CROSSLIGHT
Software Inc.

CSUPREM

Three dimensional process simulator for MEMS and IC devices

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Contents

About Crosslight Software Inc.

Crosslight Software Inc. (formerly Beamtek Software Inc.) is the leading supplier of semiconductor device and process simulation software. It is an international company established in 1993 with head office in Canada and branch offices and distribution/support centers in many countries around the world.

Crosslight Software is the world leader in providing commercial physical models of semiconductor optoelectronic/electronic devices and processes. Crosslight's customers include tens of major manufacturers of semiconductor electronic and optoelectronic components and systems. For more details, please visit us at www.crosslight.com.

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CSUPREM: 3D Process Simulator for MEMS and IC Devices

What is CSUPREM

CSUPREM (Crosslight-SUPREM) is a powerful and accurate three dimensional process simulation program for silicon and GaAs. It is based on the process simulation program code of SUPREM.IV.GS developed in Integrated Circuit Laboratory, Stanford University. SUPREM.IV.GS has been recognized as the industry standard in process simulation for the integrated circuit (IC) design for over a decade.

CSUPREM not only inherits the essential physical models in the original version from Stanford, but it also contains substantial enhancements and extensions. Most significantly, the entire mesh system has been redesigned and extended. An interface to Crosslight's Geo3d module enables CSUPREM to perform full 3D process simulation with very low computational cost.

CSUPREM is now extended to CSUPREM-3DMEMS. This option is specific to 3d process simulation of Mictro-Electro-Mechanical-Systems (MEMS). MEMS fabrication requires accurate simulation of geometry and material behavior. Process simulation and analysis of MEMS is a challenge. MEMS structures are geometrically more complicated than those in IC electronic devices. They are electro-mechanically coupled and require multi-domain physics (optical, electrical, mechanical, and micro-fluidics). CSUPREM can be used as a "black-box" geometric/physic-based process simulator for 3d MEMS. CSUPREM accurately predicts all the processing steps and generates accurate geometry suitable for simulating 3d MEMS operations.

As a result of innovative and effective software module interfacing, Crosslight is able to offer the fully supported process simulator at affordable prices. Effective and affordable CAD tools are increasingly important in controlling the explosive cost of the development and optimization of MEMS and IC fabrication steps.

An additional benefit of using CSUPREM is that it provides input/output data interface with other well established simulators of Crosslight such as APSYS/Quantum-MOS and PROCOM. Proper doping profile is known to determine the accuracy of any device simulation. An accurate and optimized geometry is the building block in simulating and predicting 3d MEMS operations.

Applications

CSUPREM may be used to model most processes in silicon and GaAs fabrication technologies. These processes include mainly ion implantation, diffusion, oxidation and annealing. CSUPREM is being extended to include strained silicon and GaN-based material systems.

CSUPREM-3DMEMS is specialized in 3d MEMS process simulation. Its features are based on improved and accurate selective etching, conformal deposition with rounded corners, domain decompisition-based 3d geometry modeling. The size of the 3d mesh generated using CSUPREM-3DMEMS is really small compared to other 3d mesh generators. This is due to our new domain decompistion-based concept for geometry modeling. Different MEMS structures can be simulated: Radio Frequency (RF) switches, Electrometers, Polysilicon MEMS, SOI MEMS, and more.

CSUPREM is designed to interface with other programs (such as Crosslight's APSYS). The output data may be stored in well-documented ASCII format so that it may be imported to any other device simulation software (commercial or educational).

Capabilites

CSUPREM is a state-of-art 1D, 2D and 3D process simulator for MEMS and IC devices. It may simulate conformal deposition, anisotropic and sacrificial etching, ion implantation, annealing, oxidation, and diffusion.

CSUPREM mesh structure is designed to handle accurately moving boundaries which occur during oxidation, deposition, or etching of thin films. It models the multidimensional effects, the volume expansion and the stress gradient produced by overlying films.

Ion implantation

Physical models:
Two different type of analytical models are available: Gauss distribution, and Pearson IV distribution.

Available impurities:
antimony, arsenic, boron, bf2, cesium, phosphorus, beryllium, magnesium, selenium, silicon, tin, germanium, zinc, carbon, generic.

Damage models:
The damage due to the implant can be calculated. The data is from Hobler and Selberherr and exist only for antimony, arsenic, boron, and phosphorus.

Tilt model:
This model allows the user the specify the implantation angle

Anisotropic and sacrificial etching

Etching capability allows the user to easily specify the etch regions in different manners. The sacrificial etching feature used in MEMS process simulation has been improved to include different geometrical shapes.

The user can also supply an input file containing the coordinates associated with the etched surface. This file could be generated by a topography simulator.

Geometrical models:
Trapezoidal shapes, Arbitrary complex shapes, Dry etching capability, Anisotropic etching, and Selective etching.

Materials:
silicon, oxide, oxynitride, nitride, polysilicon, photoresist, aluminium, gallium-arsenide.

Deposition

The deposition capability is currently purely geometrical. It allows the user to specify the deposited material, its thickness, and its doping impurity in case of doped layers. In the near future, deposition results may be imported from Crosslight's PROCOM simulation software for MOCVD reactor.

Supported materials:
Silicon, oxide,oxynitride, nitride, polysilicon, photoresist, aluminium, gallium-arsenide.

Doping types:
none, antimony, arsenic, boron, phosphorus, beryllium, magnesium, selenium, silicon, tin, germanium, zinc, carbon, generic.

Import file:
The user can also supply an input file containing the coordinates associated with the deposit surface. This file could be generated by a topography simulator.

Diffusion

Dopant diffusion model is the heart of the CSUPREM simulator and takes up most of the computation time. It is based on the most advanced 3D physical models involving the following.

- Point-defect based diffusion models
- Paired and unpaired diffusion of point defects models
- Transient enhanced diffusion (TED) for damage and clustering
- Oxidation enhanced diffusion (OED)
- Oxidation retarded diffusion (ORD)
- Interface segregation models
- Clustering models for Arsenic activation
- Dislocation loops models
- Diffusion within poly-silicon, oxide, and oxide nitride layers.
- Capability of different diffusion coefficients for grown-in and as- implanted impurities.
- Activation models for all dopants

Oxidation

Oxidation models from simple to more advanced including stress effects on oxide growth rate and volume expansions are included. These models are based on Deal-Grove theory.

Analytical models:

- Error-function fit to bird's beak shapes model.
- Parameterized error-function model.

