SILVACO

Automated Design Tools for SiC Manufacturing

Ahmed Nejim
R&D Projects Director

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Silvaco at a Glance

600+
Customers
Worldwide

200+
University Customers
Worldwide

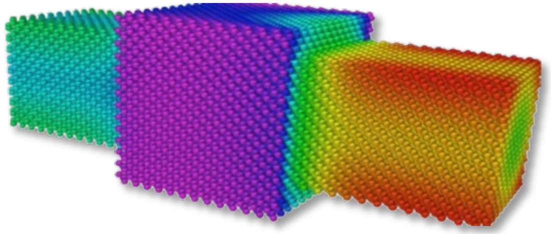
260+
Employees

#1
TCAD and Modeling
for **Flat Panel, Power**

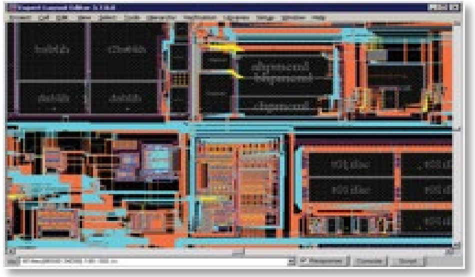
Solutions for
Display, EV Power, SoC, IoT, Fab Process Optimization

Deep Industry &
Academic
Collaborations

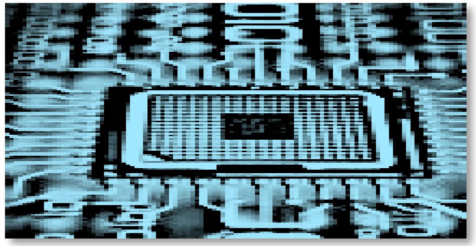
Silvaco's Solution Spectrum



Atoms



Transistors



Systems

TCAD

Analog Custom

Design IP

Number of Devices

1

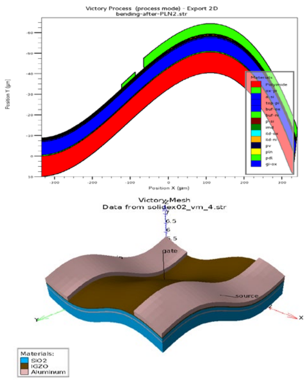
10K

10M

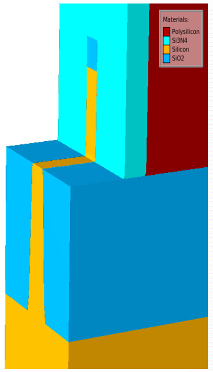
Manufacturing – process simulation

From Unit Process to Process Integration

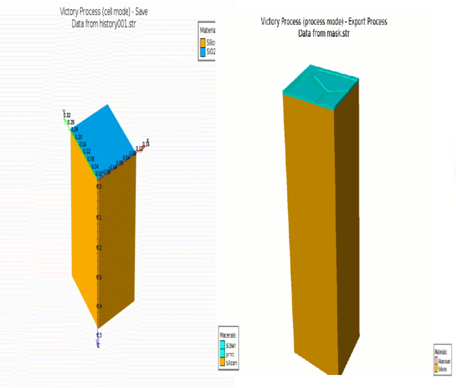
Oxidation



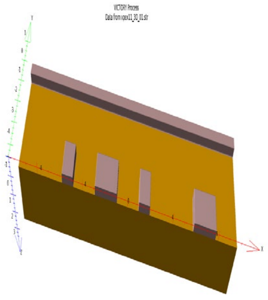
Stress/Strain



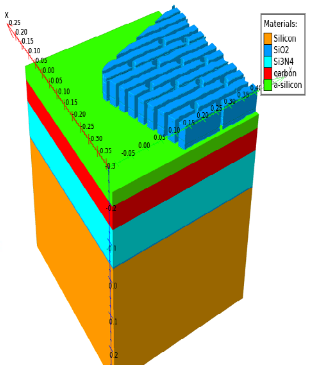
Epitaxy



Etch/Dep



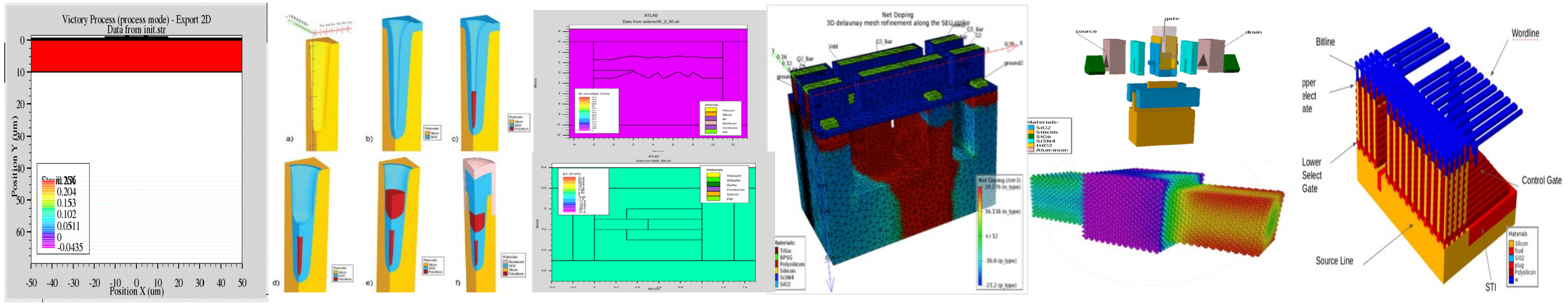
CMP



Patterning

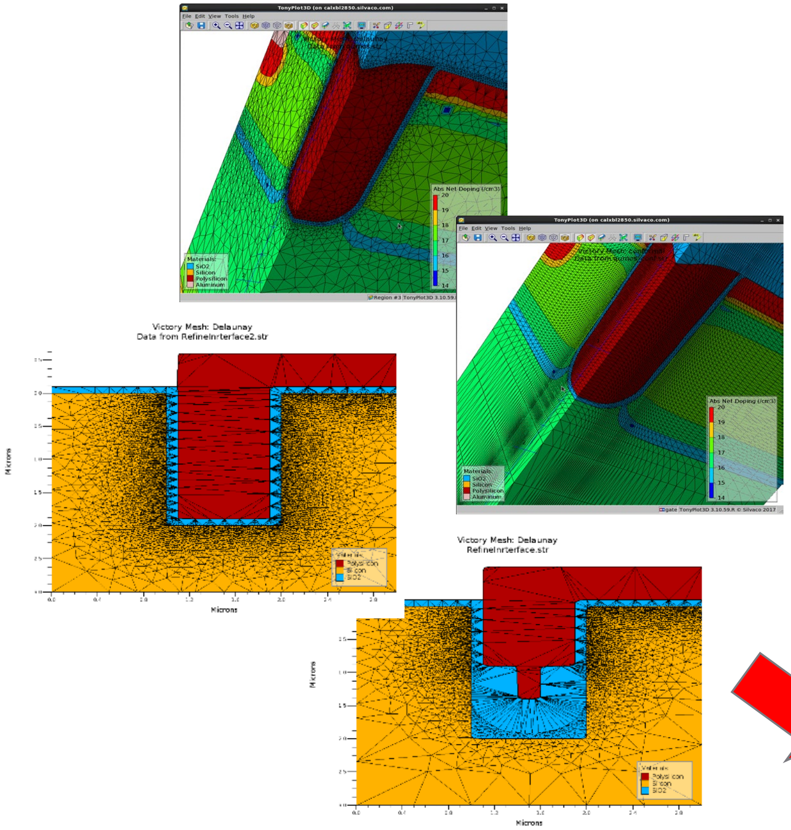
Functionality – Device simulation

