3D Micro-Electro-Mechanical Systems (MEMS) Process Simulation Using CSuprem

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<u>Outlines</u>

- Introduction
- MEMS applications
- 3D MEMS simulation with CSuprem
- 3D MEMS process simulation results

    Radio Frequency (RF) Switches

    Electrometer MEMS

    Polysilicon MEMS

    SOI MEMS

    MEMS-Tunable VCSOAs

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Introduction

- MEMS fabrication requires accurate simulation of geometry and material behavior
- Process simulation and analysis of MEMS is a challenge
- Structures are geometrically more complicated than those in IC electronic devices
- Structures are electro-mechanically coupled
- Multi-domain physics (optical, electrical, mechanical, and micro-fluidics) is required
- 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

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MEMS applications

- Optics (actuators, scanning mirrors, switches,…)
- Automotive (airbag sensors, fuel sensors, force sensors, pressure sensors, ….)
- Biomedical sensors
- RF devices
- Ink jet printers
- Military (biochemical warfare detection, inertial systems for guidance and navigation)

…. and more

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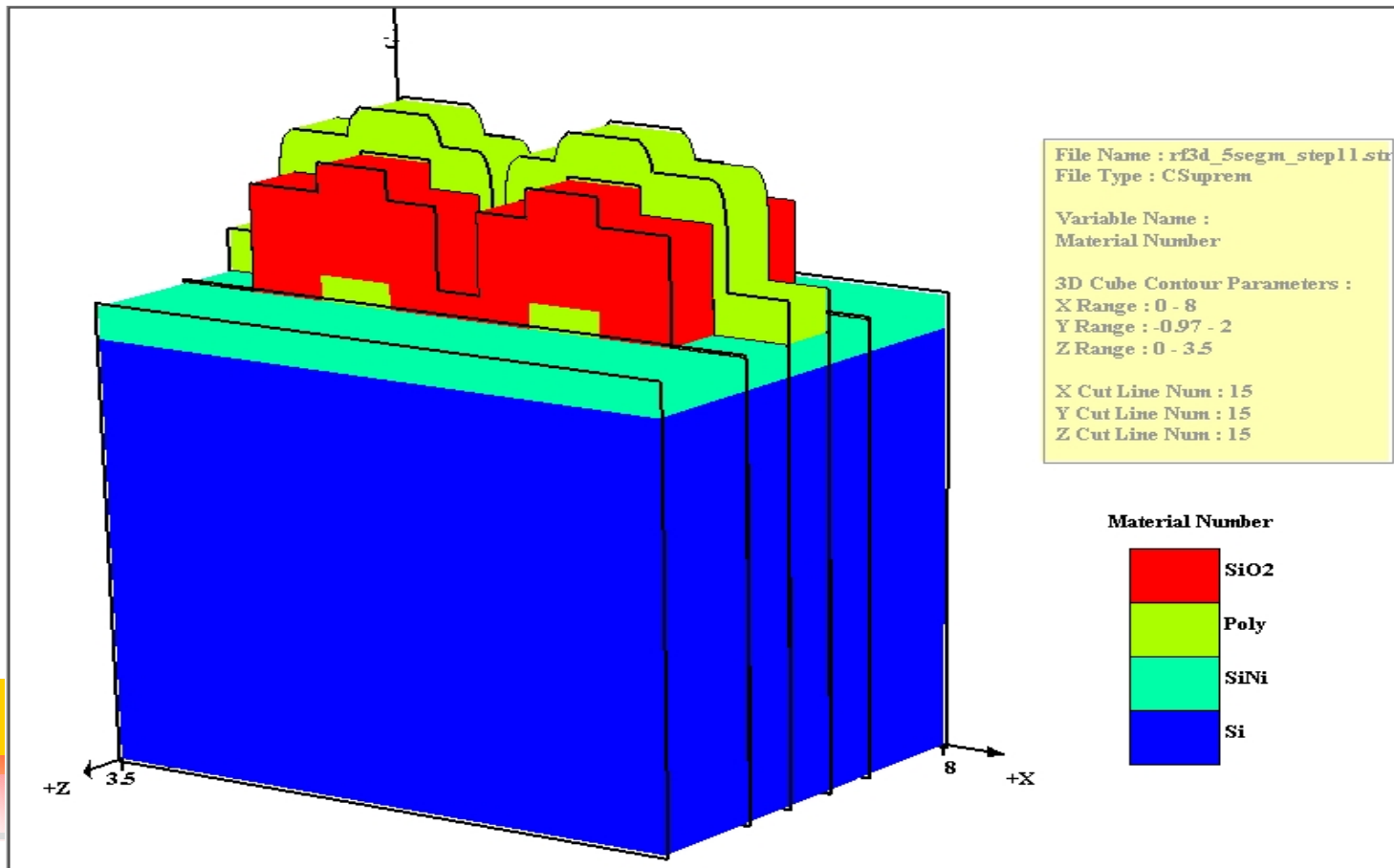# 3D MEMS simulation with CSuprem

- Accurate selective Etching/Deposition
- Implantation,Oxidation, and Diffusion
- Accurate Delaunay mesh generation
- Domain decomposition-based new concept for 3d geometry modeling
- Size of 3d mesh is very reasonable (~3000 points only for RF switch)

