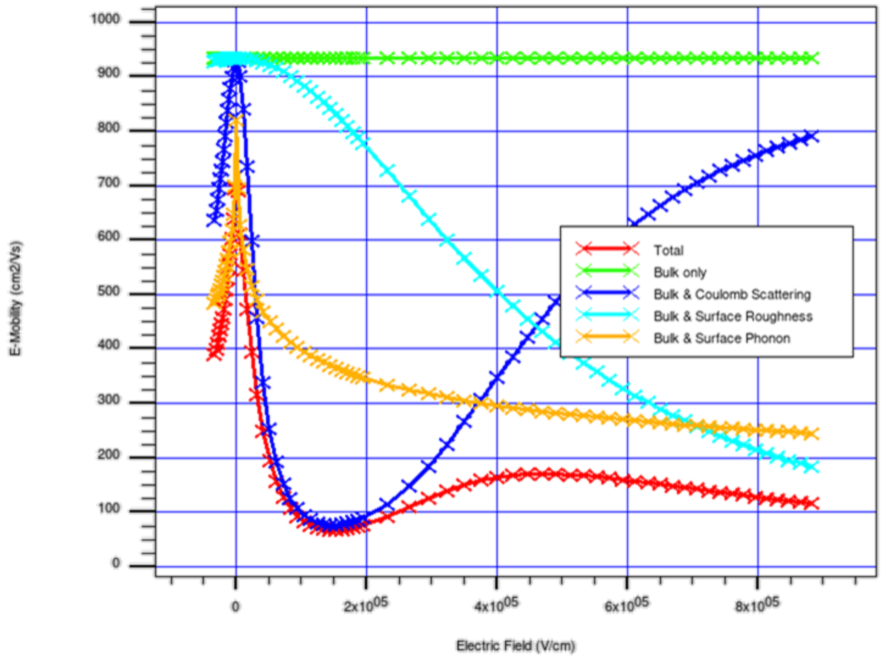
- 30 years of TCAD experience in Silicon
- Multiple models for low/high field mobility for Silicon
- Multiple inversion layer models

Mobility Models in SiC

- Calibrated parameters for SiC for many low/high field mobility models

- **SiC Inversion Layer Mobility Model**
  - Accurately model the low mobility in the channel
  - 4 major mobility components that can be adjusted to fit
    - Bulk Mobility, Surface Roughness, Acoustic Phonon Scattering, Coulomb Scattering

- **Anisotropic Mobility**
  - Users can specify mobilities for different orientations inside the device



Inversion Layer Mobility vs Electric field. Considering combined effects of mobility degradation effects

Essential Physical Models for Power Devices

Victory Device can simulate all the important effects needed to understand your power device whether it's silicon or a wideband gap material

Impact Ionization

Understand how breakdown can occur in your device

- Multiple impact ionization models for Si
- Anisotropic Impact Ionization for SiC
  - User-definable orientation of crystal axis

Incomplete Ionization of Impurities

Can directly or indirect effect mobility and other physical properties in device

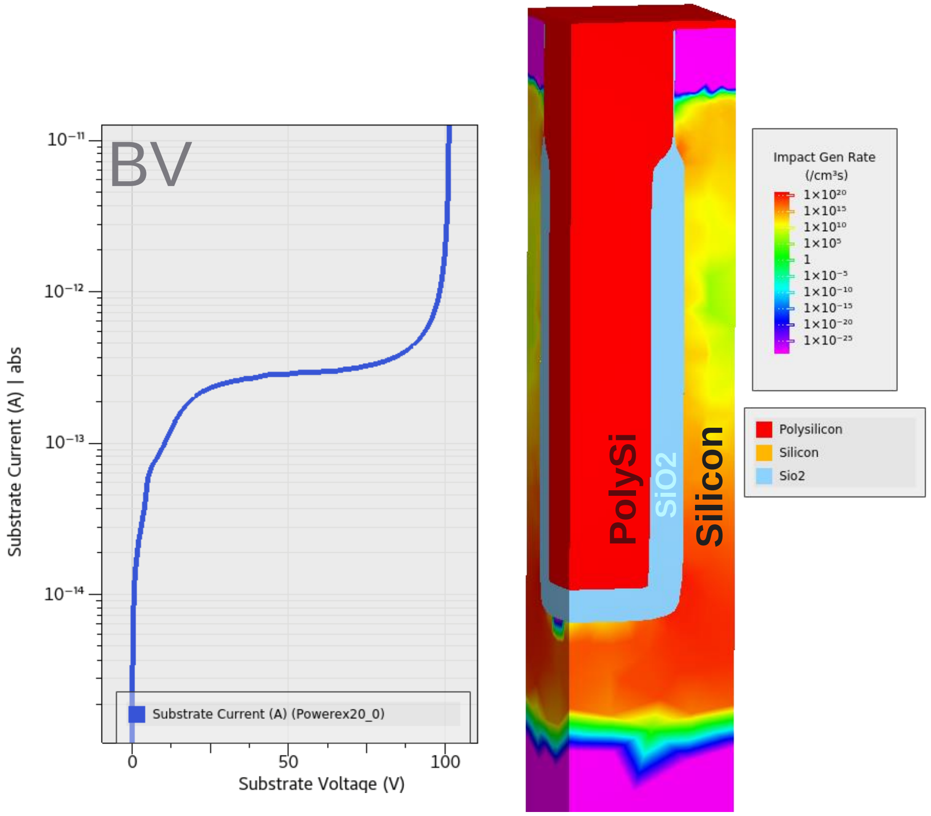
- Two-Level Model for SiC for hex and cubic sites

Bulk and Interface State Models

- Correctly model the interface traps and charges between a SiC/Oxide interface

Contact modeling for Si & SiC

- Definable work-function and contact properties (resistance, workfunction, tunneling)
- Schottky Parabolic Field Emission Model for 4H-SiC
- Ability to add lumped resistance/inductance or distributed resistance