Numerical models:

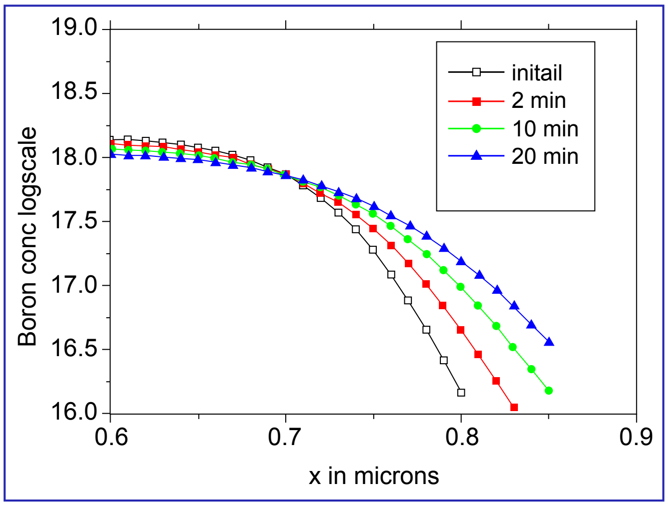
- Vertical model where oxidant diffuses and the oxide boundaries move vertically at the rate determined by the local oxidant concentration.
- A compressible viscous flow model accounting for volume expansion
- Non-linear viscous flow model including stress effects

Other capabilities:

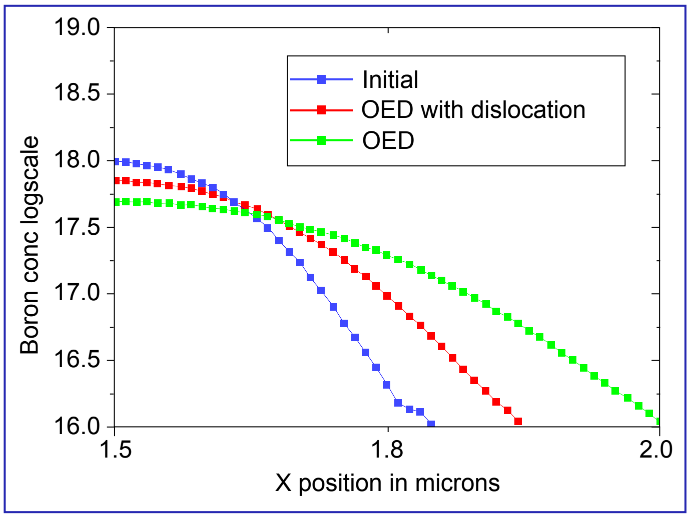
- Dry and wet oxidation capability
- Effects of HCl, orientation, doping level and pressure on oxidation rate.

Simulation Results

1D Results for advanced diffusion



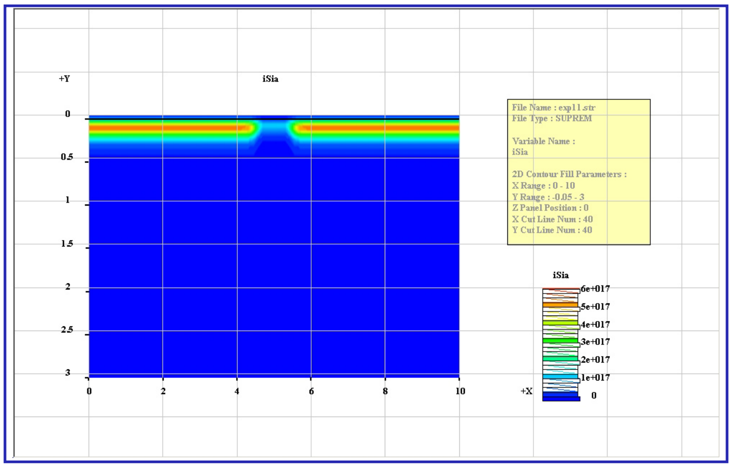
Interstitial cluster dissolution effect on boron diffusion.



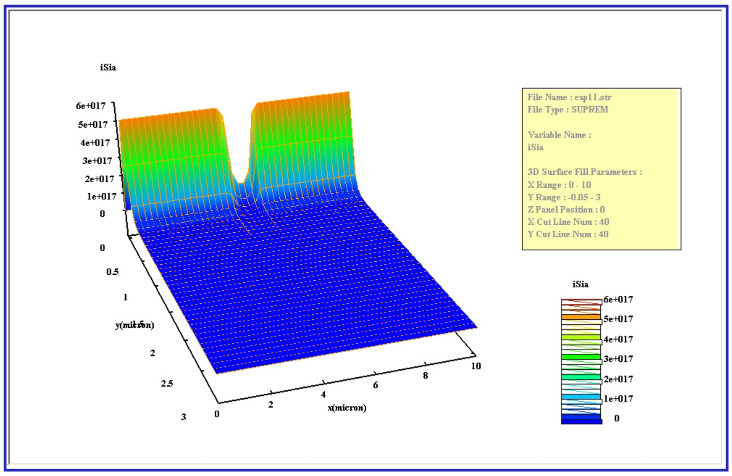
Diffusion in presence of dislocation loops.

2D Results for IC Semiconductor Devicesn

GaAs MESFET



Silicon active concentration.



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File Type : SUPREM

Variable Name :
iSia

3D Surface Fill Parameters :
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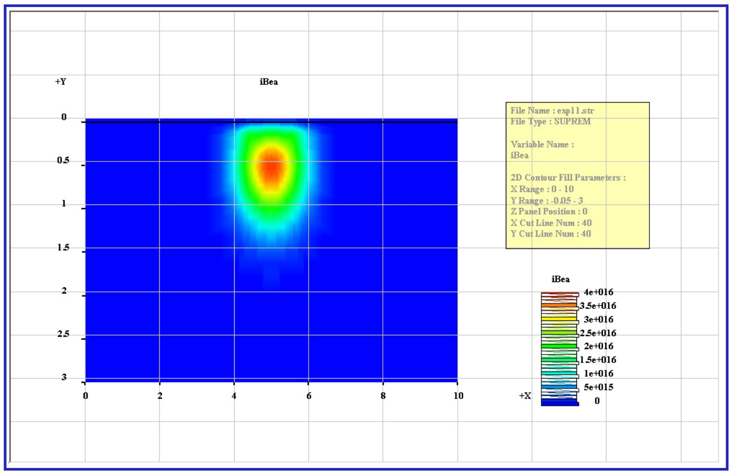
Y Range : -0.05 - 3
Z Panel Position : 0
X Cut Line Num : 40
Y Cut Line Num : 40

Silicon active concentration's surface fill.