Tracking carriers under different settings

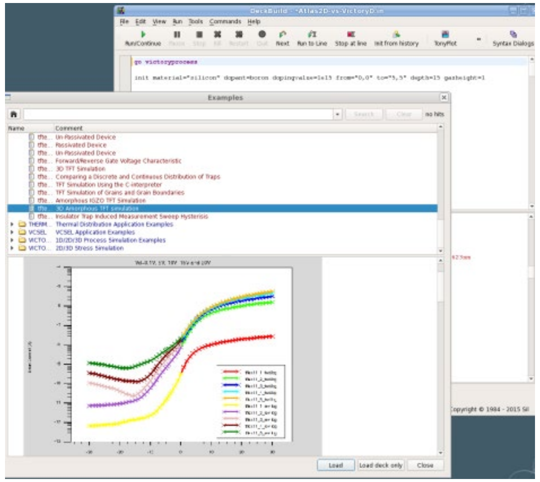


Display **Power** **Optical** **Radiation** **Adv CMOS** **Memory**

Technology Computer Aided Design (TCAD)
a crash course



Define structure



```
go victoryprocess

init material="silicon" dopant=boron dopingvalue=1e15 from="0,0" to="5,5" depth=15 gasheight=1
```

Name	Comment
tfte...	Un-Passivated Device
tfte...	Passivated Device
tfte...	Un-Passivated Device
tfte...	Forward/Reverse Gate Voltage Characteristic
tfte...	3D TFT Simulation
tfte...	Comparing a Discrete and Continuous Distribution of Traps
tfte...	TFT Simulation Using the C-interpreter
tfte...	TFT Simulation of Grains and Grain Boundaries
tfte...	Amorphous IGZO TFT Simulation
tfte...	3D Amorphous TFT simulation
tfte...	Insulator Trap Induced Measurement Sweep Hysterisis
THERM...	Thermal Distribution Application Examples
VCSEL	VCSEL Application Examples
VICTO...	1D/2D/3D Process Simulation Examples
VICTO...	2D/3D Stress Simulation

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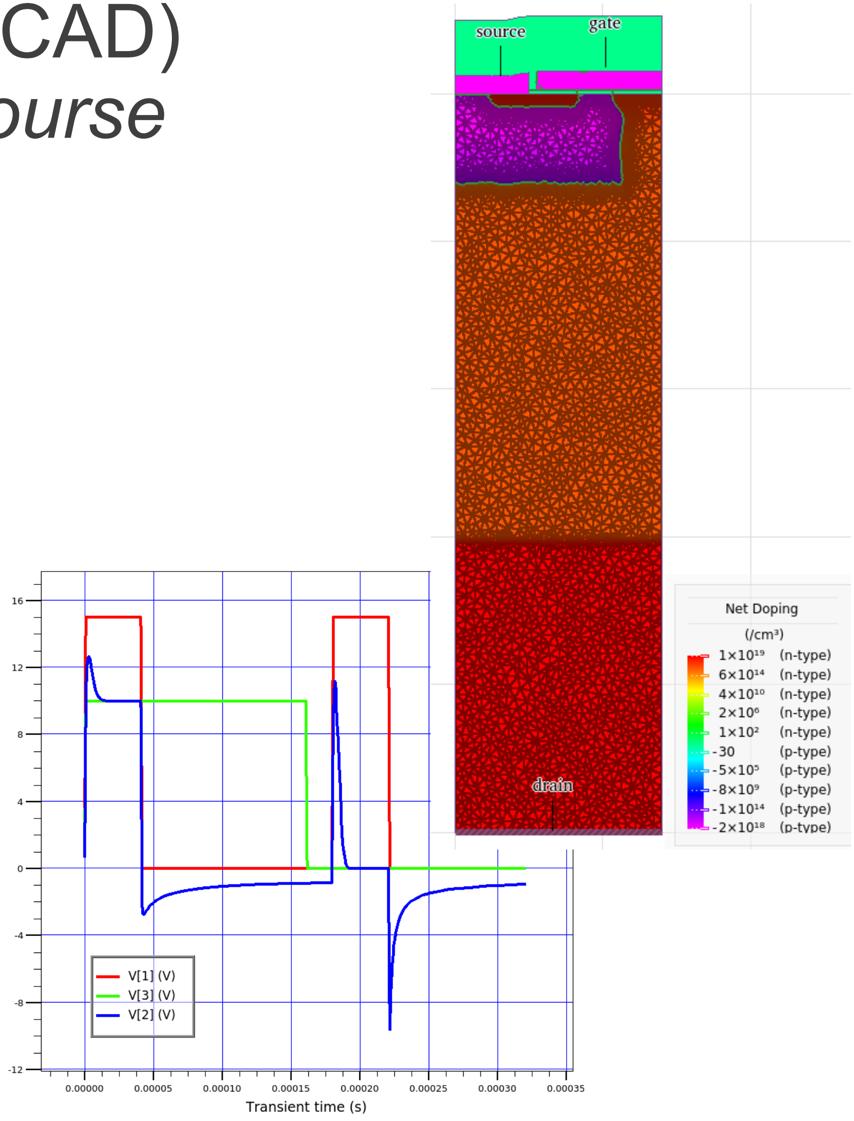
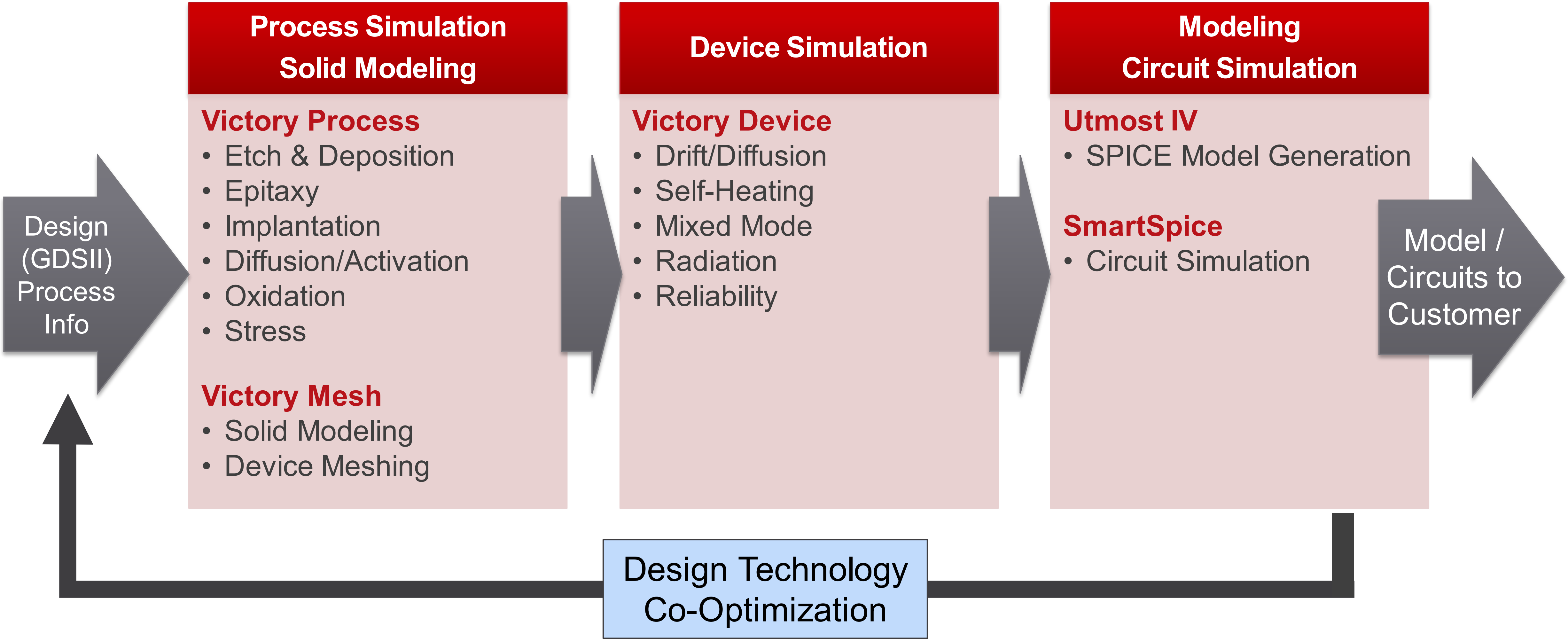
Define models