Breakdown of Silicon Power Device and Impact Generation Rate

Silicon and Silicon Carbide Examples

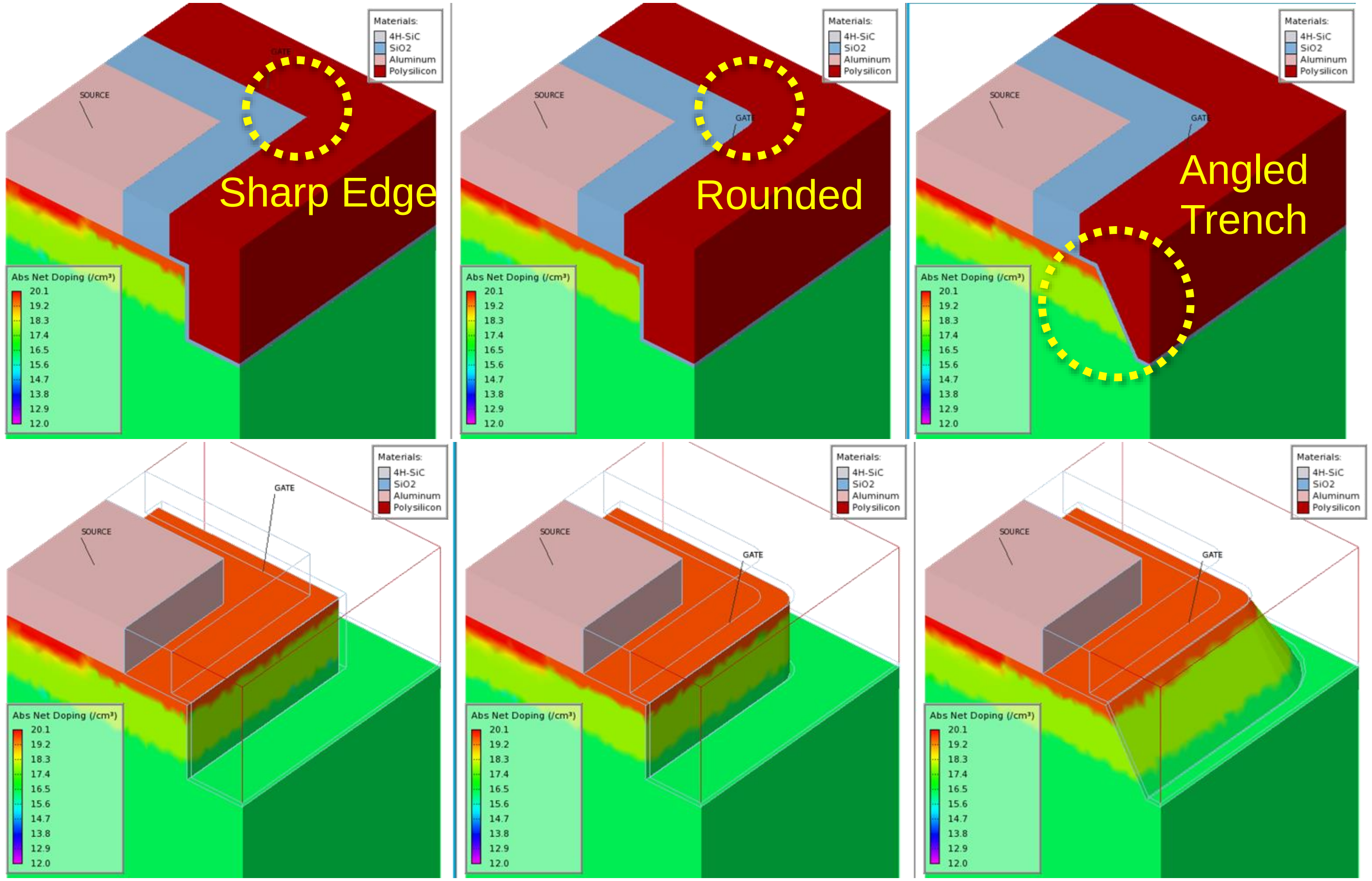
3D Design – Layout and Process Optimization

Trench Shape Effects
Breakdown voltage

- Process->Mesh->Device

Compare 3 different structures

1. Manhattan - Right angle corner, vertical trench
2. Rounded corner, vertical trench sidewall
3. Rounder corner sloped trench sidewall