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Variable Name :
iBea

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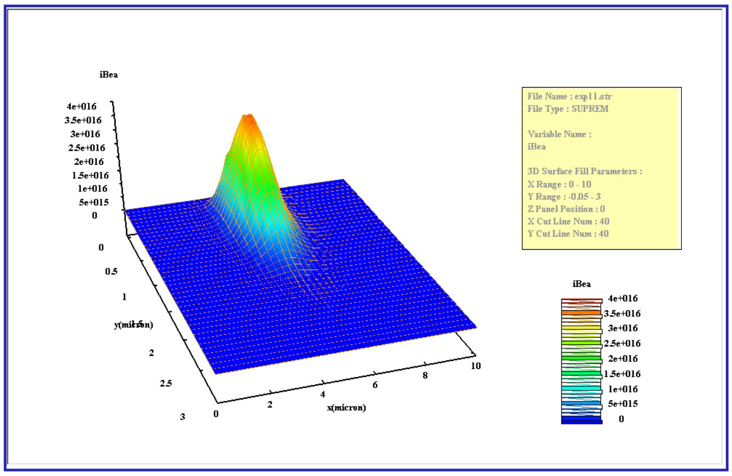
Beryllium active concentration.



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Variable Name :
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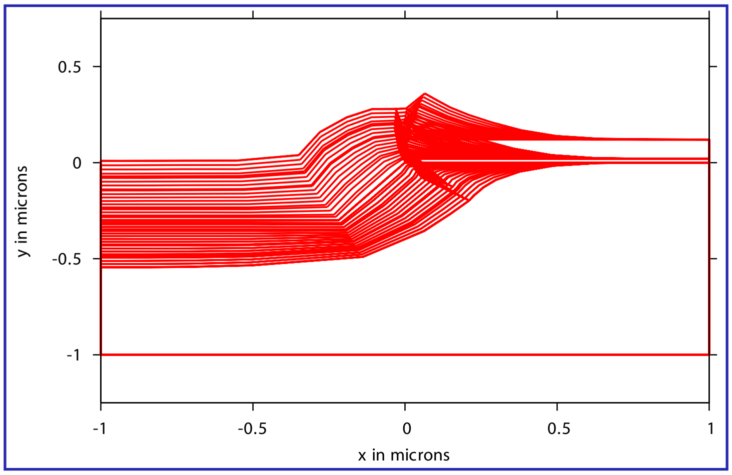
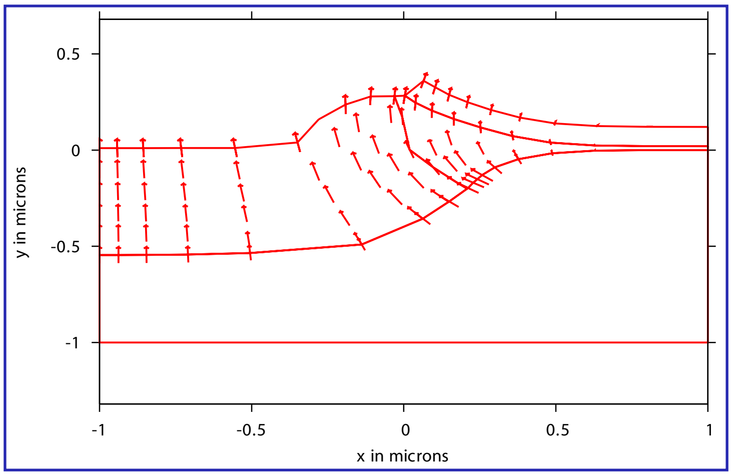
Beryllium active concentration's surface fill.

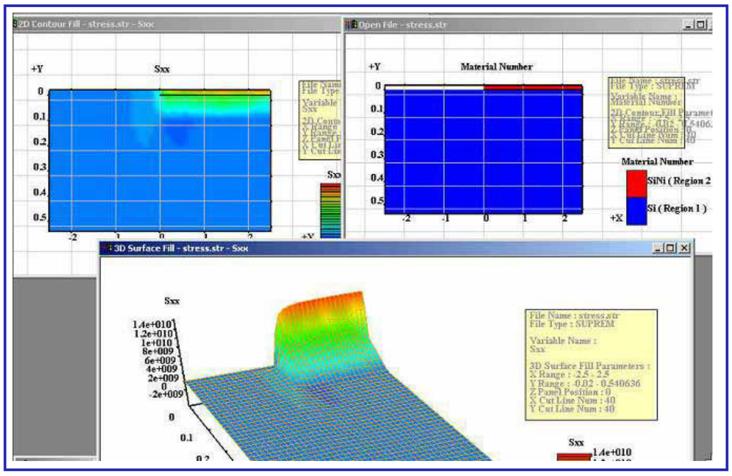
Stress effects on oxide growth



Evolution of bird's beak profile



Flow vectors at the end of oxidation.



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File Type : SUPREM

Variable Name :
Sxx

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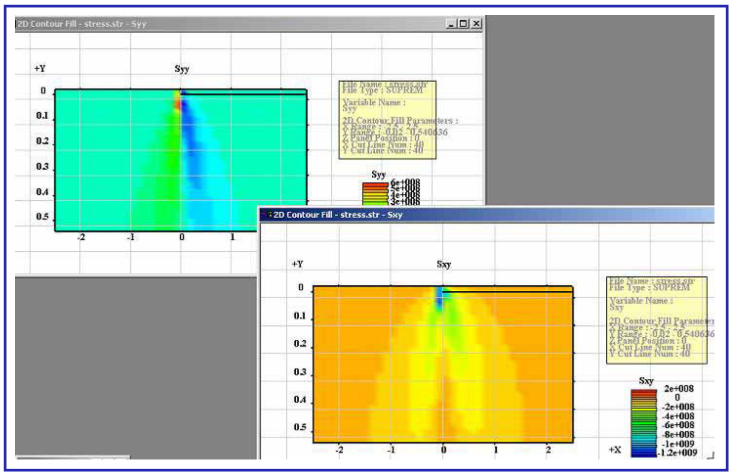
Y Cut Line Num : 40

Stress induced by Silicon Nitride-I.