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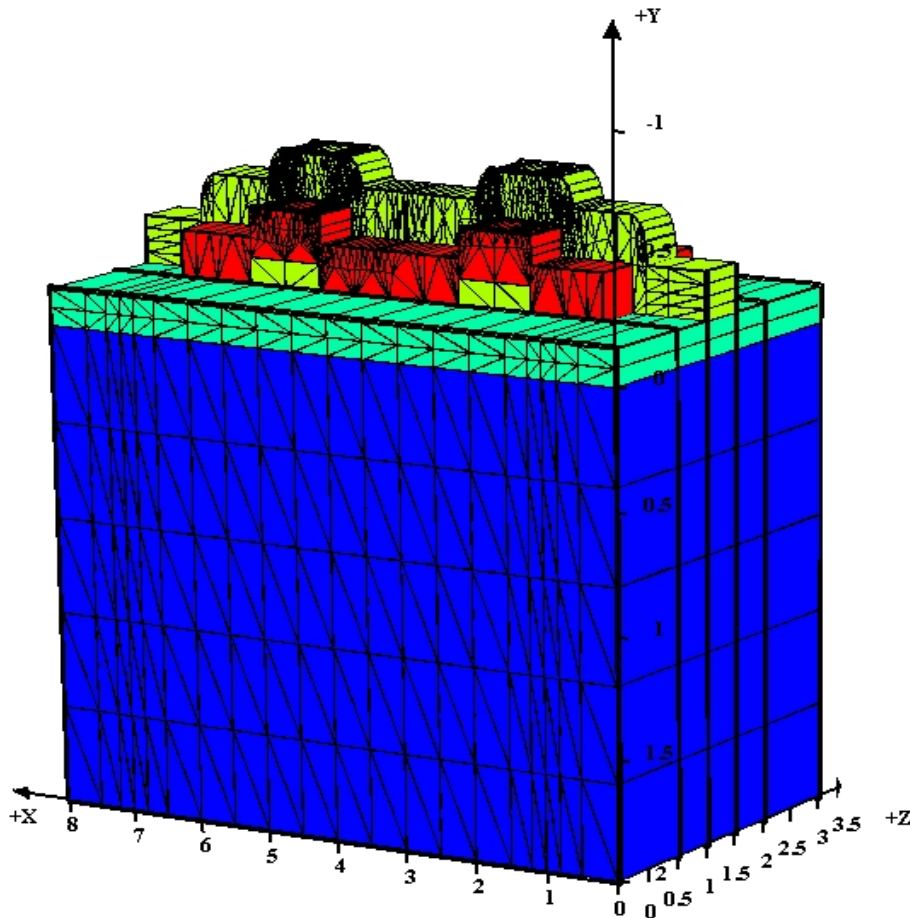# 3D MEMS simulation results

- RF Switches process simulation
- Electrometer process simulation
- Polysilicon MEMS process simulation
- SOI MEMS process simulation
- MT-VCSOA process simulation

I- RF Switch process simulation
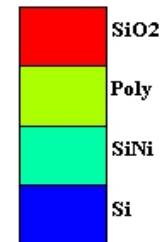
Structure before release

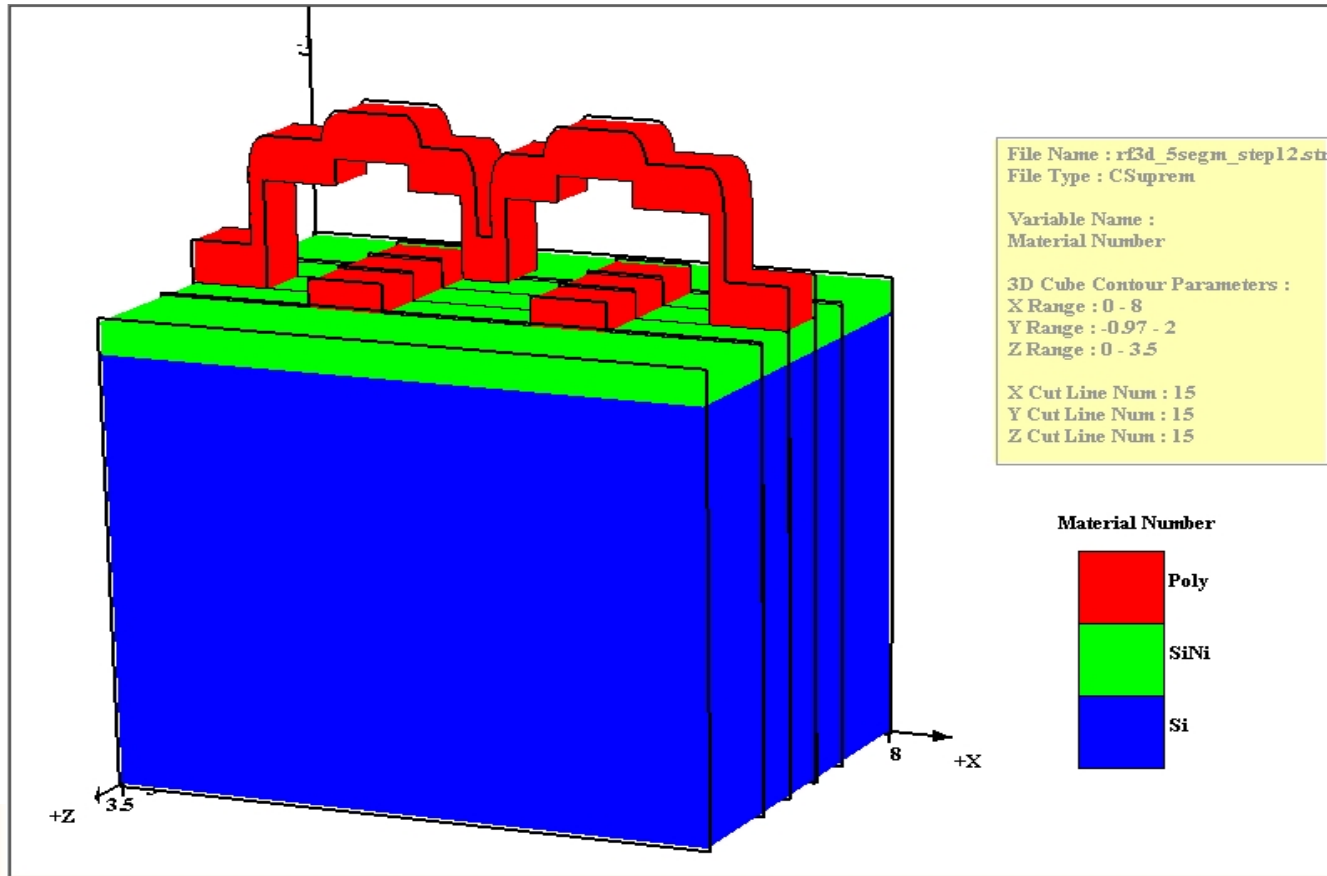File Name : rf3d_5segm_step11.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0 - 8
Y Range : -0.97 - 2
Z Range : 0 - 3.5