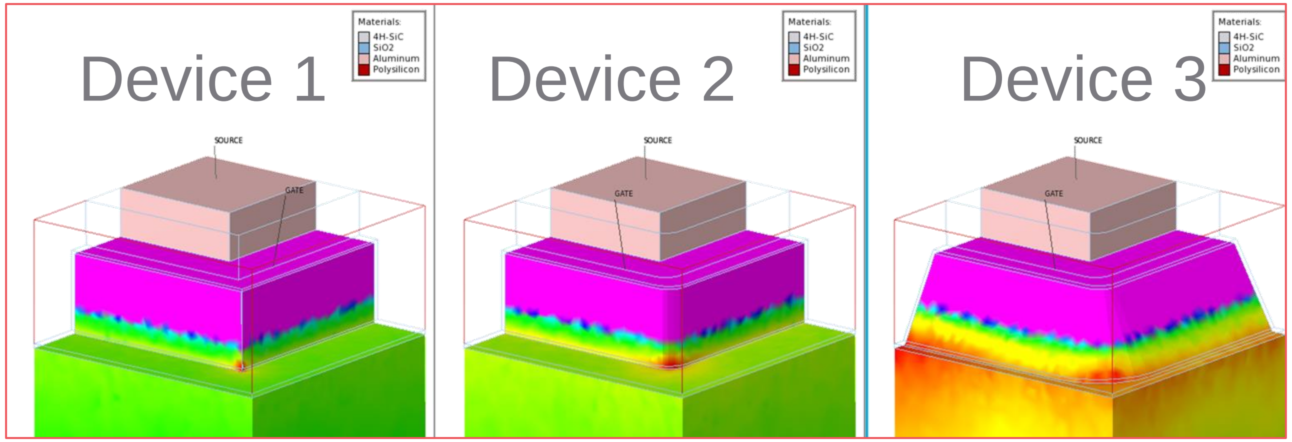


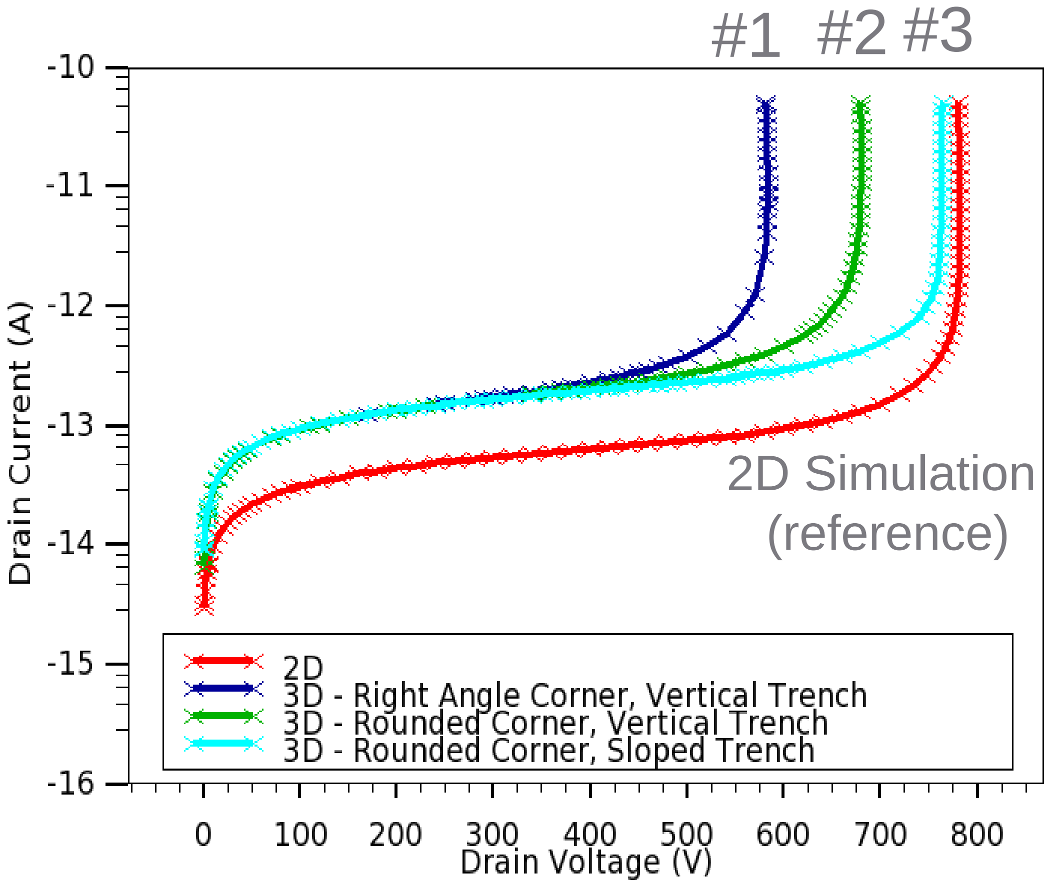
Device 1 Device 2 Device 3

3D Trench Shape Effect on Breakdown Voltage

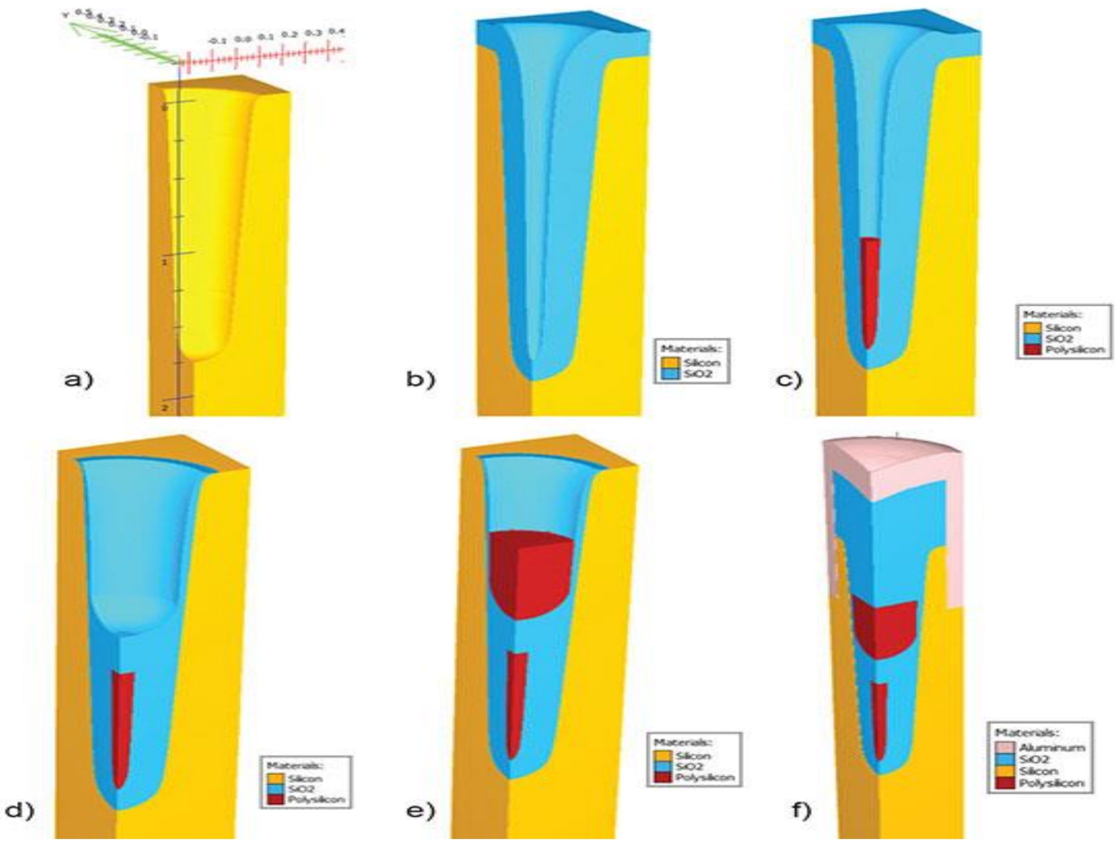
Trench Shape Effects

- Anisotropic Impact Ionization
- BV can be increased by 30% using rounded layout and angled trench
- Impact ionization not occurring only at the corner of the trench



