Avant! . . . Solutions & Products

> Sea
> Site
> Con
> Hor

- SYSTEMS PRODUCTS
- LOGICAL PRODUCTS
- PHYSICAL IMPLEMENTATION
- SIMULATION AND ANALYSIS
- LIBRARIES
- **TCAD**
  - Aurora
  - DFM WorkBench
  - Davinci
  - Medici
  - Raphael
  - Raphael-NES
  - Silicon Early Access
  - **TSUPREM-4**
  - Taurus-Device
  - Taurus-Lithography
  - Taurus-OPC
  - Taurus-Process
  - Taurus-Topography
  - Taurus-Visual
  - Taurus-WorkBench

TSUPREM-4

Semiconductor Process Simulation Software

TSUPREM-4 is the industry-standard 1D/2D process simulation tool that is widely used by semiconductor companies to optimize IC fabrication processes. With the most advanced mode commercially available, TSUPREM-4 simulates the physical effects (e.g. transient enhanced diffusion and stress-dependent oxidation) found in leading-edge semiconductor processing. Th result is the generation of precise device structures that allow inexpensive what-if experiments through simulation, minimizing the need for processing test wafers. Thus, TSUPREM-4 can hel optimize device geometry to reduce product development cycles and shorten product time to market.

TSUPREM-4 helps you:

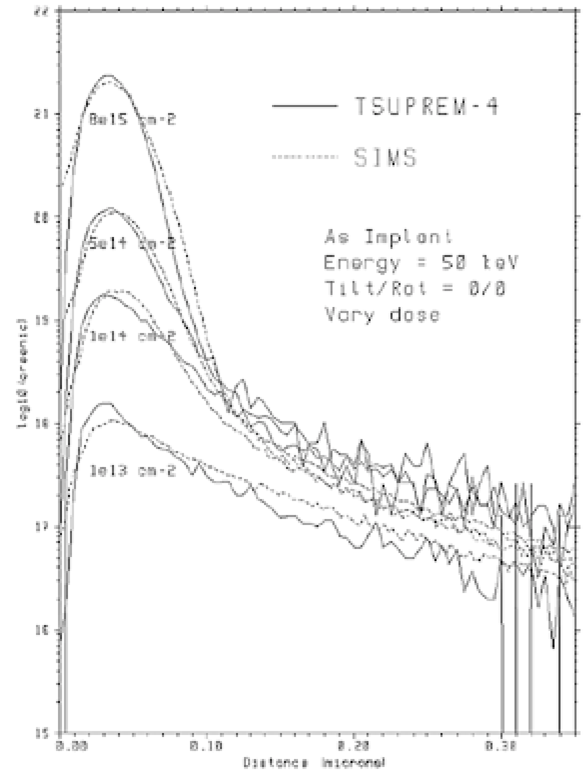
- Design leading-edge MOS and bipolar manufacturing processes and devices.
- Predict one- and two-dimensional device structure characteristics by accurately simulatir ion implantation, diffusion, oxidation, silicidation, epitaxy, etching, deposition and photore processing.
- Evaluate and refine novel isolation technologies, such as LOCOS, SWAMI, deep trench shallow trench isolation (STI).
- Investigate ion implantation processes, including the effects of arbitrary wafer tilt and rot on dose, implant depth, shadowing, damage and ion channeling.
- Study impurity diffusion, including transient enhanced diffusion (TED), oxidation-enhance diffusion (OED), interstitial clustering and trapping of dopants at interface (dose-loss). Analyze stresses in all layers as a result of non-uniform oxidation, thermal mismatch, etc or deposition.
- Determine basic device electrical characteristics, such as sheet resistance, threshold vo and C-V curve (including quantum-mechanical correction).
- Create process structures for two- and three-dimensional device analysis using Avant!'s Medici™, Davinci™ and Taurus-Device™.