Obtain data

TCAD flow

Victory TCAD Solution for Power Devices



Design (GDSII) Process Info

Process Simulation Solid Modeling

Victory Process
- Etch & Deposition
- Epitaxy
- Implantation
- Diffusion/Activation
- Oxidation
- Stress

Victory Mesh
- Solid Modeling
- Device Meshing

Device Simulation

Victory Device
- Drift/Diffusion
- Self-Heating
- Mixed Mode
- Radiation
- Reliability

Modeling Circuit Simulation

Utmost IV
- SPICE Model Generation

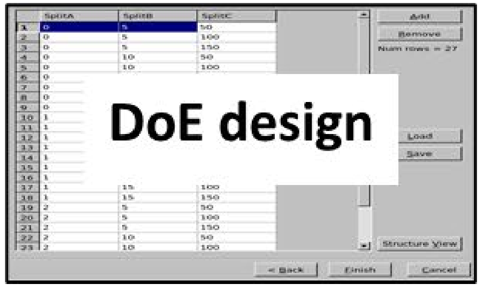
SmartSpice
- Circuit Simulation

Model / Circuits to Customer

Design Technology Co-Optimization

Accelerating Fab Engineering with TCAD powered ML

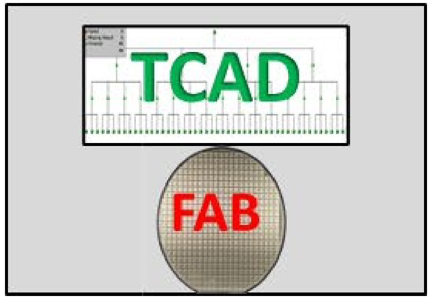
Optimized Sampling



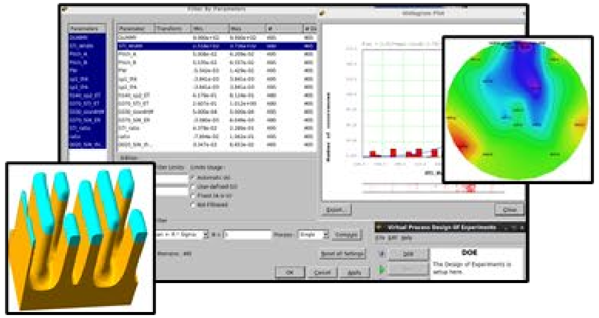
	SplitA	SplitB	SplitC
1	0	5	50
2	0	5	100
3	0	5	150
4	0	10	50
5	0	10	100
6	0		
7	0		
8	0		
9	0		
10	1		
11	1		
12	1		
13	1		
14	1		
15	1		
16	1		
17	1	15	100
18	1	15	150
19	2	5	50
20	2	5	100
21	2	5	150
22	2	10	50
23	2	10	100

Num rows = 27

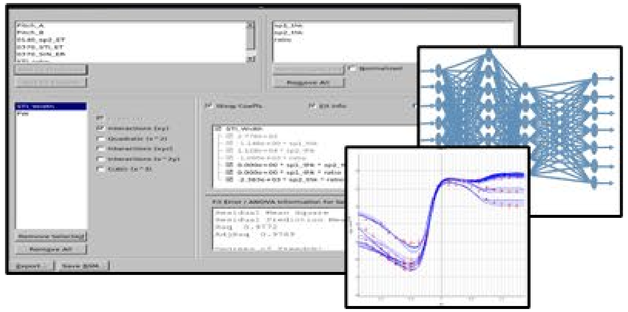
Experiment



Data analysis, visualization



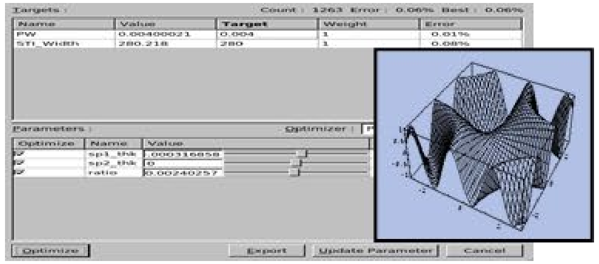
Supervised ML for Nonlinear Modeling



ML-based Incremental sampling

Good Model

Model-based Global Sizing



Targets : Count : 1263 Error : 0.06% Best : 0.06%

Name	Value	Target	Weight	Error
PW	0.00400021	0.004	1	0.01%
STI_Width	280.218	280	1	0.08%

Parameters : Optimizer :

Optimize	Name	Value
☑	sp1_thk	.000316858
☑	sp2_thk	0
☑	ratio	0.00240257

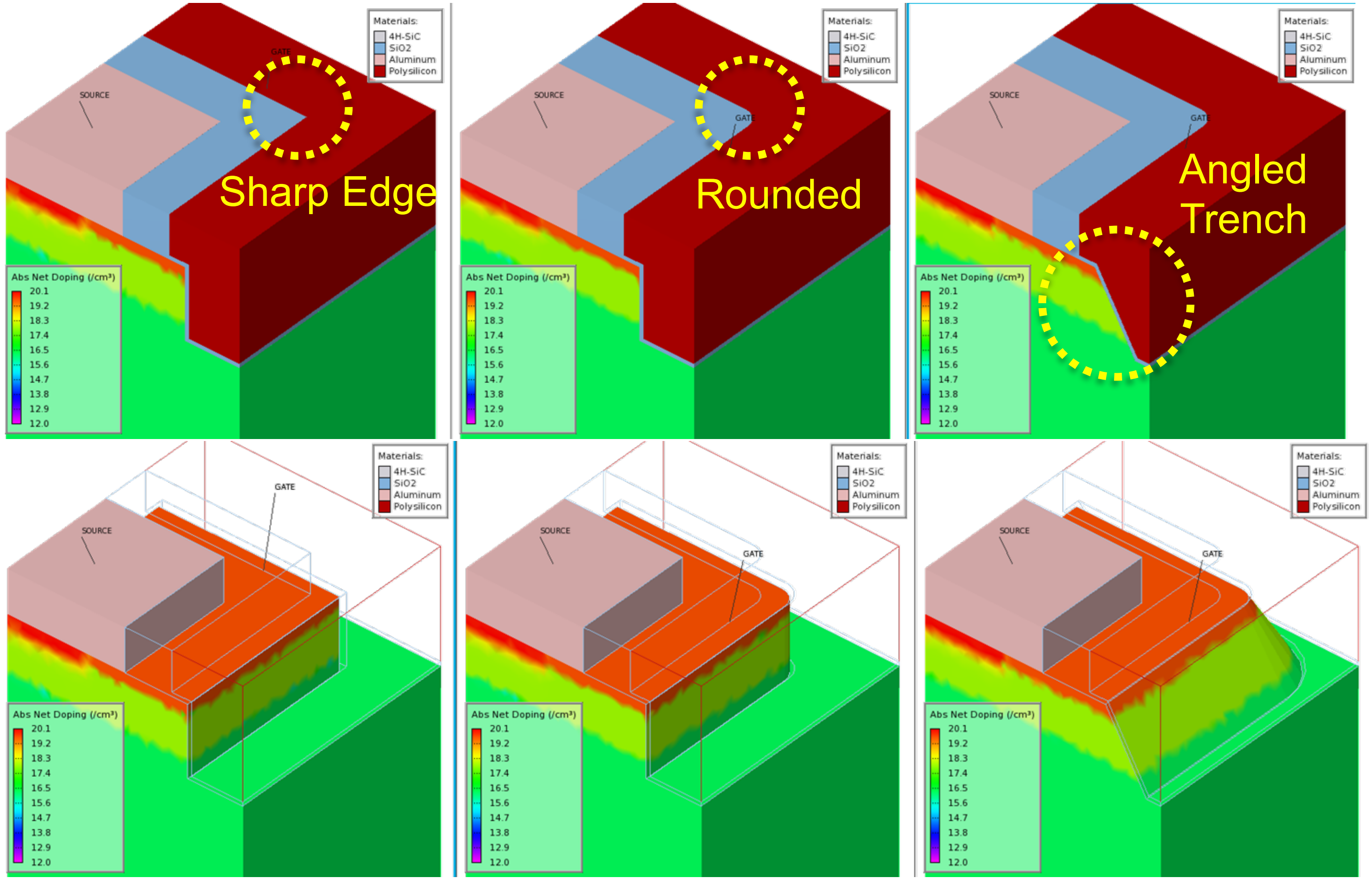
3D Design – Layout and Process Optimization