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File Type : SUPREM
Variable Name :
Syy
2D Contour Fill Parameters :
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Y Range : 0.02 - 0.540636
Z Panel Position : 0
X Cut Line Num : 40
Y Cut Line Num : 40

File Name : stress.str
File Type : SUPREM
Variable Name :
Sxy
2D Contour Fill Parameters :
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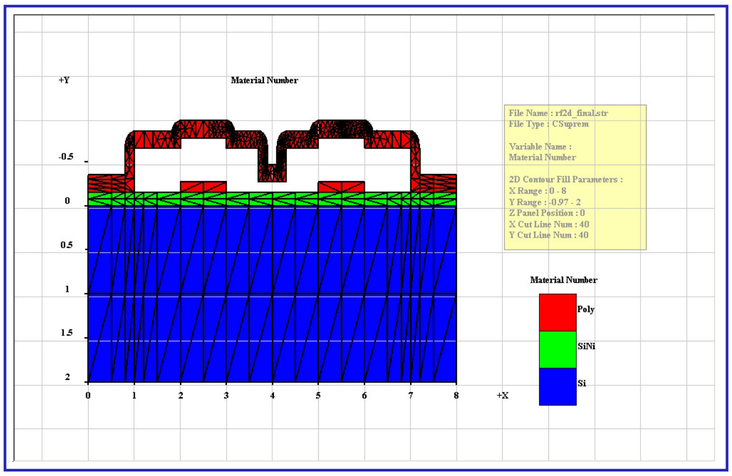
Y Cut Line Num : 40

Stress induced by Silicon Nitride-II.



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Variable Name :
Material Number
2D Contour Fill Parameters :
X Range : 0 - 8
Y Range : -0.97 - 2
Z Panel Position : 0
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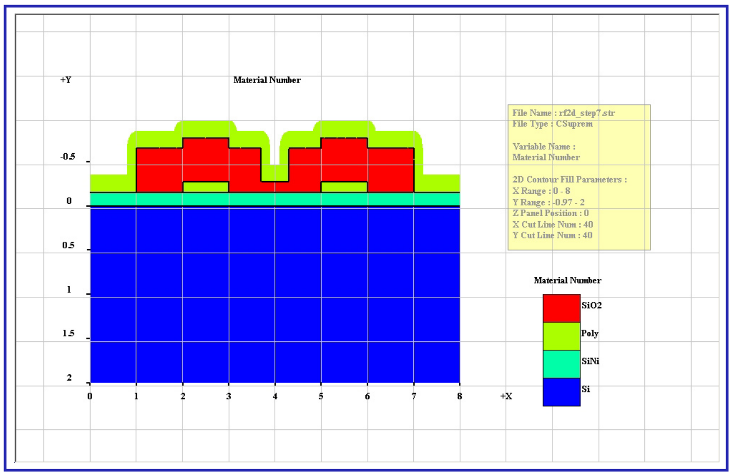
Y Cut Line Num : 40

Radio Frequency switch after release

2D Results for MEMS Devices

Radio Frequecy Switches



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File Type : CSuprem
Variable Name :
Material Number
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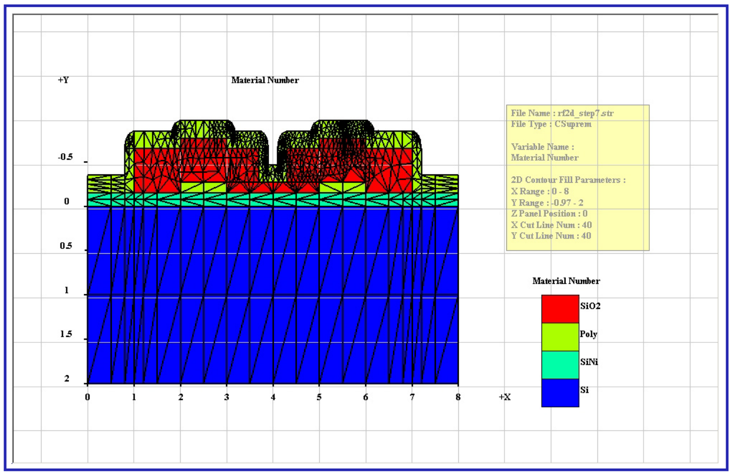
Y Cut Line Num : 40

Radio Frequency switch before release



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Material Number
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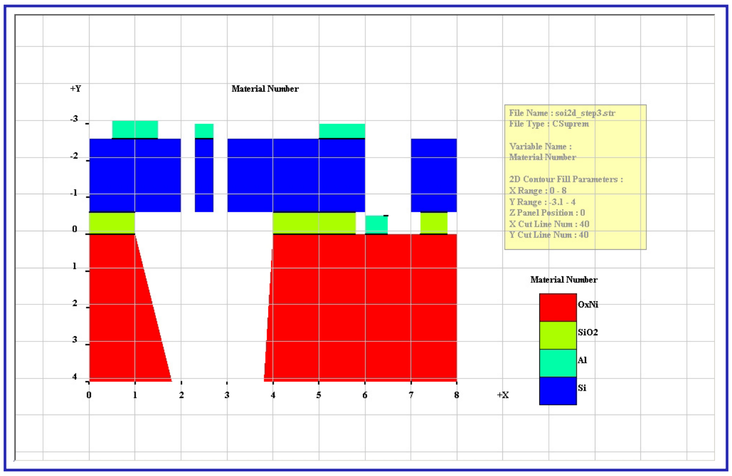
Y Cut Line Num : 40

Mesh of cross section

SOI MEMS



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Variable Name :
Material Number
2D Contour Fill Parameters :
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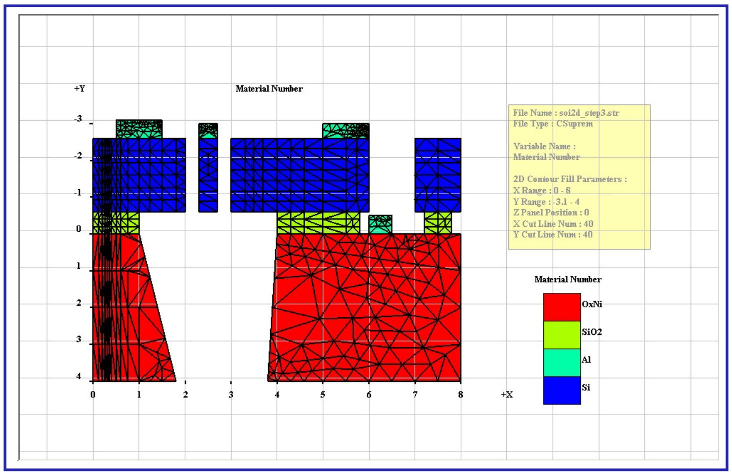
SOI MEMS: Cross section after release