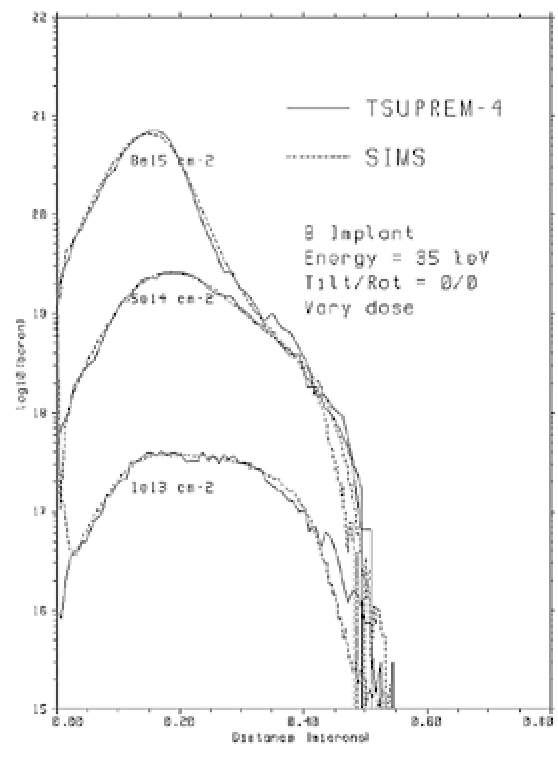
DEEP SUBMICRON (DSM) DEVICE SIMULATION

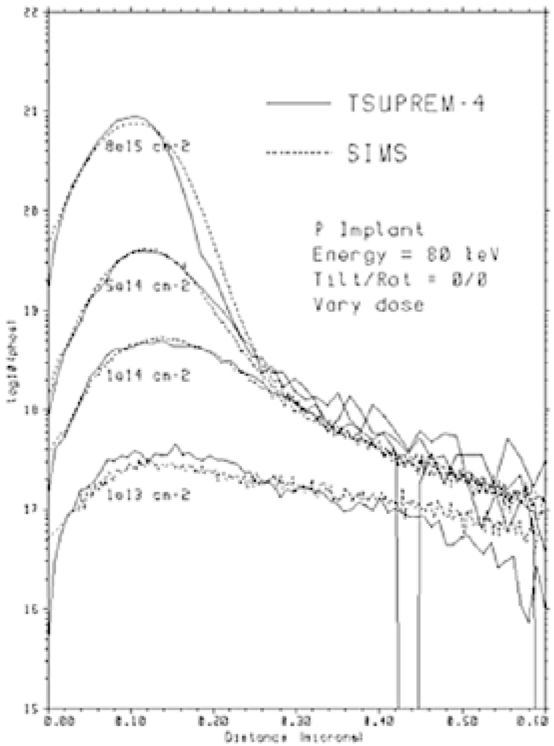
Simulating sub-quarter-micron devices requires the most advanced modeling capabilities. Fron source/drain junction formation to isolation (e.g. STI), TSUPREM-4's physics-based models produce excellent prediction of the final device geometry and impurity profiles.

Tables of ion implantation coefficients derived from thousands of measurements and the Monte Carlo model give accurate implanted impurity profiles. And state-of-the-art diffusion models, including the interactions among dopant atoms, point defects, and dopant/defect pairs, are important to simulate the phenomena that give rise to reverse short-channel effect (RSCE) and dose loss (interface trapping in RTA) found in deep submicron devices. A calibrated stress-dependent oxidation model generates the precise shape of LOCOS oxidation and perfor stress calculations to identify high stress process steps.

TSUPREM-4 provides essential information for optimizing process conditions to refine device structure designs and electrical characteristics (with Medici, Davinci or Taurus-Device).


TSUPREM-4
SIMS
8e15 cm-2
5e14 cm-2
1e14 cm-2
1e13 cm-2
As Implant
Energy = 50 keV
Tilt/Rot = 0/0
Vary dose
Distance (microns)


TSUPREM-4
SIMS
8e15 cm-2
5e14 cm-2
1e13 cm-2
B Implant
Energy = 35 keV
Tilt/Rot = 0/0
Vary dose
Distance (microns)