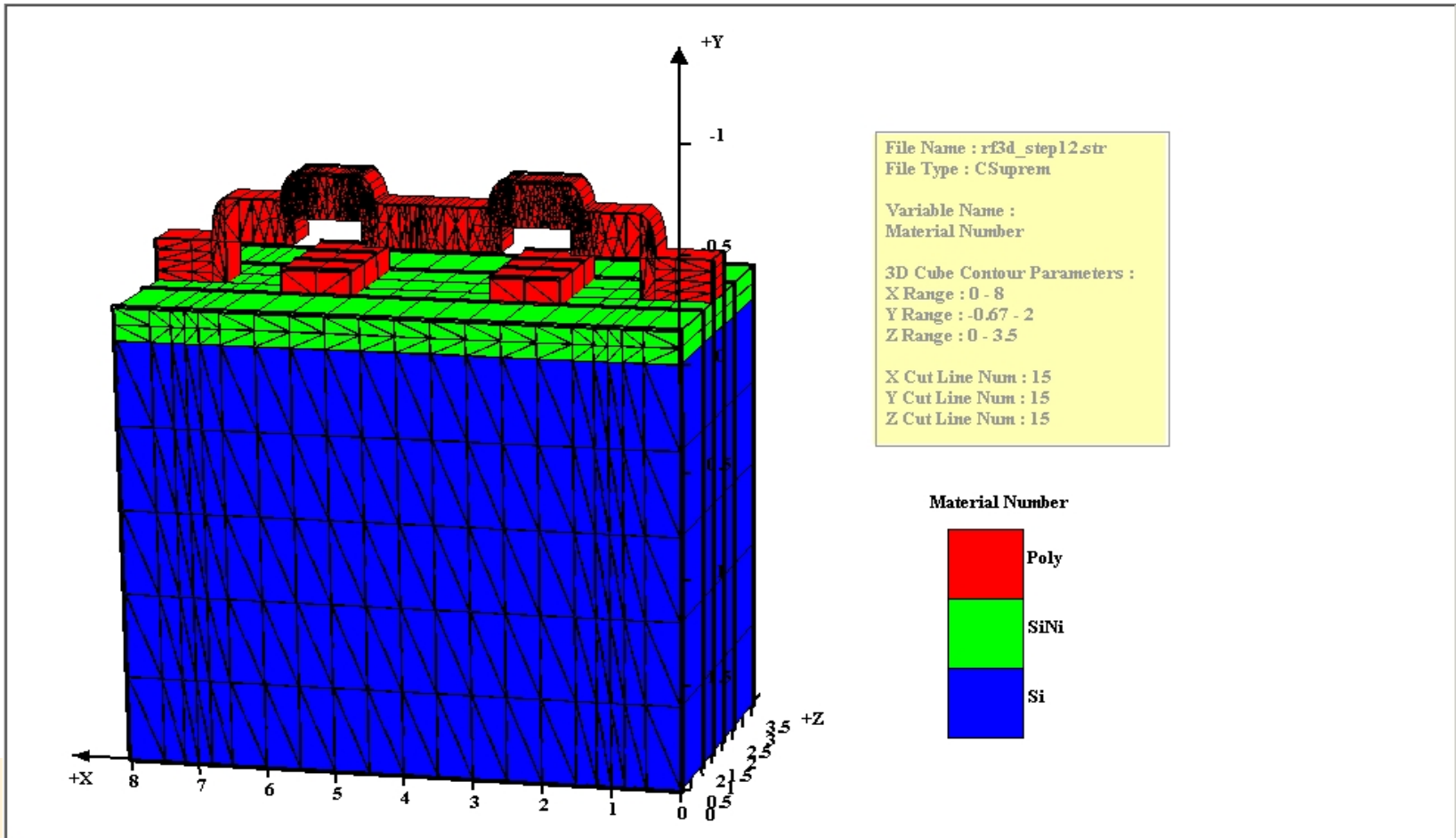X Cut Line Num : 15
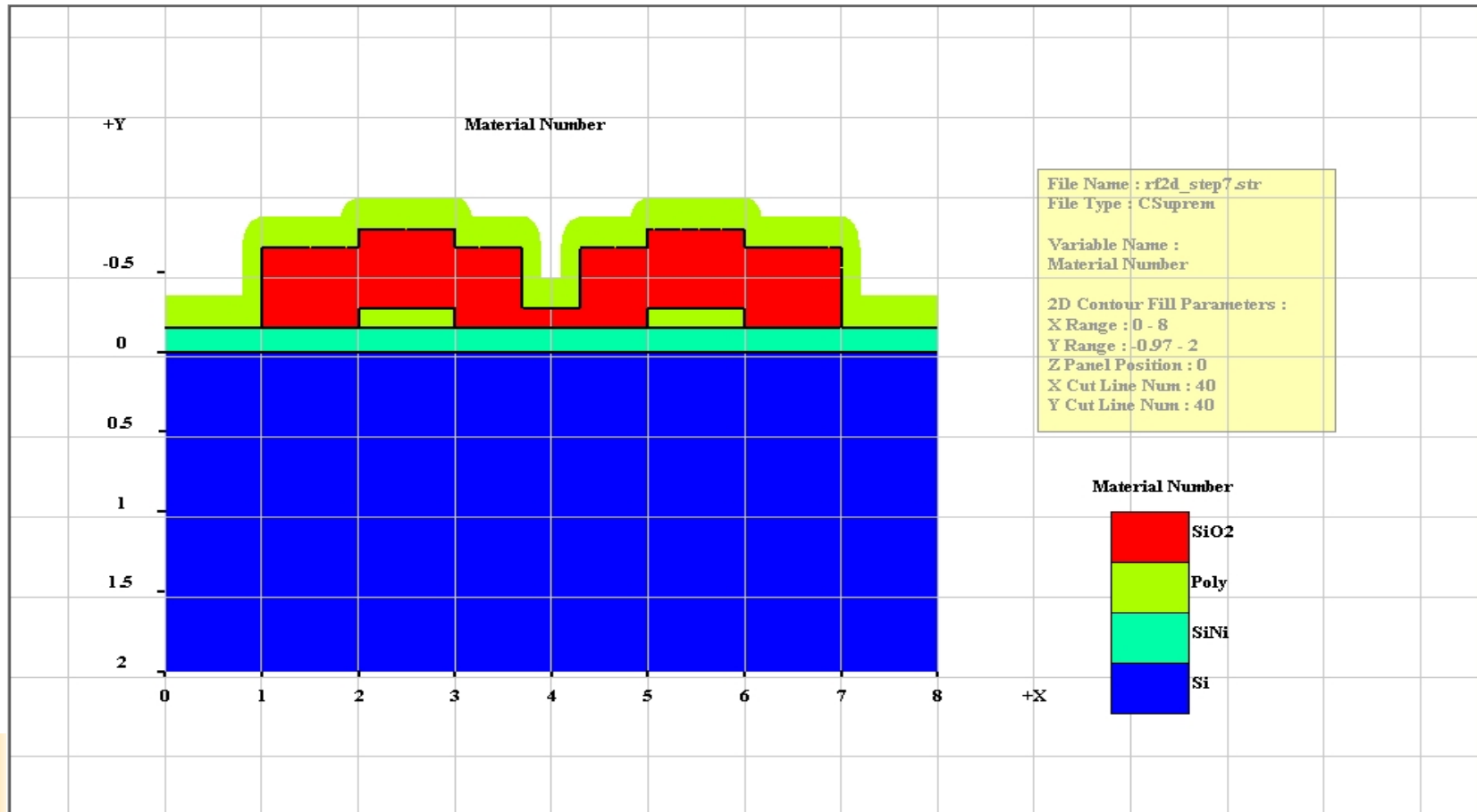