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Variable Name :
Material Number
2D Contour Fill Parameters :
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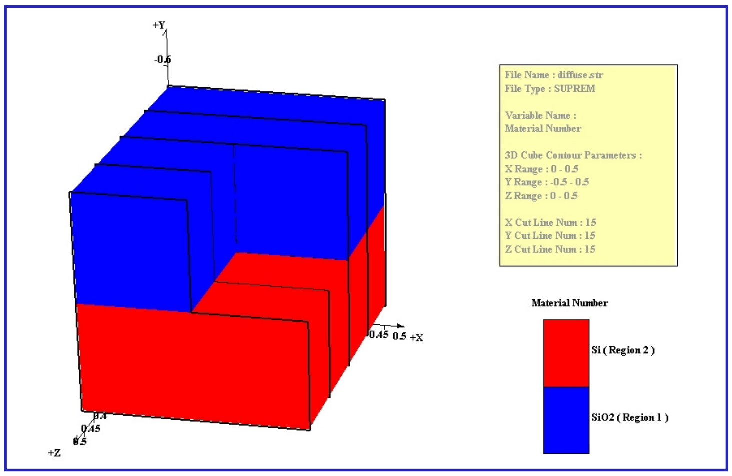
Z Panel Position : 0
X Cut Line Num : 40
Y Cut Line Num : 40

SOI MEMS: Cross section's mesh

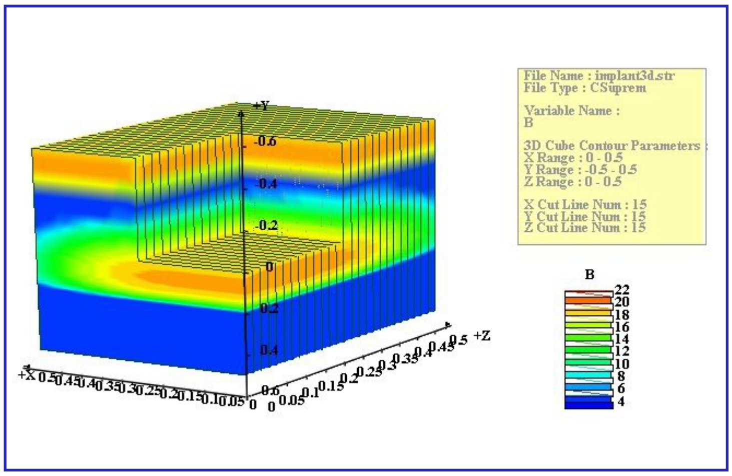
3D Results for IC Semiconductor Devices

Structure with two segments

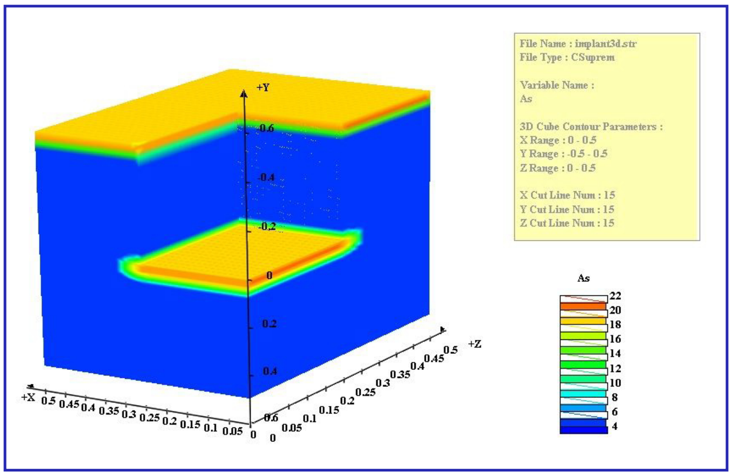


3d mask structure.

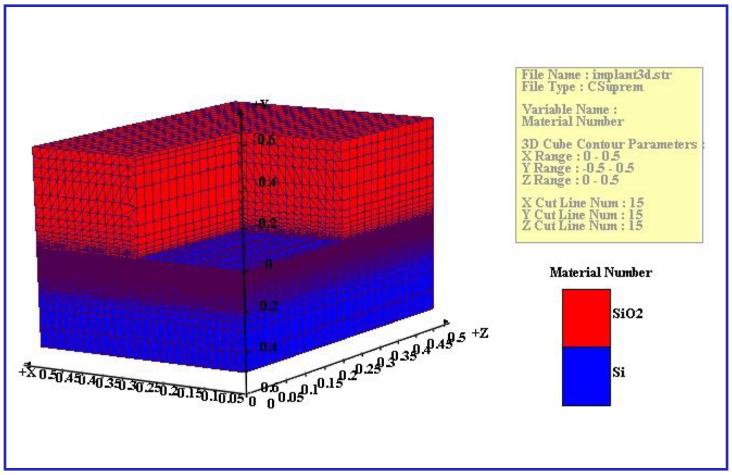
Lightly doped drain



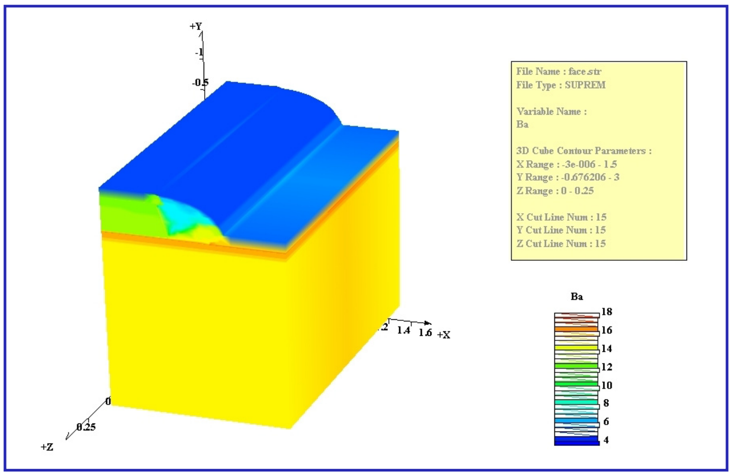
3d mask effects on Boron implant distribution.



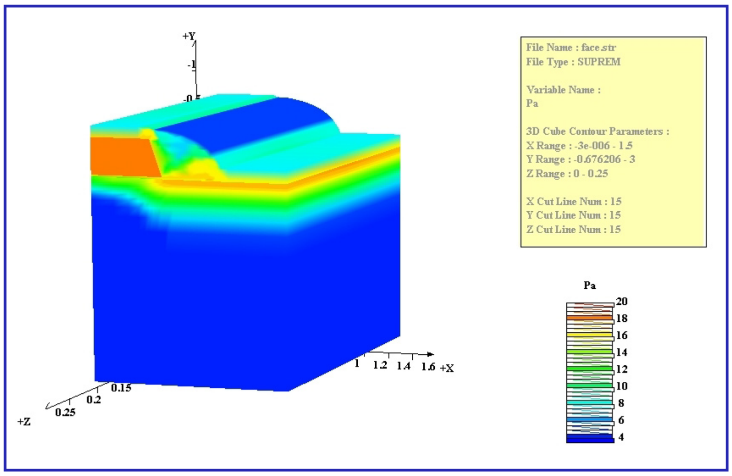
3d mask effects on Arsenic implant distribution.