TSUPREM-4
SIMS
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1e14 cm-2
1e13 cm-2
P Implant
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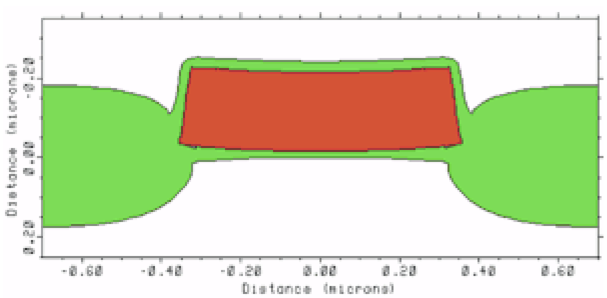
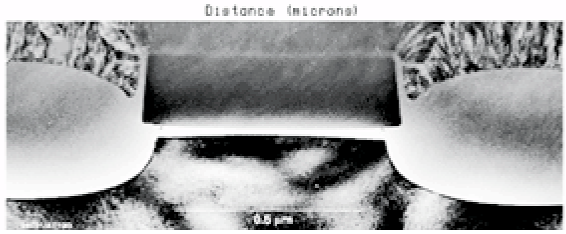
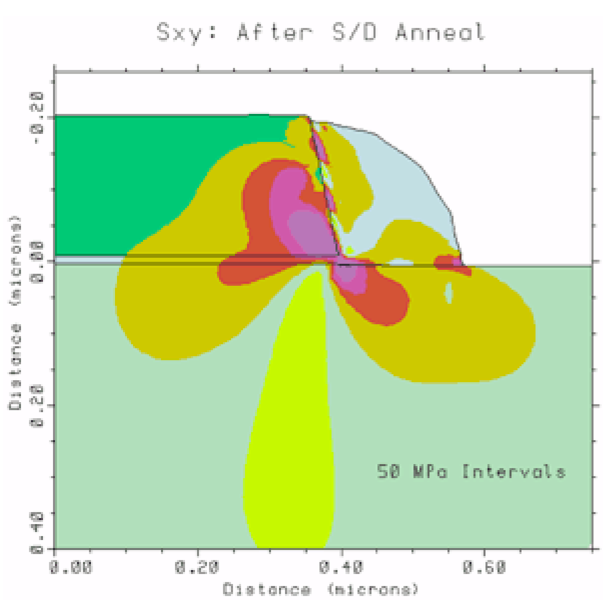
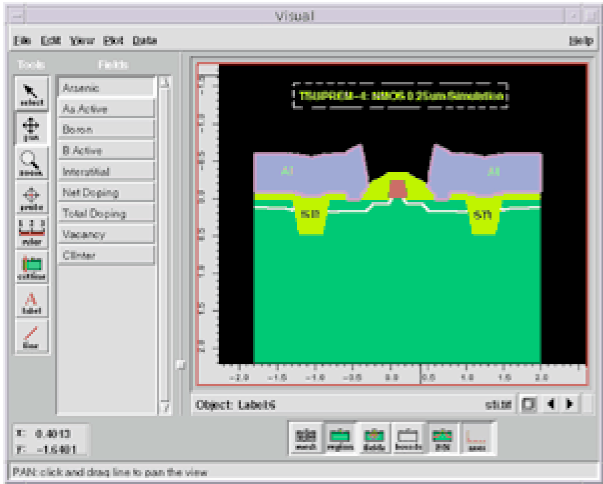
Tilt/Rot = 0/0
Vary dose
Distance (microns)


Distance (microns)
Distance (microns)

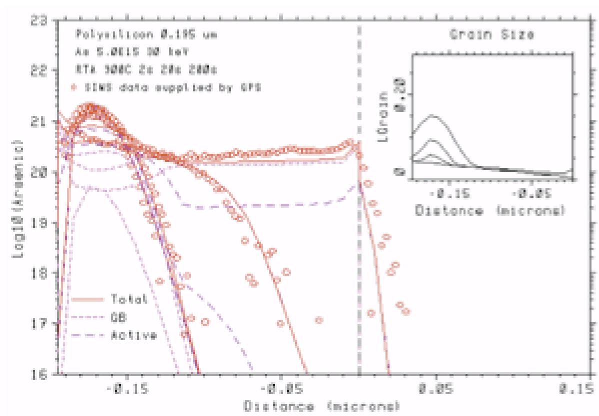



Sxy: After S/D Anneal
50 MPa Intervals
Distance (microns)
Distance (microns)