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

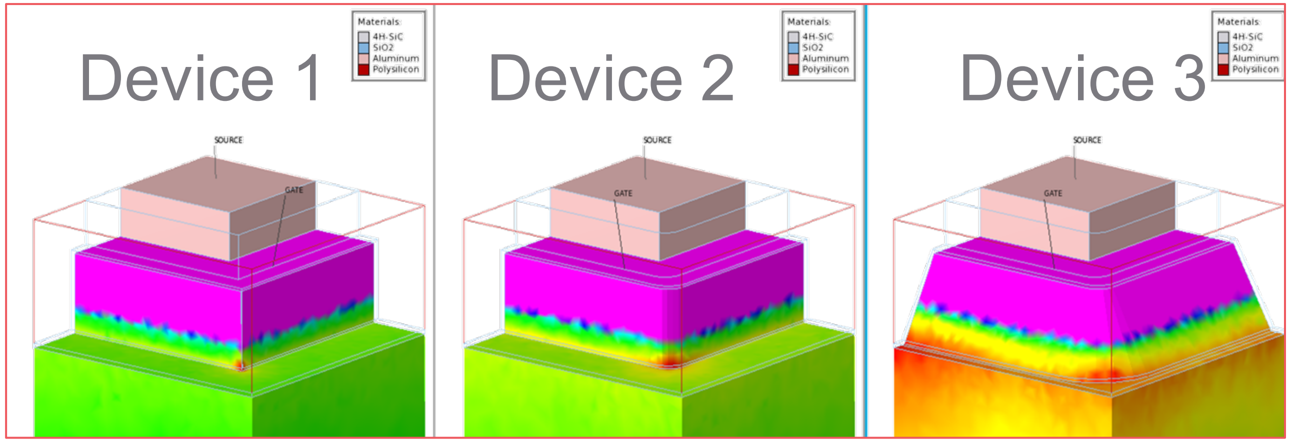


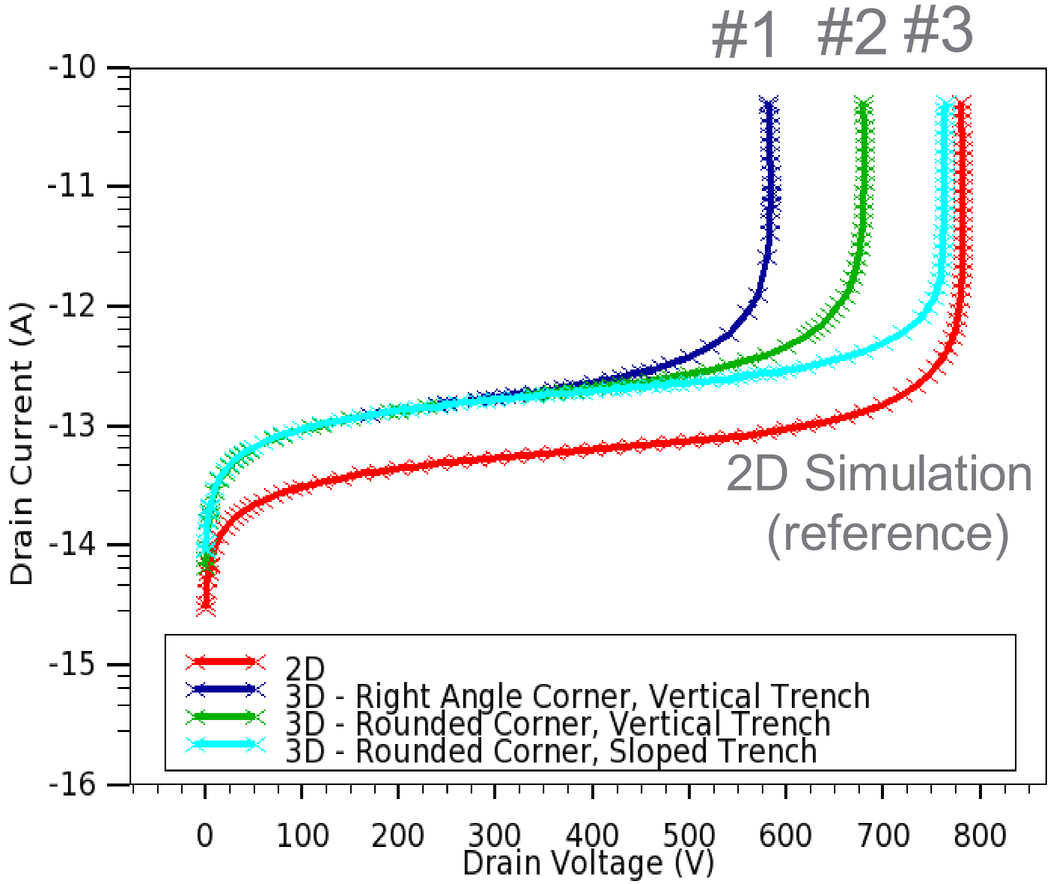
Device 1 Device 2 Device 3

3D Trench Shape Effect on Breakdown Voltage

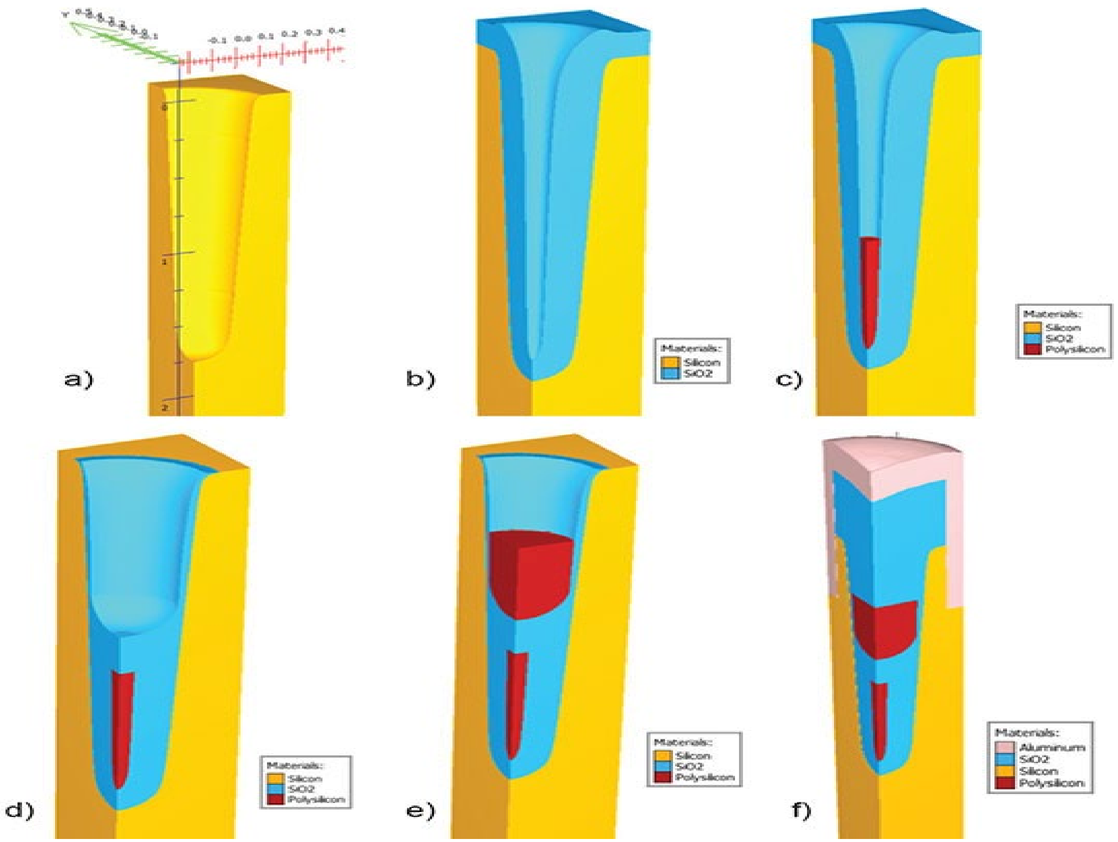
Trench Shape Effects