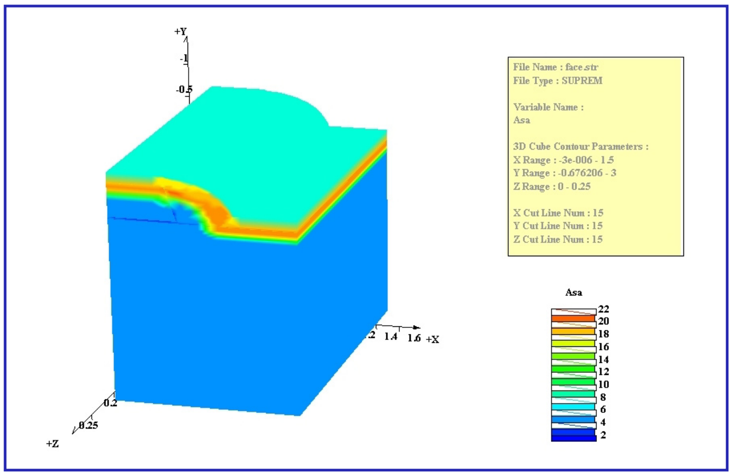
3d mesh.



Boron active after diffusion.

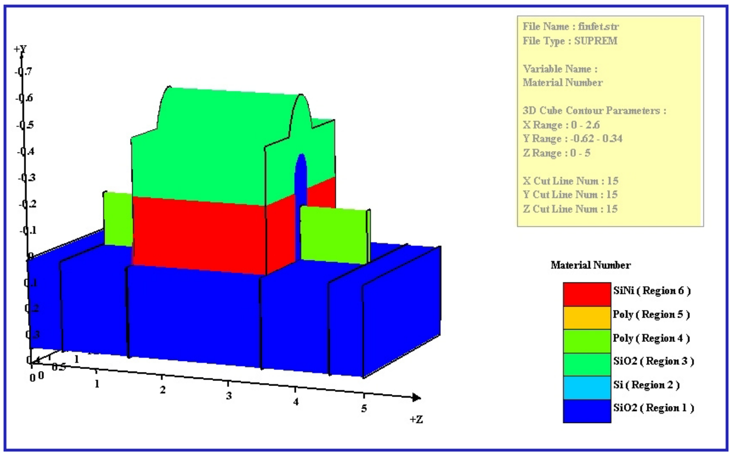


Phosphorus active after diffusion.

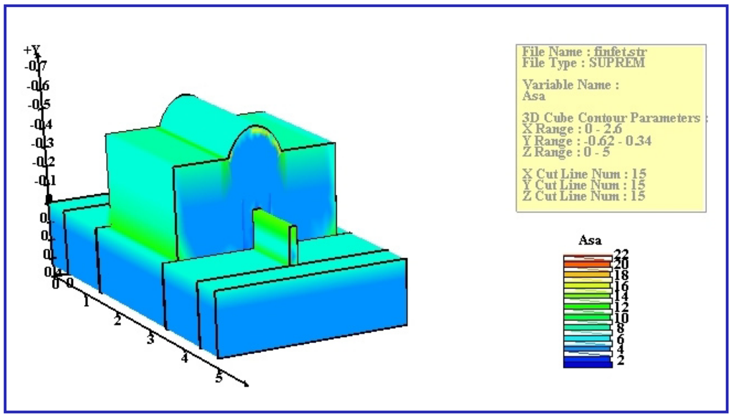


Arsenic active after diffusion.

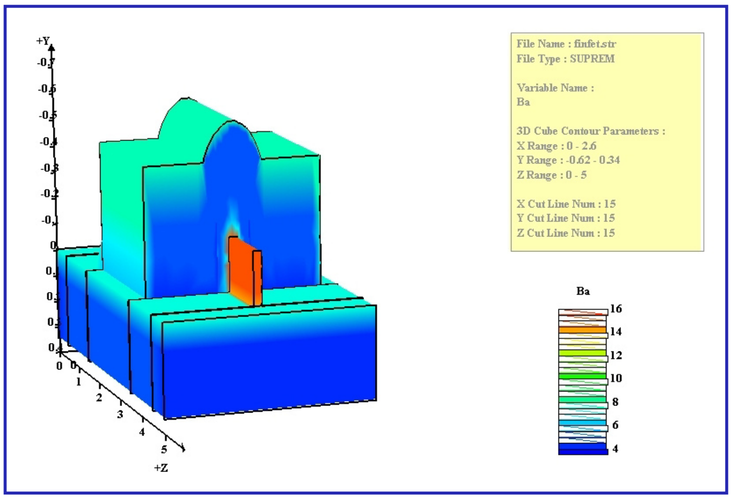
Independent Gate N-Type FinFET



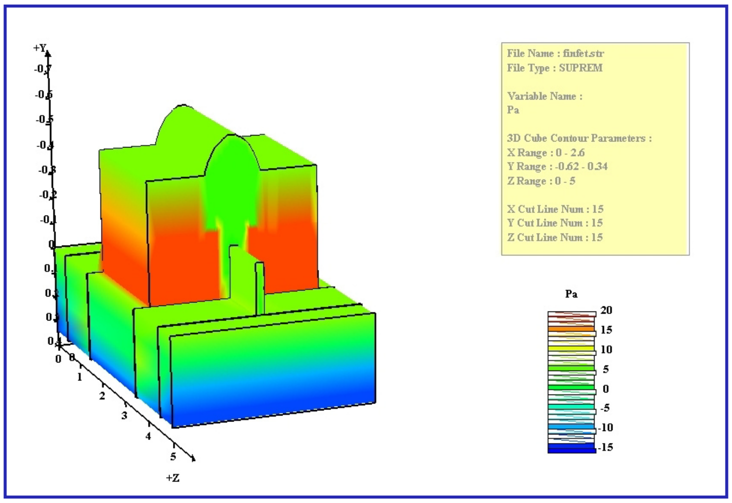
Independent gate FinFET structure.