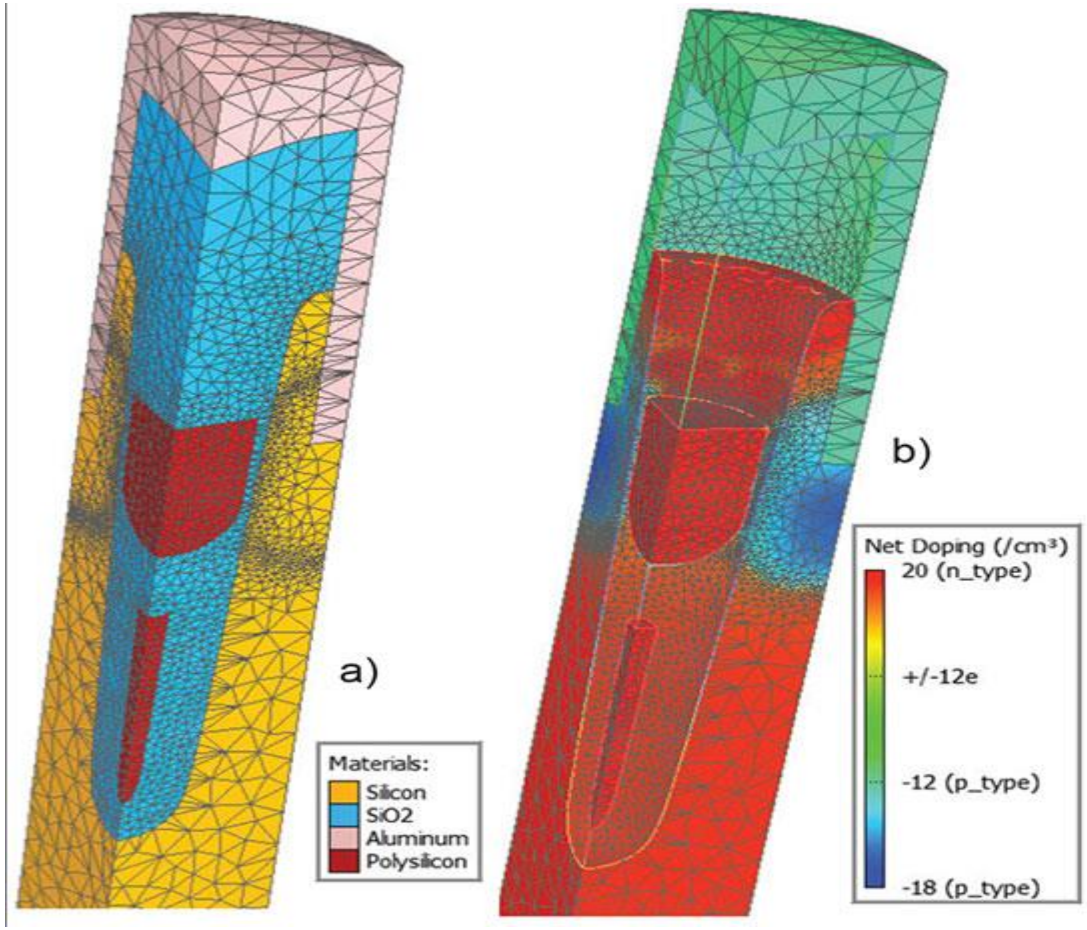


Split-Gate Trench UMOSFET



Victory Process simulation of key process steps to fabricate the Split-Gate UMOSFET

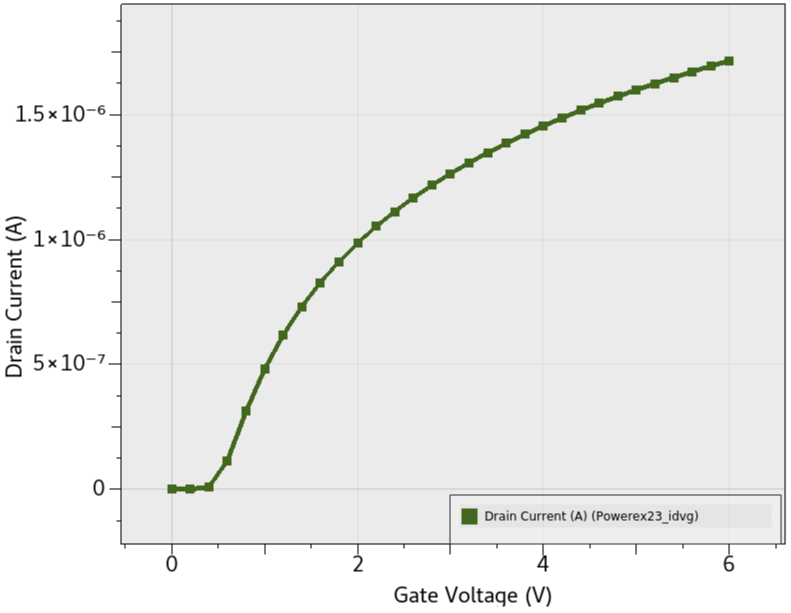
Delaunay mesh to resolve complex 3D geometry features (a) and doping profiles (b)