- 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



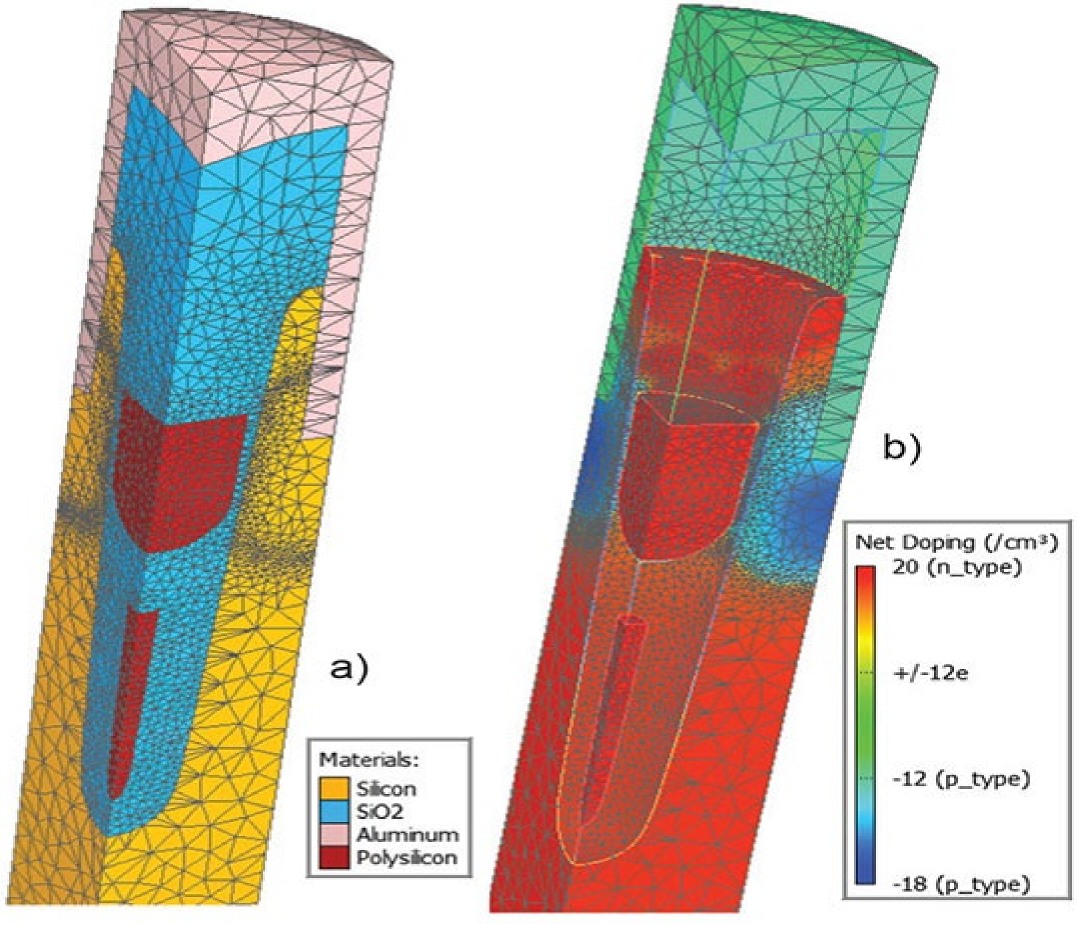


Split-Gate Trench UMOSFET



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

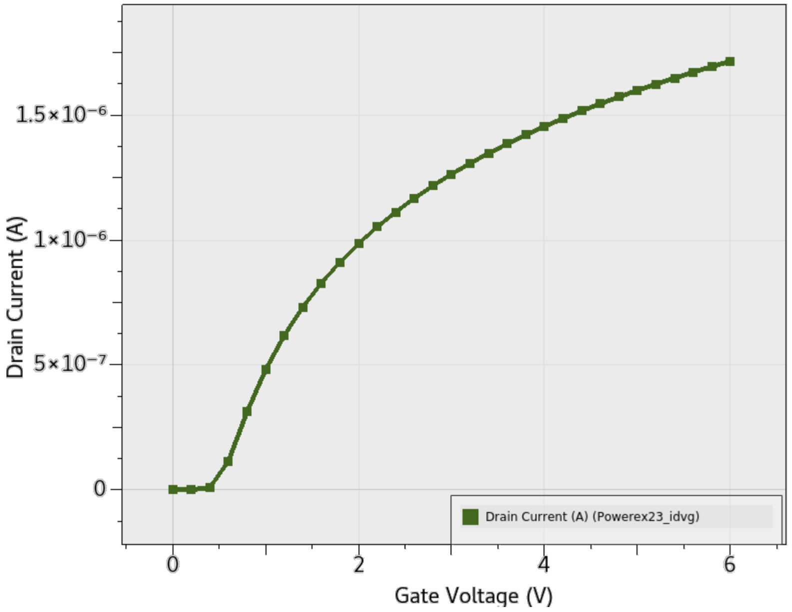
Delaunay mesh to resolve complex 3D geometry features (a) and doping profiles (b)