Arsenic active profile after diffusion



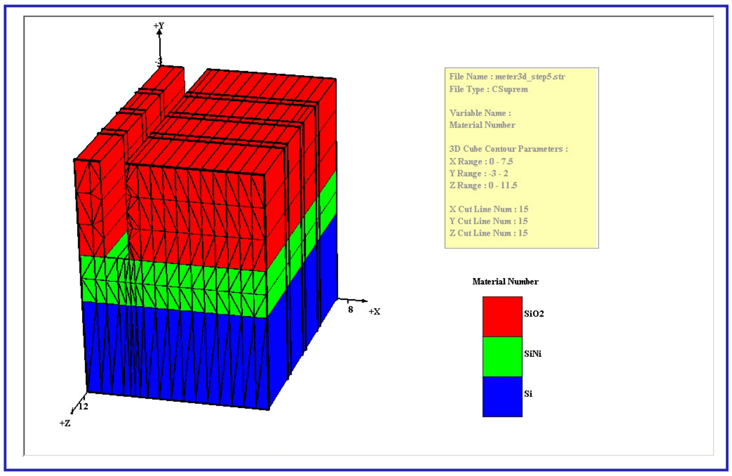
Boron active profile after diffusion



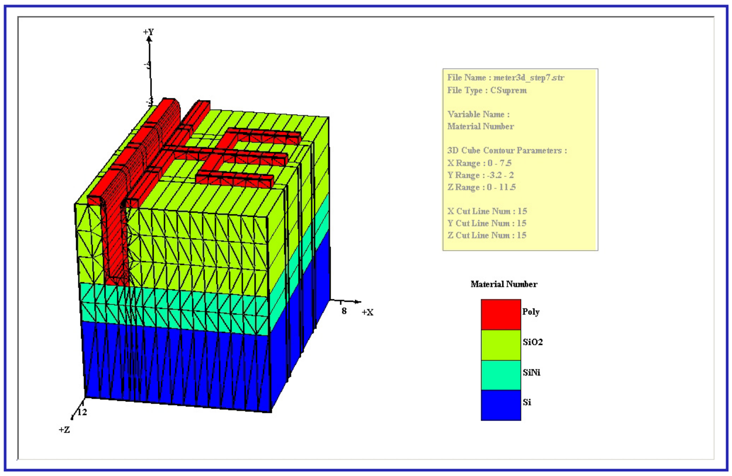
Phosphorus active profile after diffusion