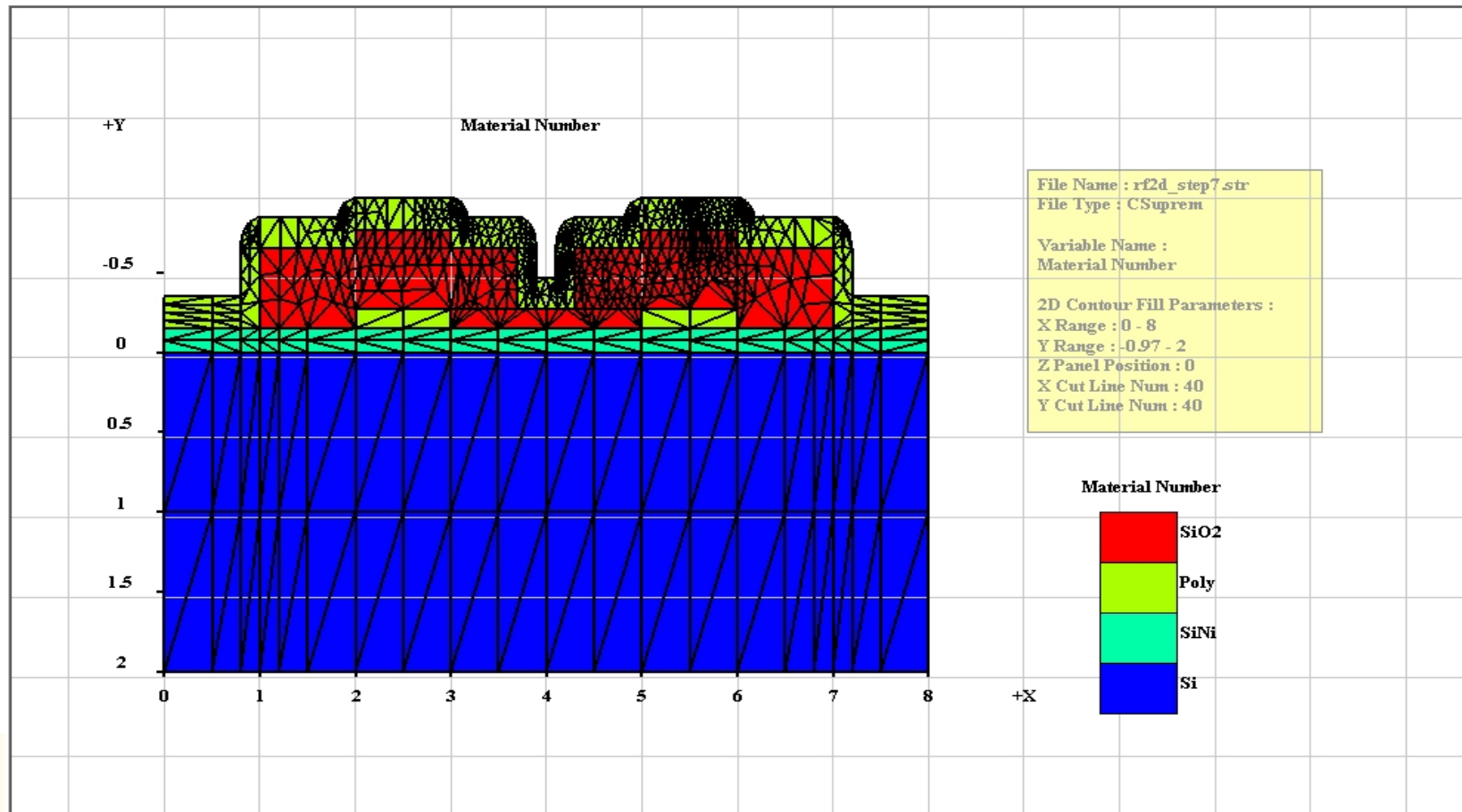Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