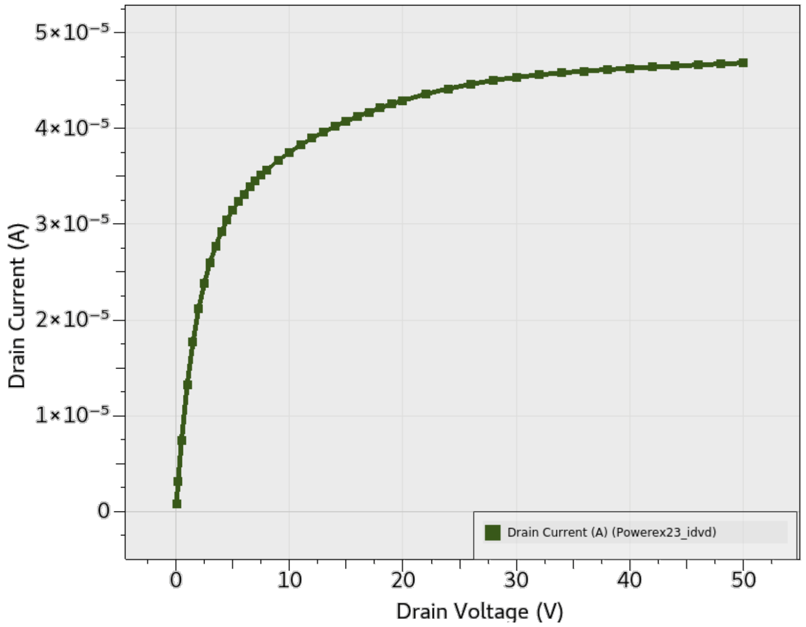
Split-Gate Trench UMOSFET

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

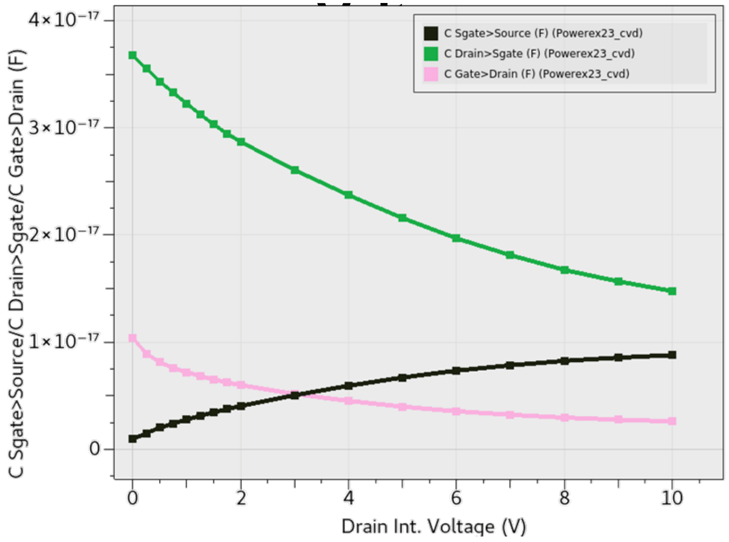
IdVg



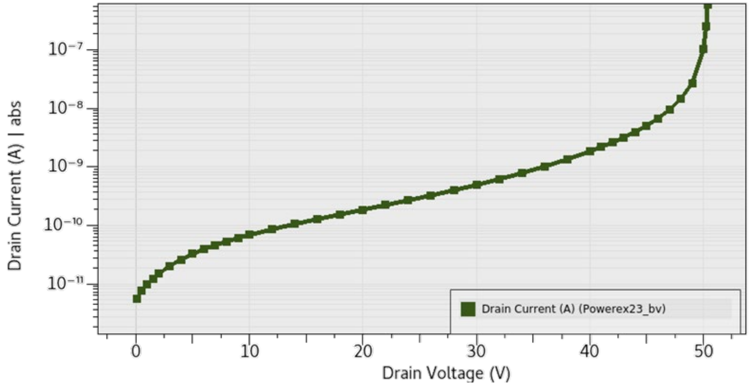
IdVd



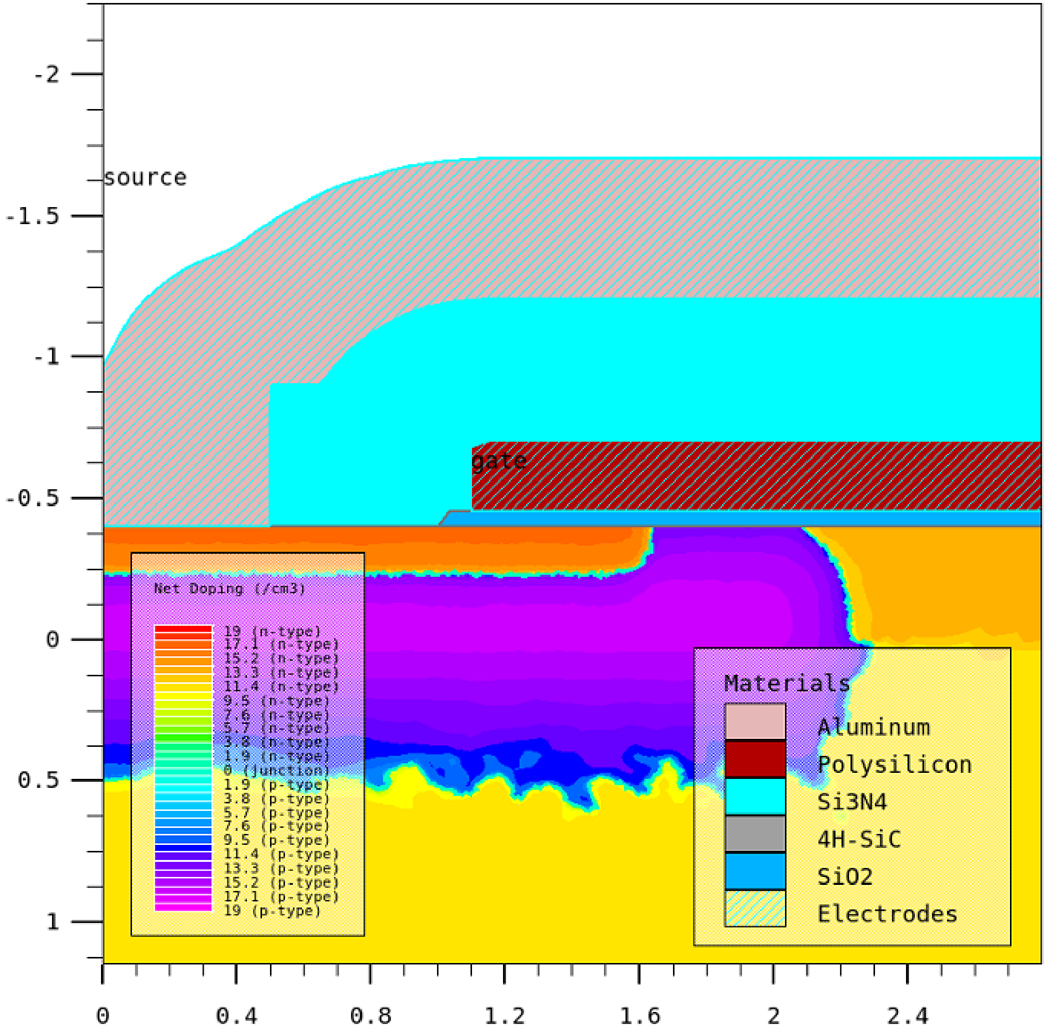
Capacitances vs Drain



Breakdown



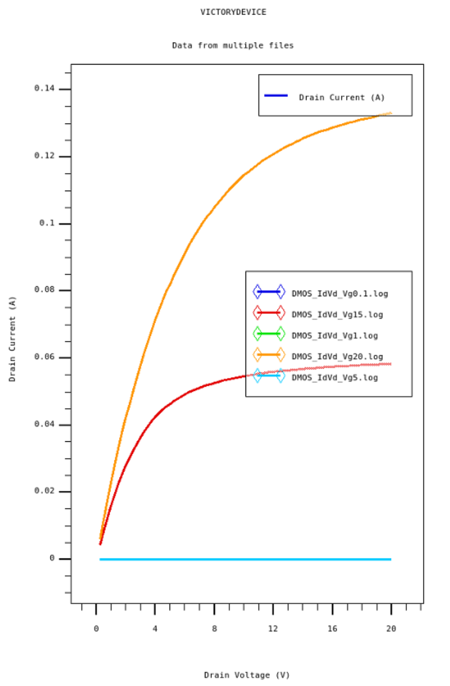
Silicon Carbide DMOS Process & Device