3D Results for MEMS Devices

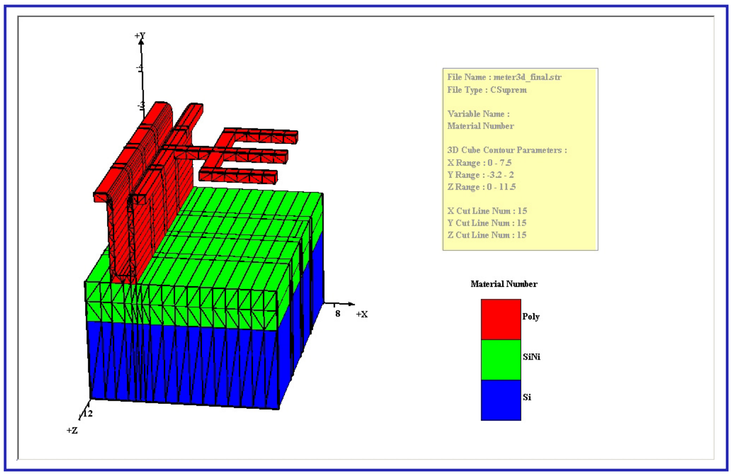
Electrometer



Electromter: Processing step 5

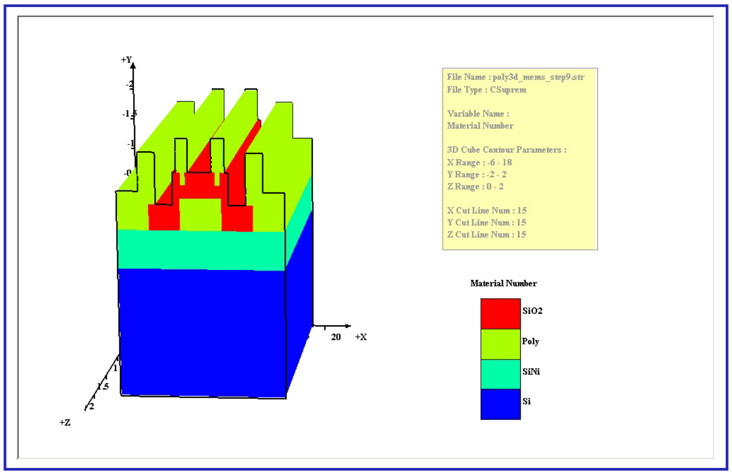


Electromter: Processing step 7

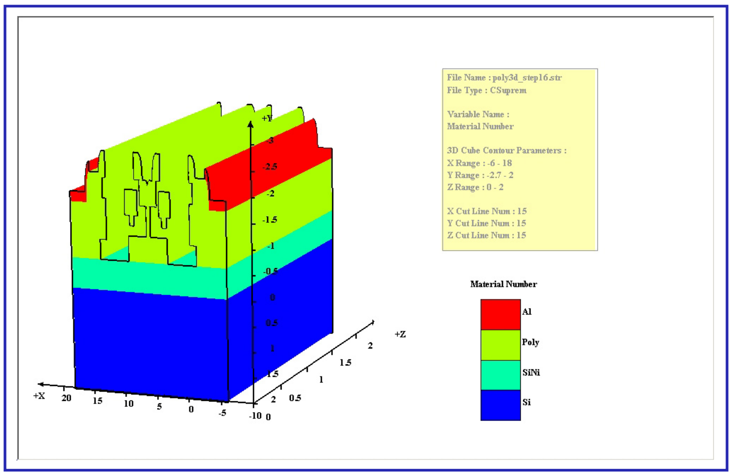


Electromter: Final processing step

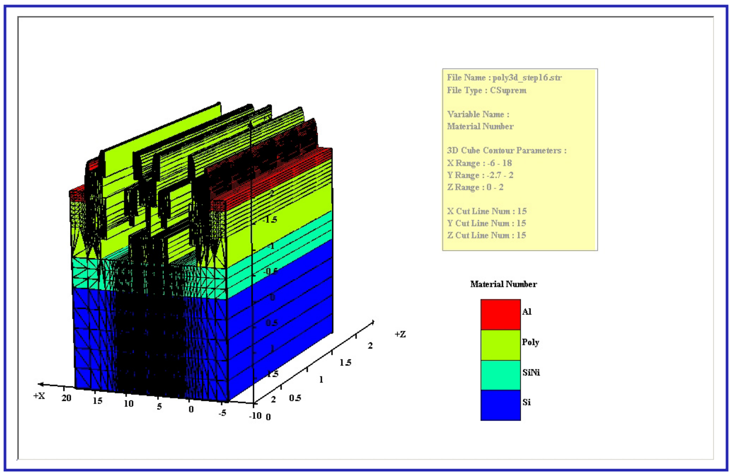
Polysilicon MEMS



Polysilicon MEMS before release

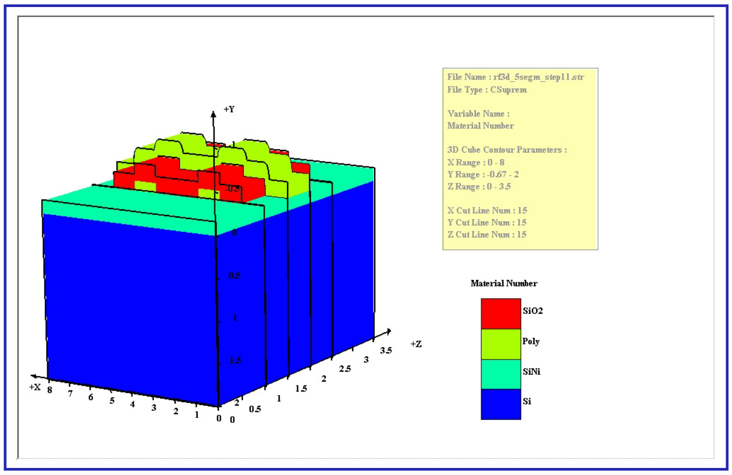


Ploysilicon MEMS after release

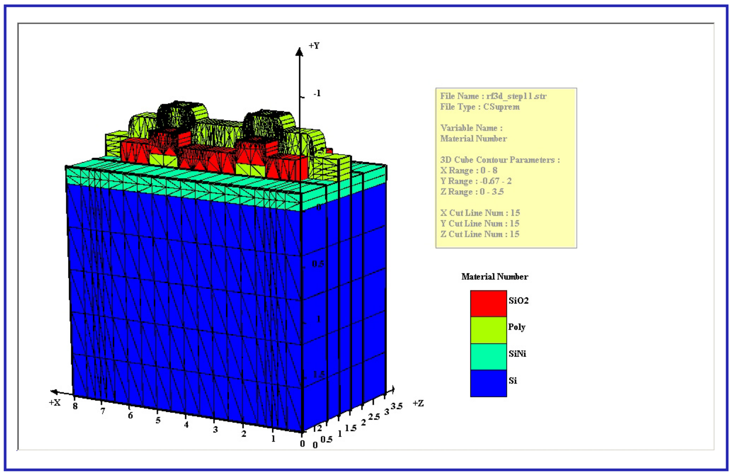


Ploysilicon MEMS with 3d mesh

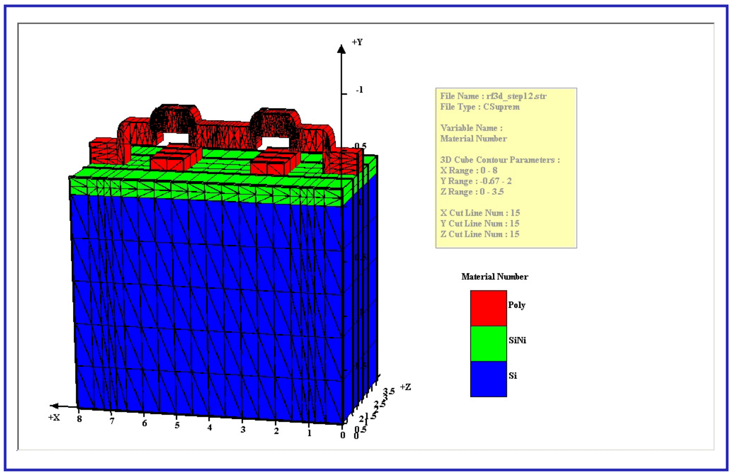
Radio Frequency Switches



RF: before release

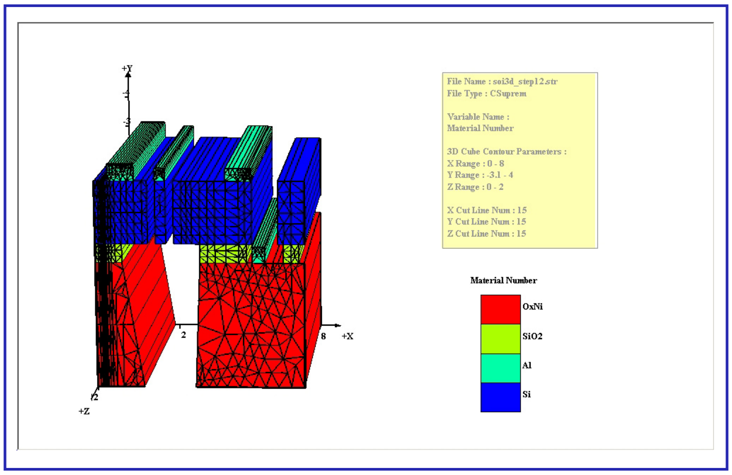


RF: 3d mesh before release

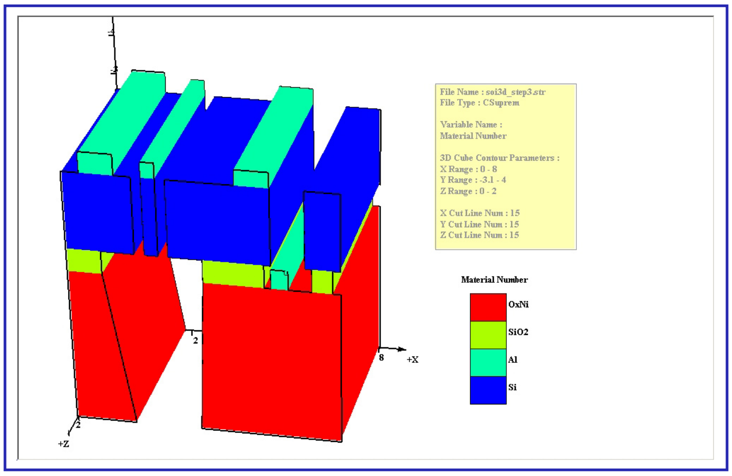


RF: 3d mesh after release

SOI MEMS



SOI MEMS before release



SOI MEMS after release