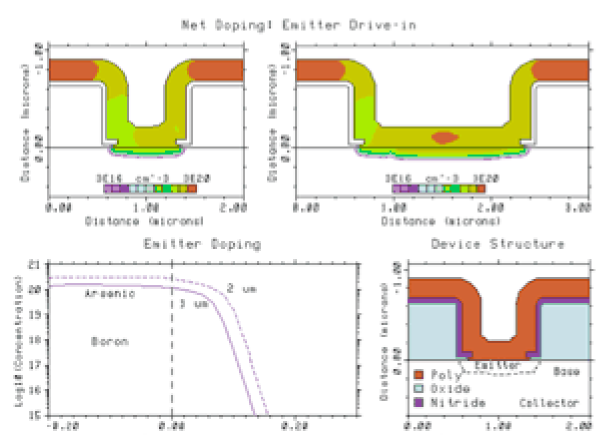


POLY-EMITTER BIPOLAR DEVICE SIMULATION

Polysilicon diffusion is a complicated phenomenon to model in the simulation of advanced poly-emitter bipolar devices. TSUPREM-4 uses a comprehensive poly-diffusion model to simul the diffusion of dopant through grain interiors and along grain boundaries, as well as dopant segregation between grain interiors and boundaries. Also, the poly-diffusion model includes the simulation of dopant pile-up, diffusion along material interfaces, anisotropic diffusion due to columnar grain orientation in two dimensions, concentration-dependent grain growth with segregation drag effects, and polysilicon/silicon interface break-up and epitaxial regrowth of polysilicon. TSUPREM-4 can model this complex polysilicon diffusion process by simulating the inter-dependencies of arsenic activation on polysilicon grain size and polysilicon grain growth o arsenic concentration. The result is accurate simulation of poly-emitter bipolar devices, includin effects of emitter width on the final junction.



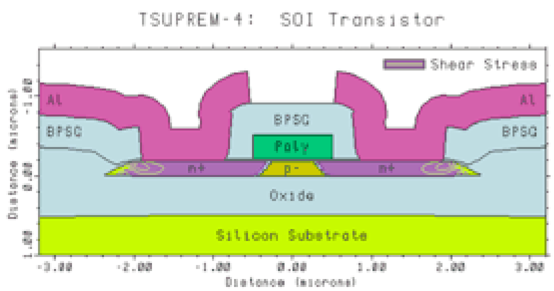
TSUPREM-4's comprehensive modeling of polysilicon diffusion.



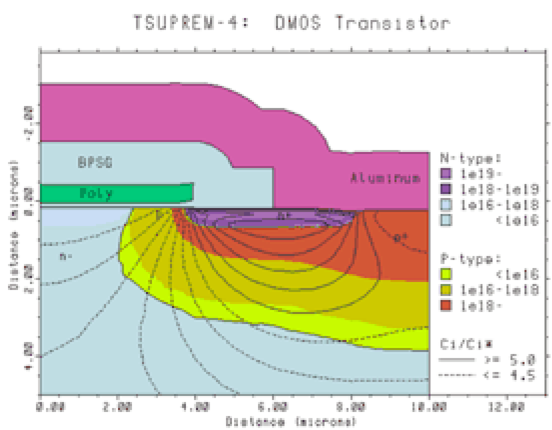
Emitter junction dependency on emitter width.

OTHER APPLICATIONS

Because of its flexibility and technology independence, TSUPREM-4 is applicable to a variety o silicon structures. For example, these figures show simulations of SOI and DMOS devices. The simulation involves local oxidation completely through the surface silicon film. As indicated by tl yellow contours in the figure, the volume expansion during the oxidation causes severe stress a corners of the silicon island. TSUPREM-4 is also capable of simulating large power devices. Th plot of the DMOS simulation structure shows how interstitial/phosphorus pair diffusion in the hig concentration source/drain region injects excess interstitials into the underlying boron drift regic causing enhanced boron diffusion.