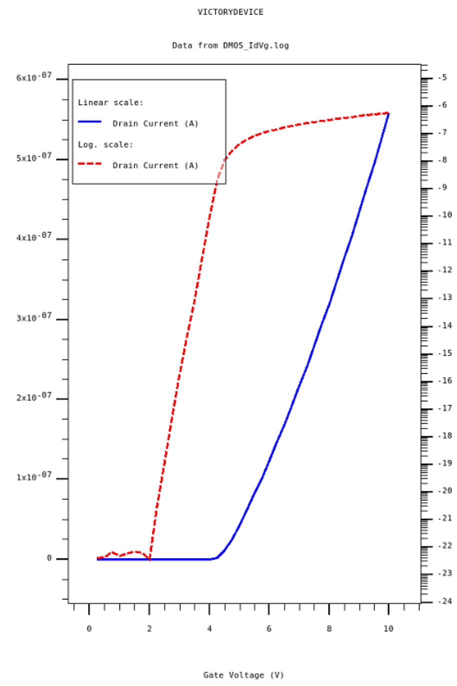


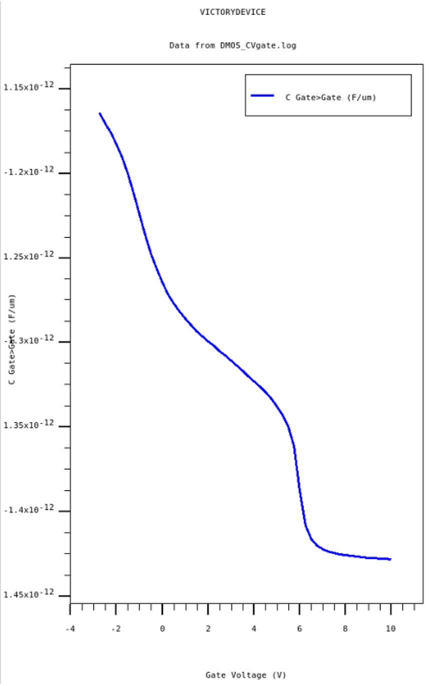
Full Process Simulation to Device Simulation

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"





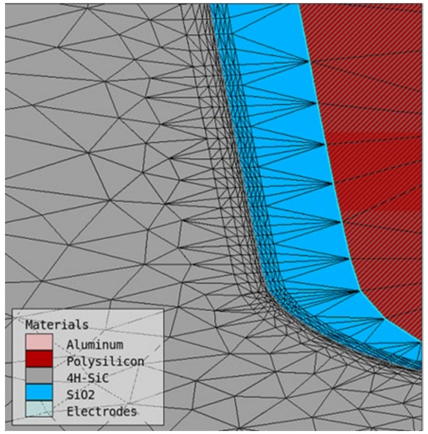


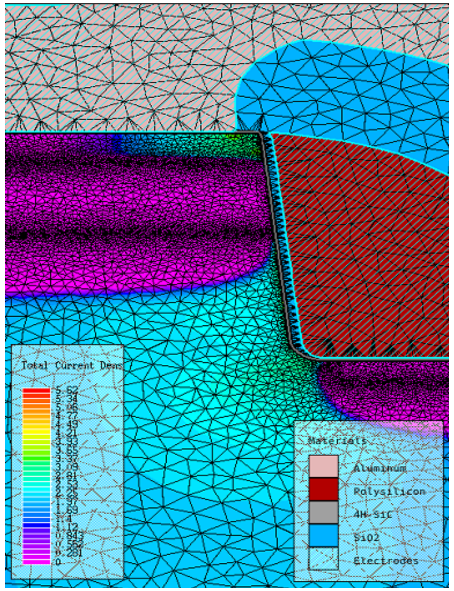
SiC Trench MOSFET Process & Device

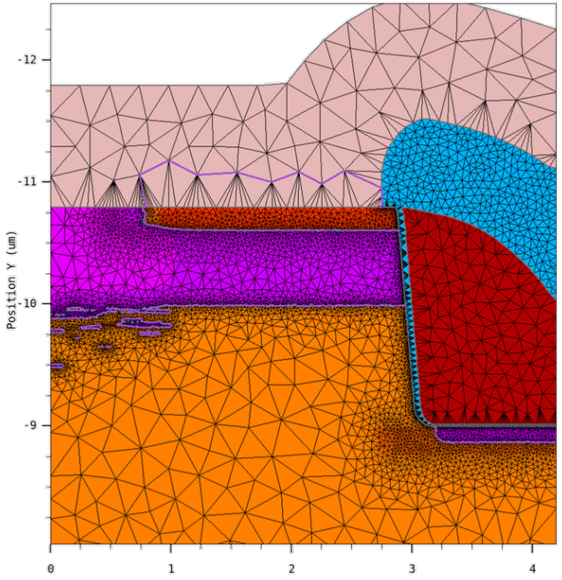
Full Process Simulation to Device Simulation