- SiO2
- Poly
- SiNi
- Si

+Z 3.5

8 +X

3D Mesh with rounded corners

Structure after release

3D Mesh after release

File Name : rf3d_step12.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0 - 8
Y Range : -0.67 - 2
Z Range : 0 - 3.5

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

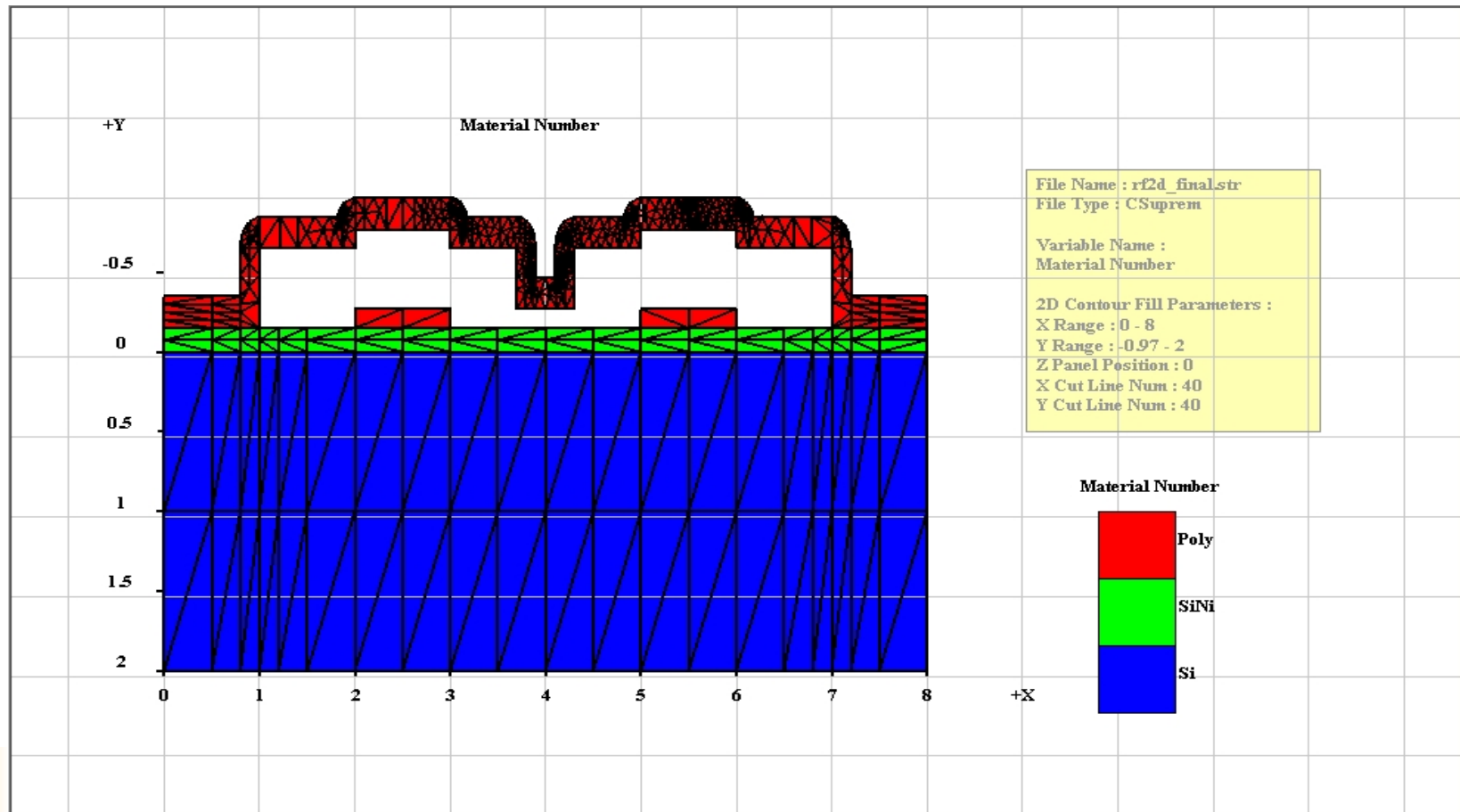**Material Number**

Poly

SiNi

Si

RF switch cross-section

Cross-section's mesh before release

Cross-section's mesh after release

II- Electrometer process simulation

Structure before release

File Name : surf3d_7segm_step6.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0 - 7.5
Y Range : -3.2 - 2
Z Range : 0 - 11.5

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

- Poly
- SiO2
- SiNi
- Si

Structure after release

File Name : surf3d_7segm_final.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0 - 7.5
Y Range : -3.2 - 2
Z Range : 0 - 11.5