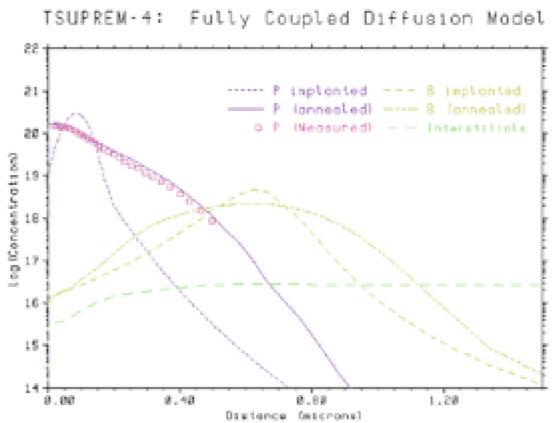
SOI simulation



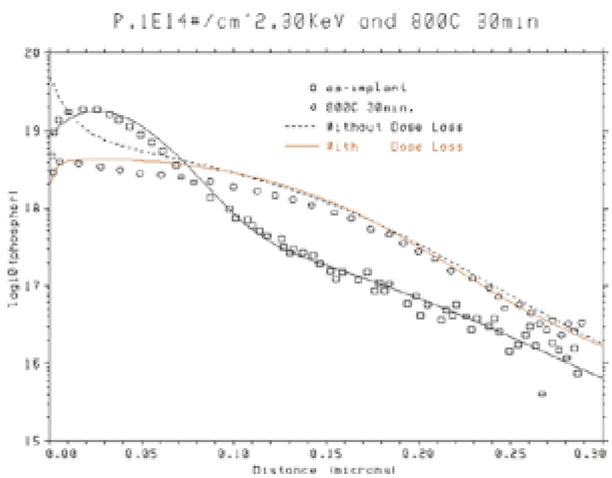
DMOS simulation

ADVANCED DIFFUSION MODELS

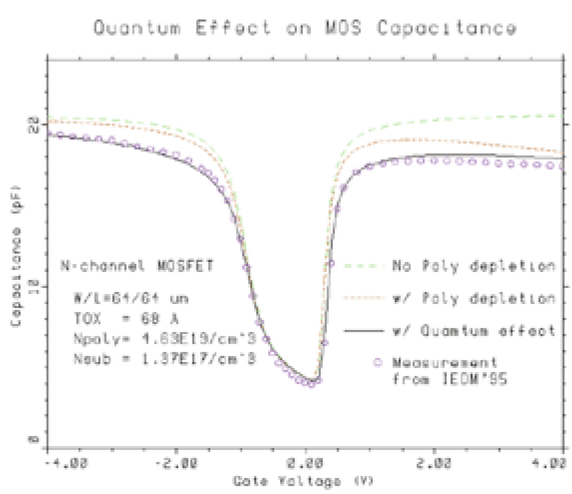
TSUPREM-4 contains the most advanced and robust diffusion models commercially available. example, accurate modeling of advanced semiconductor processing involving RTA requires ful coupled point defect diffusion and interface trap charge models to capture the underlying physic transient enhanced diffusion (TED) and dose loss, respectively. Comprehensive model validatic done through joint development with industry partners, such as Philips Research Labs, IBM, etc This example shows a high dose phosphorus implant into a wafer containing a deeper, lower concentration boron profile. After a 30-minute anneal at 920 degrees C, the phosphorus has diffused via phosphorus/interstitial pairs. The diffusion of these pairs carries interstitials into the substrate where they cause enhanced diffusion of the boron profile as well as of the phosphoru tail. The advanced diffusion models available in TSUPREM-4, which take into account the dopa defect and dopant/defect pair interactions during thermal anneal, make it possible to accurately simulate shallow-junction processes. This example shows the modeling of dose-loss using the interface trap model in TSUPREM-4.



Fully coupled diggusion model showing impurity and interstitial profiles before and after anneal.



Interface trap model accounts for dose-loss after low-temperature anneal.