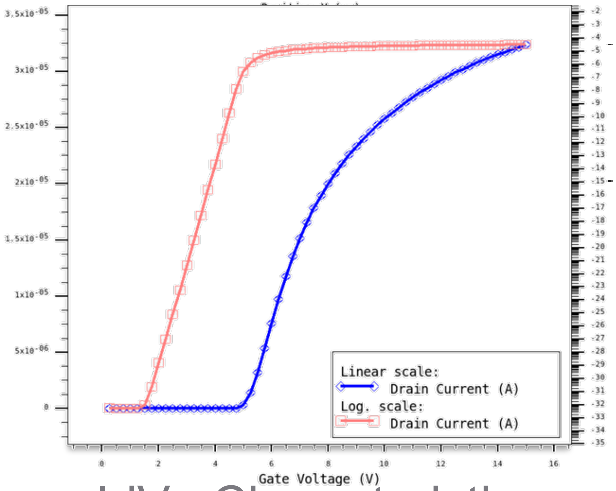
OFFSET statement used in Victory Mesh

- 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

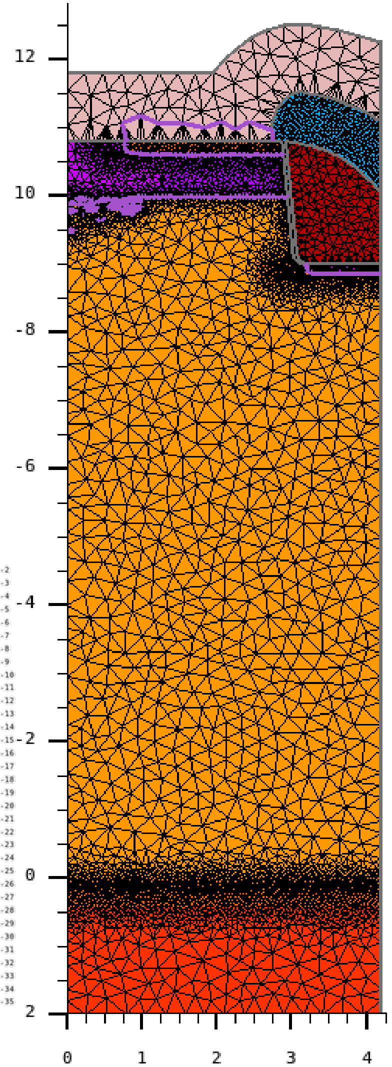






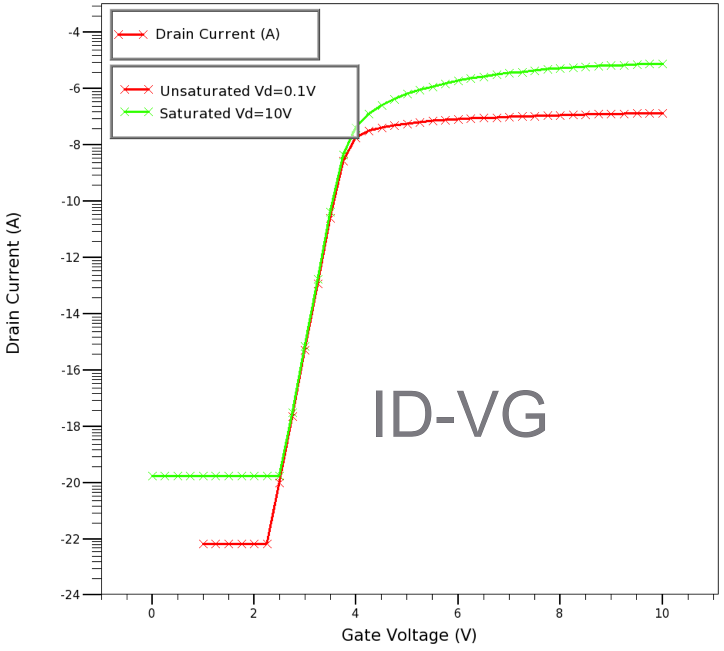


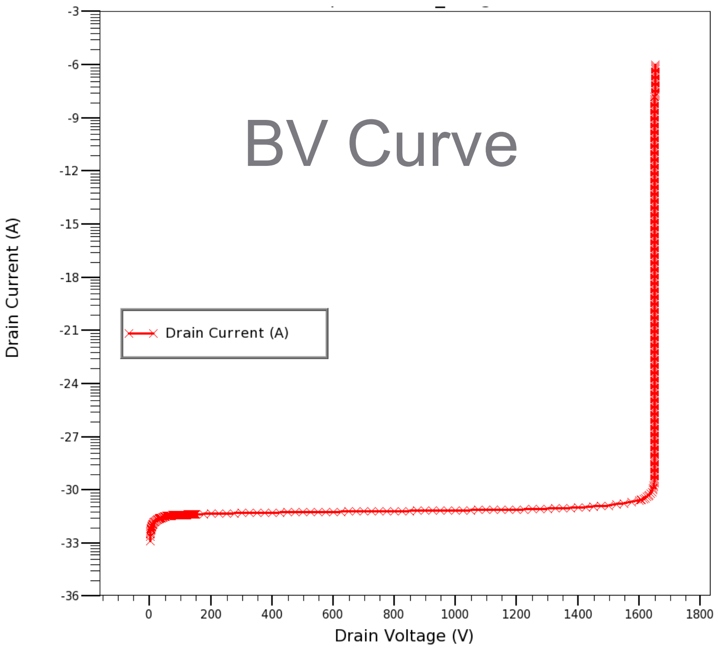
IdVg Characteristics

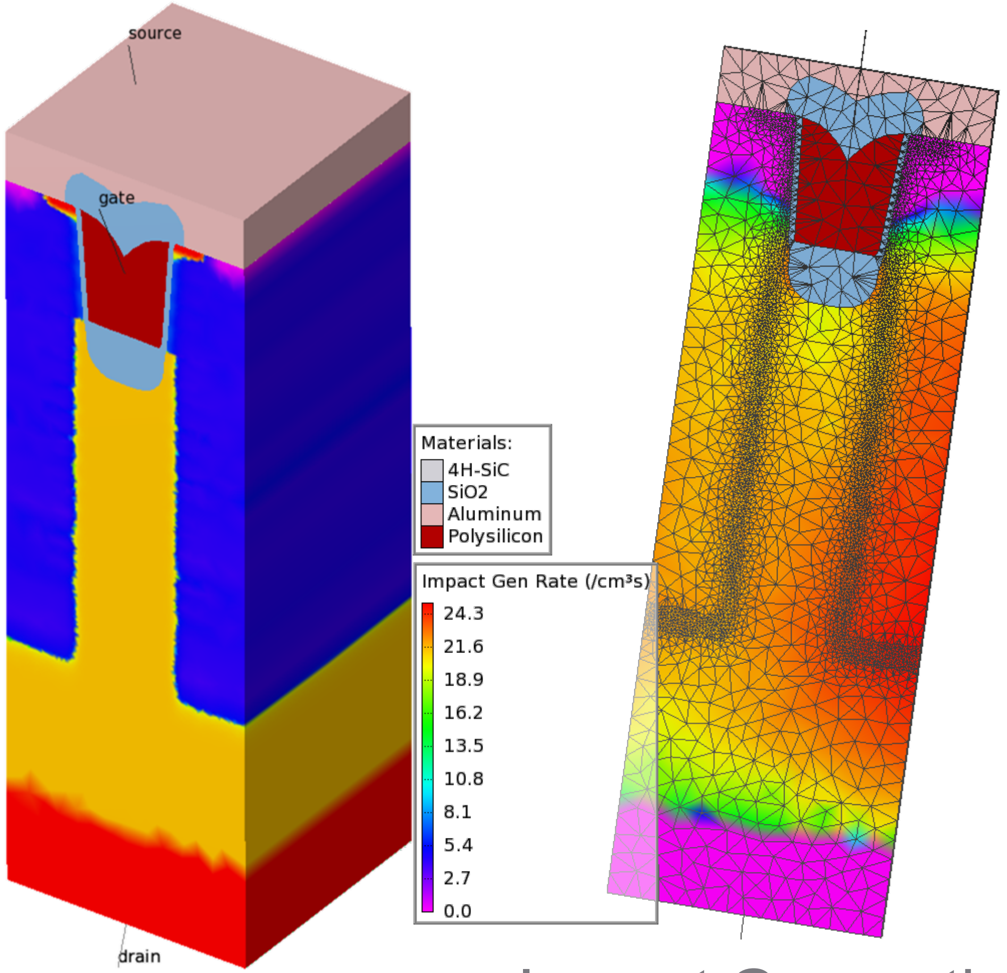


SiC Super-Junction Device

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







Net Doping

Impact Generation

Summary

Multiscale flow

Automated flow from process to circuit design.
Multiphysics is essential for mature technology design.

Design Space Exploration

TCAD & EDA tools are essential for optimizing technology performance.
Increasing complexity requires advanced numerical methods.

Ramping up R&D

Design software provides insight.
Generate deep understanding of technology potential.
Safeguard company knowledge and IP.

Multiscale – It’s a matter of survival

Multiscale + time – It’s the closest thing we have to a crystal ball!

Eddard Stark by Amok©

The Strategist

The tactician

Robb Stark by Magali Villeneuve ©

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

SiC
- DMOS
- TrenchMOS
- JBS

Silicon
- BCD
- Power Diode
- Thyristor
- IGBT

GaN
- Lateral HEMT
- Vertical HEMT
- P-GaN Gate HEMT