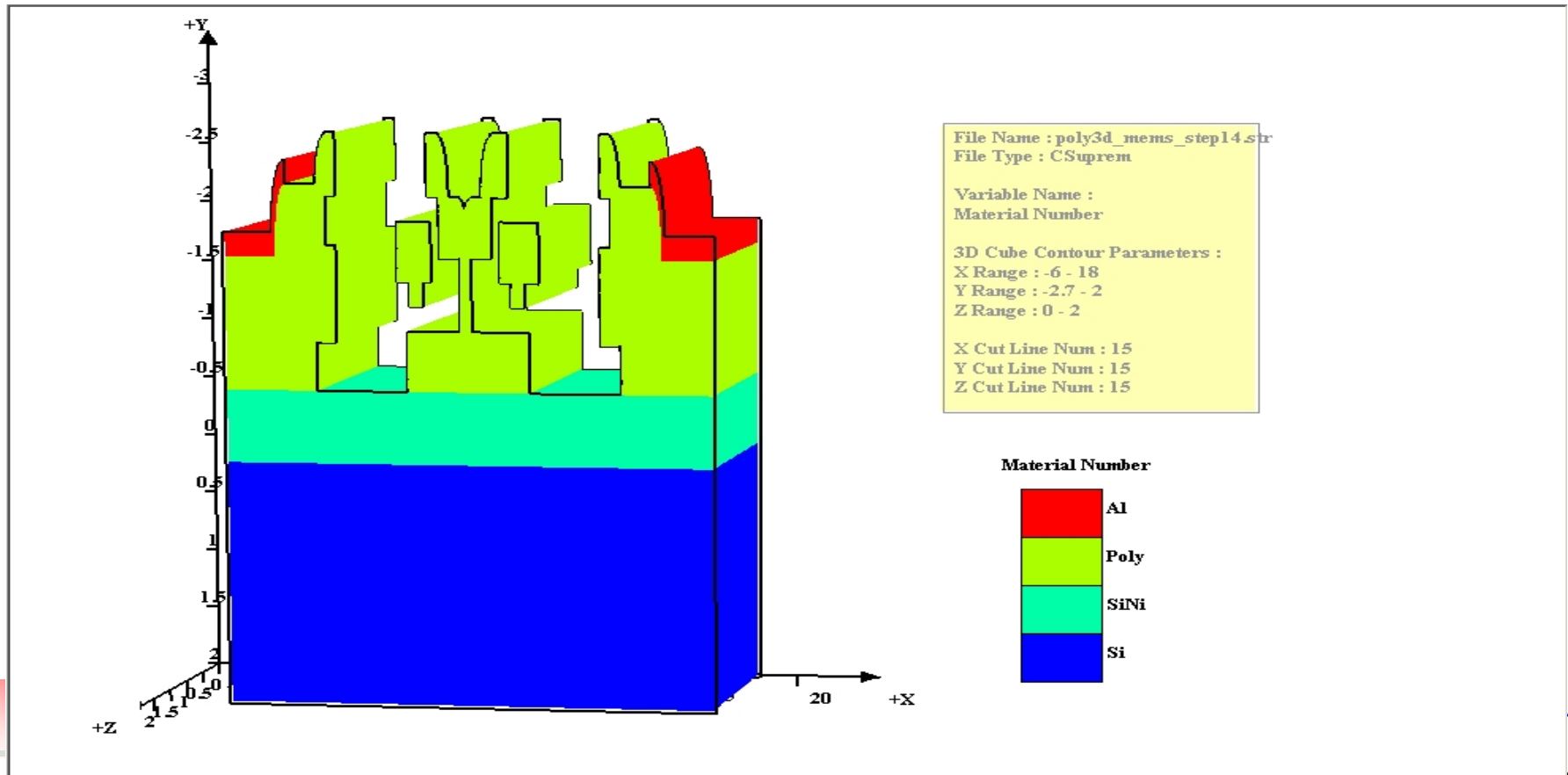X Cut Line Num : 15
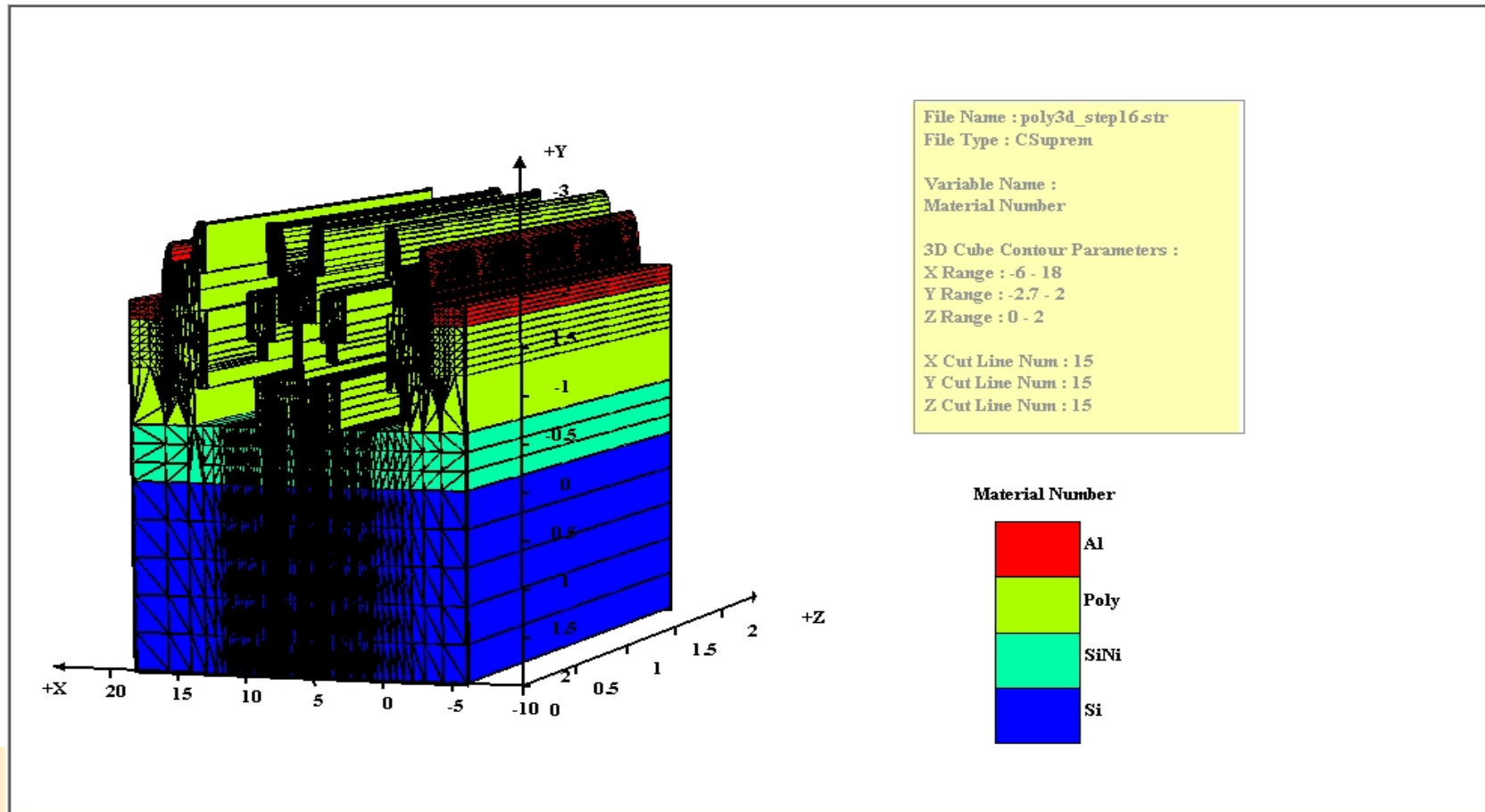Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

Poly

SiNi

Si

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File Name : meter3d_final.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0 - 7.5
Y Range : -3.2 - 2
Z Range : 0 - 11.5