C-V curve with and without Q-M correction

ELECTRICAL CALCULATIONS

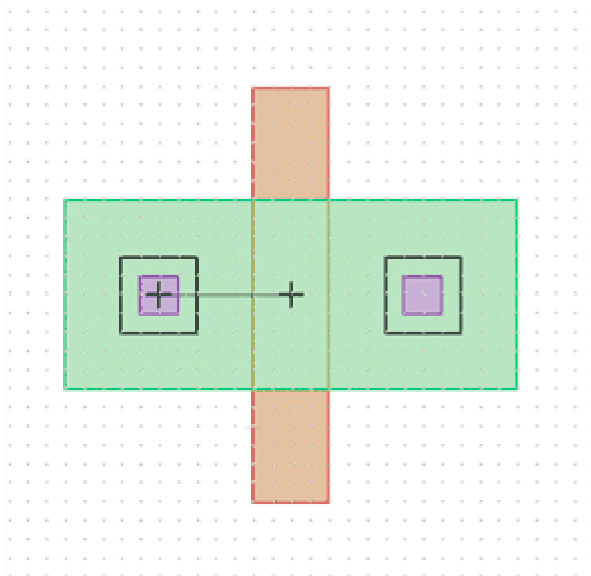
TSUPREM-4 includes a utility that allows electrical calculations such as sheet resistance, thres voltage and C-V, making it very convenient to quickly evaluate the impact of process conditions basic device performance. To account for the quantum-mechanical effects associated with the gate oxide used in deep submicron devices, TSUPREM-4 models the effective band-gap wider for MOS inversion layers. The bottom figure shows a C-V plot simulated with and without the quantum-mechanical effect in TSUPREM-4.

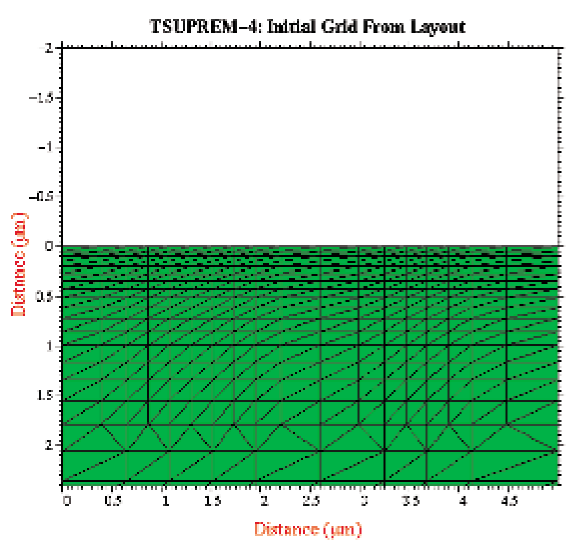
ADVANCED MESHING CAPABILITIES

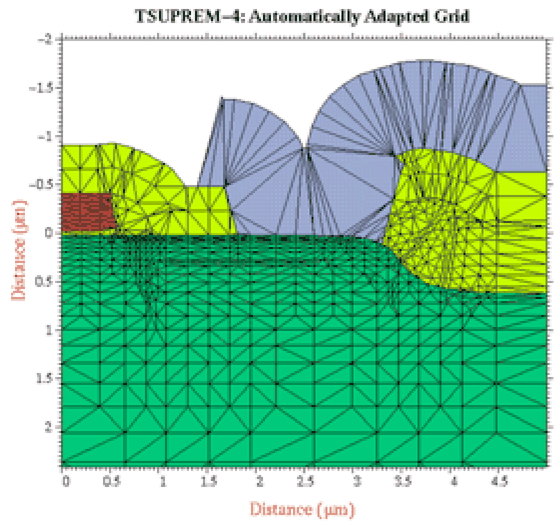
TSUPREM-4 simplifies process simulation by automating the mesh-generation process. Most simulations can use an automatically generated initial mesh. All the user needs to specify is the width of the simulation region, and even that is not required when mask information from Taurus-Layout is used.

The mask layout link provides the capability to examine a two-dimensional mask layout descrip (in GDSII format) and select cross sections for simulation with TSUPREM-4. With the mask information, TSUPREM-4 automatically generates an initial mesh, placing finer grid spacing nea mask edges and eliminating unnecessary grid points along the depth of the structure. Using the Avant! proprietary adaptive meshing algorithms, TSUPREM-4 continuously monitors and refine mesh during the simulation (implant, oxidation and diffusion steps) to ensure that the accuracy the spatial discretization is maintained. Adaptive meshing not only eliminates the time required hand-craft a suitable grid, but it also reduces simulation time by not adding grid points until they needed.