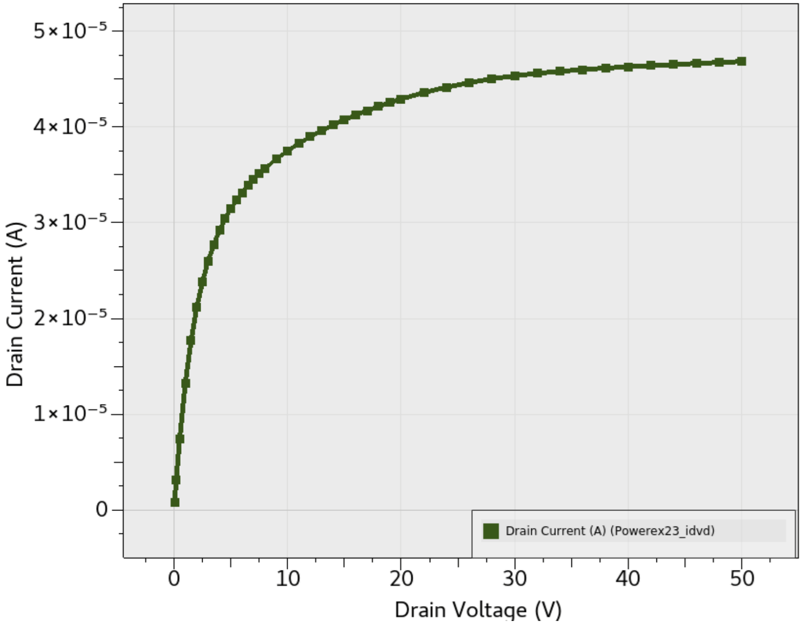
Split-Gate Trench UMOSFET

Victory Device can handle complex 3D geometries, for efficient and accurate device characterization