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

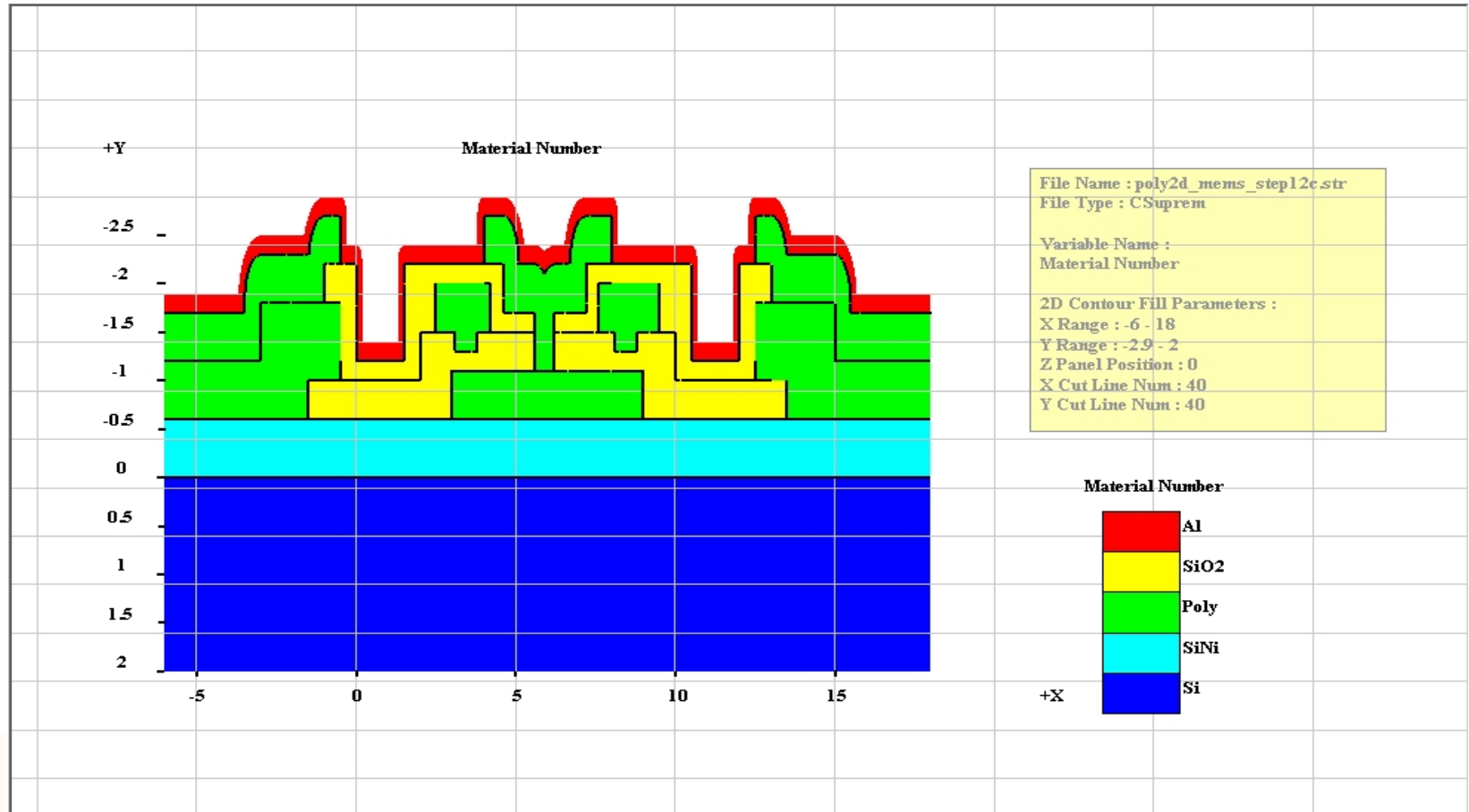Material Number

Poly

SiNi

Si

3D Mesh after release

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III- PolyMEMS process simulation

3d structure after release

File Name : poly3d_mems_step14.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : -6 - 18
Y Range : -2.7 - 2
Z Range : 0 - 2

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

- Al
- Poly
- SiNi
- Si

3D Mesh after release

File Name : poly3d_step16.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : -6 - 18
Y Range : -2.7 - 2
Z Range : 0 - 2

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

Al
Poly
SiNi
Si

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Cross-section before release