This example shows the final simulation grid that has been refined (from the initial grid) in respo to the needs of the process. Note the fine grids TSUPREM-4 places near the edges of the source/drain junction to resolve the LDD extension.







TSUPREM-4 SPECIFICATIONS

SIMULATION FEATURES

- One- and two-dimensional simulation of arbitrary semiconductor structures.
- Simulates all common materials and impurities, plus user-defined materials, impurities a reactions.
- Advanced models for diffusion, oxidation, silicidation, epitaxial growth, ion implantation a reflow.
- Basic models for deposition, etching and photolithography.
- Printing and plotting of structures, doping profiles, stresses and electrical characteristics
- Automatic grid generation and adaptive refinement; simple control of grid density and simulation accuracy.

MODELS

- Diffusion
  - Physically based dopant/defect pair model.
  - Oxidation enhancement and retardation.
  - High-concentration and coupled-impurity effects.
  - Transient enhancement effects.
  - Generation, diffusion and recombination of point defects.
  - Dopant-assisted recombination of point defects.
  - Saturation of dopant/defect pair concentrations.
  - Interstitial clustering (formation and dissolution of {311} defects).
  - Interface dopant pile-up (dose-loss) during low- temperature transient diffusion.
  - Dopant diffusion through polysilicon with dependence on grain size and boundary
  - Dislocation loops.

- Implantation
  - Gaussian, Pearson and dual-Pearson analytic models.
  - Dual-Pearson model for energy, dose, tilt and rotation effects.
  - Shadowing effects due to wafer tilt and rotation.
  - Choice of models for multilayer targets.
  - Implant damage model.
  - Physically based Monte Carlo model includes channeling, amorphization, tempera dependence, damage self-annealing, substrate orientation and tilt/rotation effects

- Oxidation
  - Two-dimensional stress-dependent visco-elastic and viscous flow model.
  - Concentration-dependent oxidation rates.
  - Thin-oxide enhancement.

  - Gas partial pressures calculated from flow rates.
  - User-defined ambients.
  - Effect of HCl on oxidation rates.

- Silicidation
  - Deposition and growth of titanium and tungsten silicides.
  - User-defined models for other silicides.

- Deposition and etching.
- Conformal deposition.
- Epitaxial growth, with impurity diffusion.
- Dry etching with masked undercutting and angled sidewalls.
- Isotropic etching.
- Etching of arbitrary regions.
- Exposure and development of photoresist.
- Advanced deposition and etching through the
- Taurus-Topography interface.

EASE OF USE

- Automatic or manual generation of simulation grid.
- Automatic adaptive refinement of simulation grid.
- Single-parameter controls for grid density and accuracy.
- Interactive or batch mode operation.
- Fast 1D simulation of 1D structures, with automatic conversion to 2D mode when neede
- Command language allows parameterization of simulation input, repetition of process st and hierarchical definition of subprocesses in separate input files.

INPUT/OUTPUT

- Printing and plotting of impurity and point defect concentrations, stresses and flow rates along one-dimensional cross sections.
- Saving and loading of structures and solution values for later examination or continued simulation.
- Interactive viewing with Taurus-Visual.
- Saving of structures and doping information for use by Medici, Davinci, Taurus-Device o MINIMOS 5.
- Mask layout information available from Taurus-Layout.
- Extensive graphics capabilities including support for all major graphics devices and remo network graphics.
- Contour and vector plots in two dimensions, and three-dimensional raised-surface plots.
- Extraction of concentrations, depths and locations at junctions, profile minima or maxima arbitrary points.
- Extraction of sheet resistance, junction capacitance, MOS capacitance and threshold voltage.
- Bidirectional interface with Taurus-Lithography for precise simulation of photolithography
- Bidirectional interface with Taurus-Topography for precise simulation of topography (e.g deposition, etch, CMP).
- Fully compatible with Taurus-WorkBench.

SYSTEM REQUIREMENTS

- Platforms: UNIX-based computers from Hewlett-Packard, IBM and Sun Microsystems.
- Memory: 5 to 32 Mbytes.
- Disk Space: 30 Mbytes (including on-line manual).