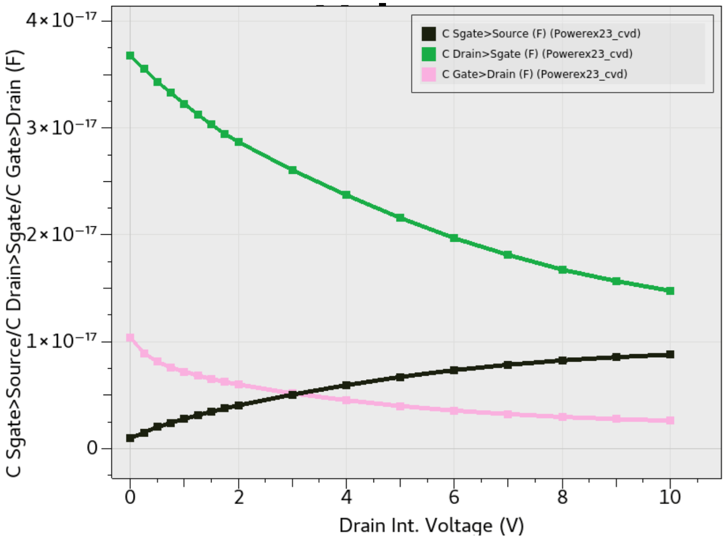
IdVg



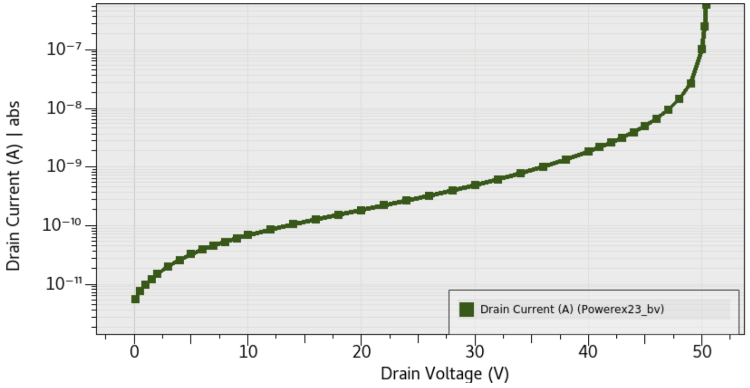
IdVd



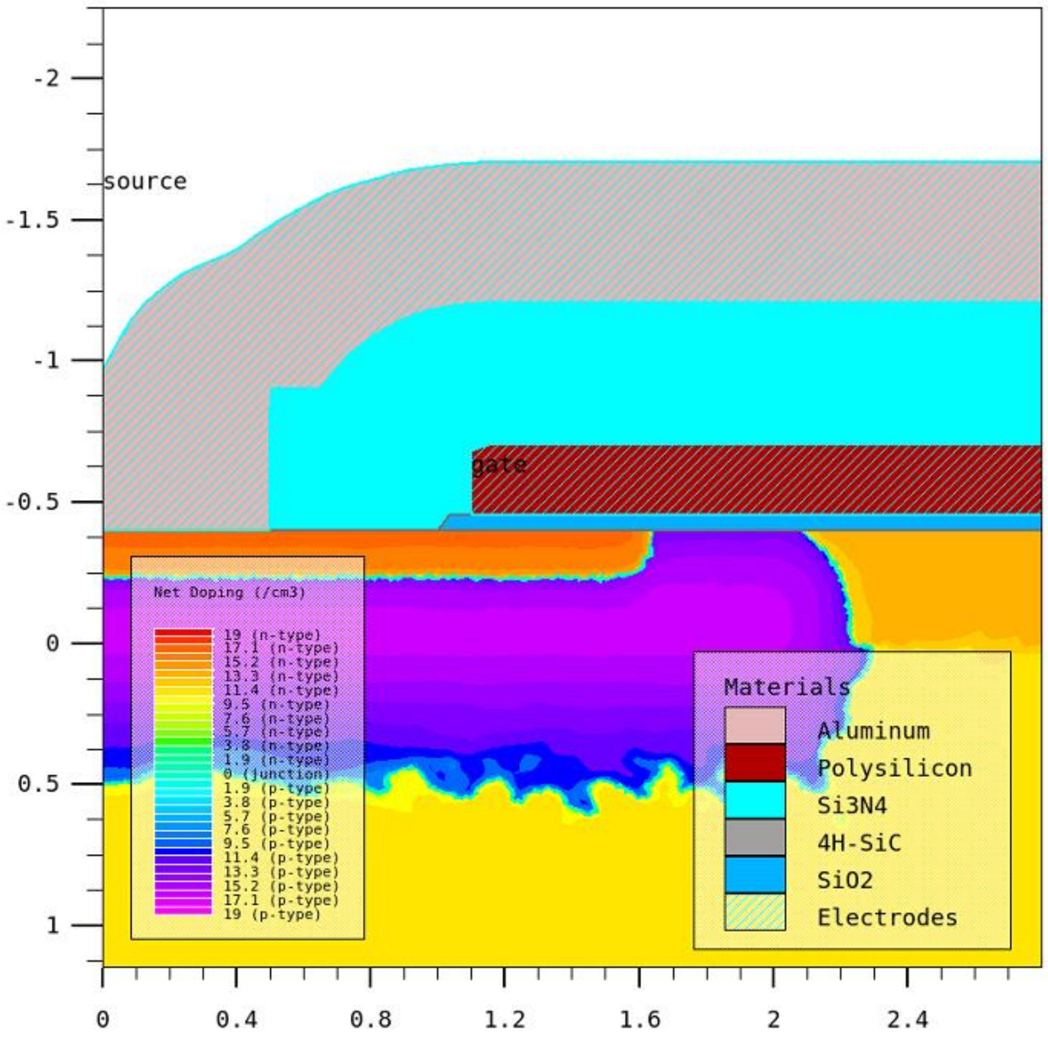
Capacitances vs Drain



Breakdown



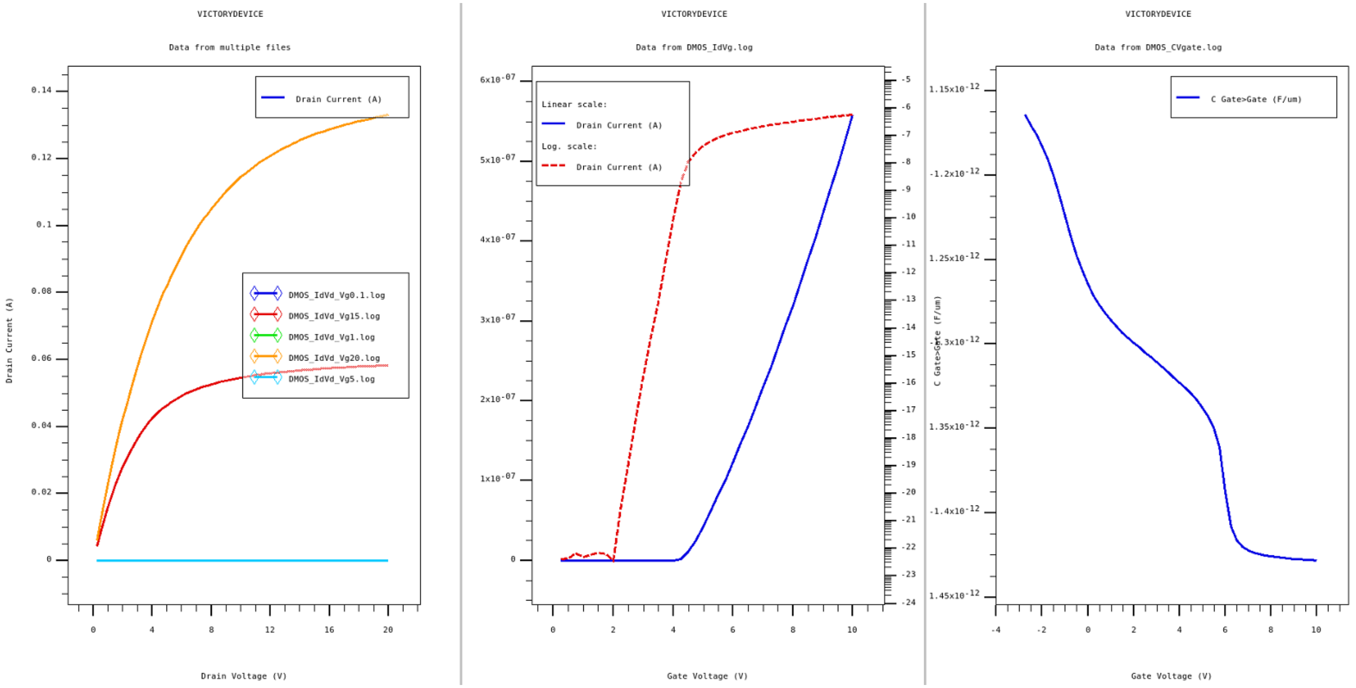
Silicon Carbide DMOS Process and Device



Full Process Simulation to Device Simulation

Based on IEEE EDL paper:

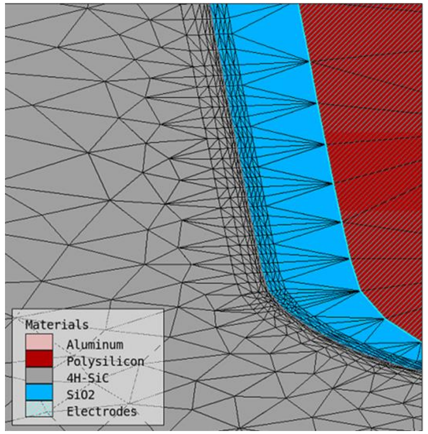
"600 V 4H-SiC MOSFETs Fabricated in Commercial Foundry With Reduced Gate Oxide Thickness of 27 nm to Achieve IGBT-Compatible Gate Drive of 15V"

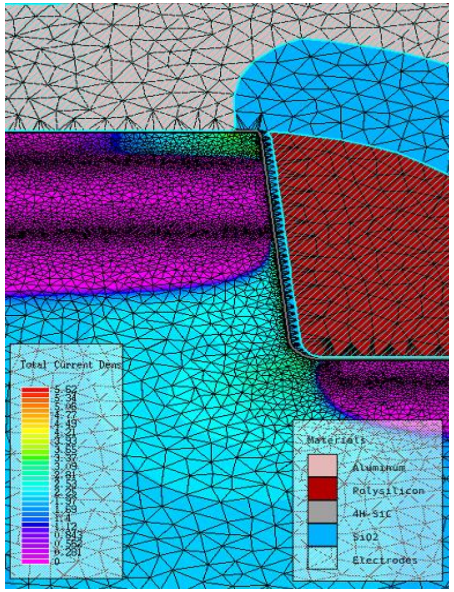


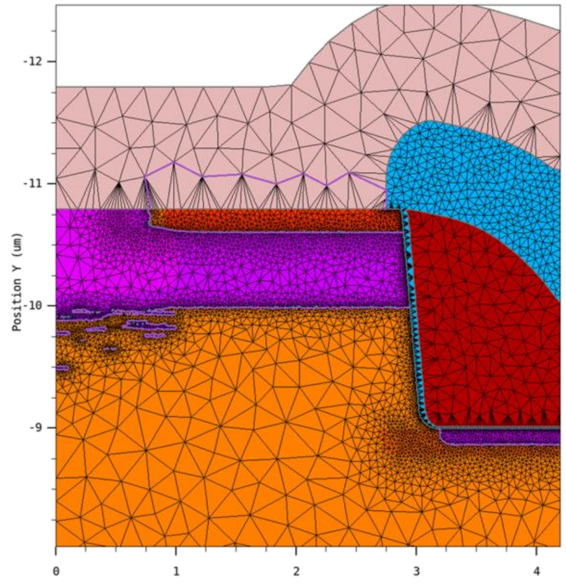
SiC Trench MOSFET Process & Device

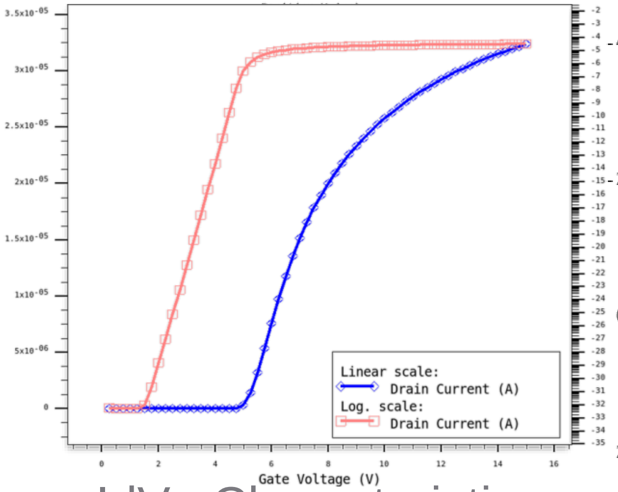
Full Process Simulation to Device Simulation
OFFSET statement used in Victory Mesh

- Generates offset slices at an interface
- Can be used with Delaunay Remeshing
  - Mesh conforms to curved interface
- Useful for inversion layers of non–planar devices

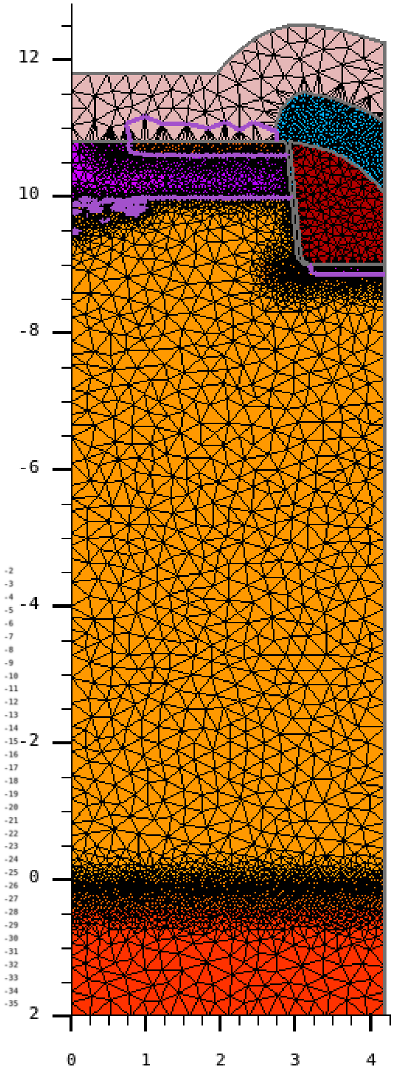






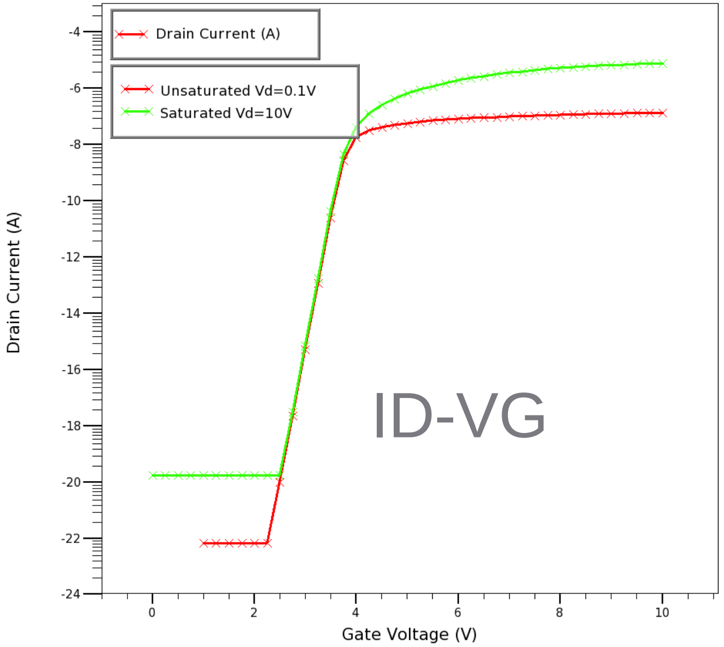


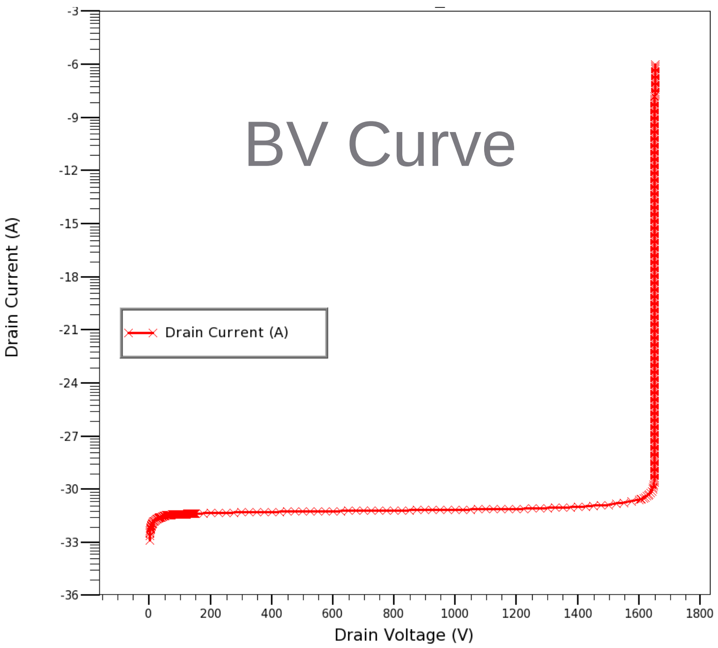
IdVg Characteristics

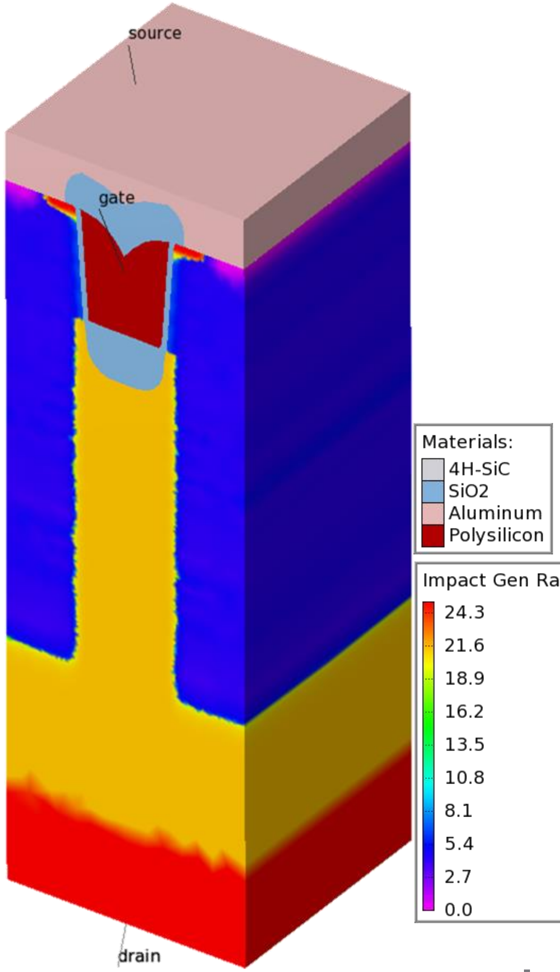


SiC Super-Junction Device

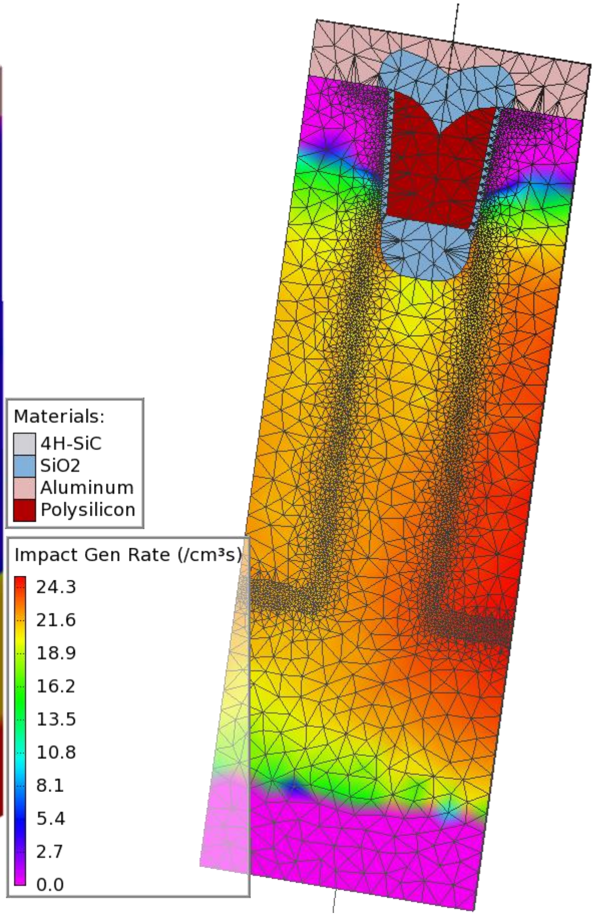
- Full Process Simulation to Device Simulation
- Monte Carlo Implantation
- Charge Balance of active dopants
- Simulates IV and BV







Net Doping



Impact Generation

Silvaco is leading the way for next generation Power Device Technology simulation