Cross-section after release
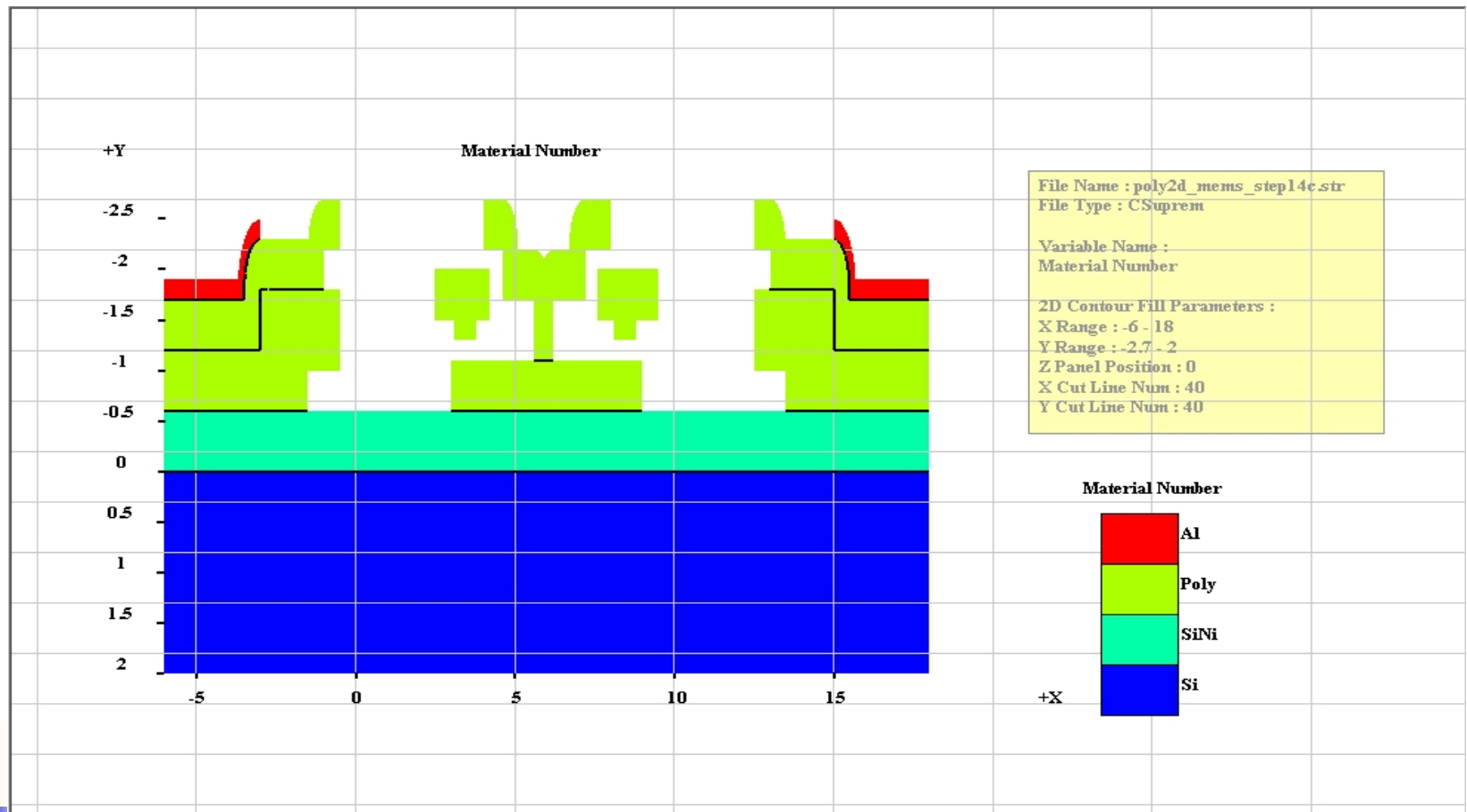
Cross-section's unstructured mesh
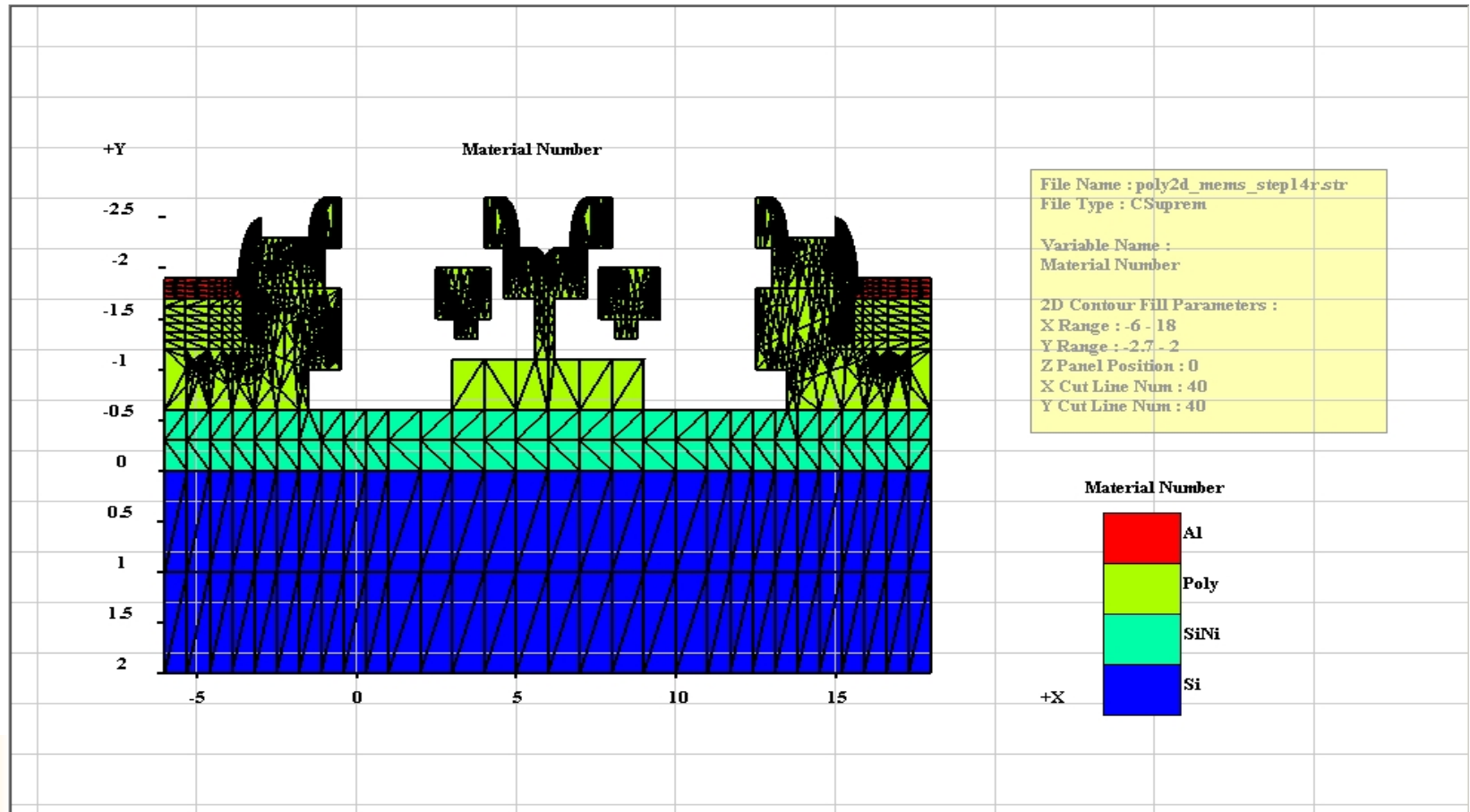
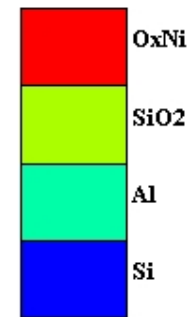# IV- SOI MEMS process simulation

Structure at final processing step
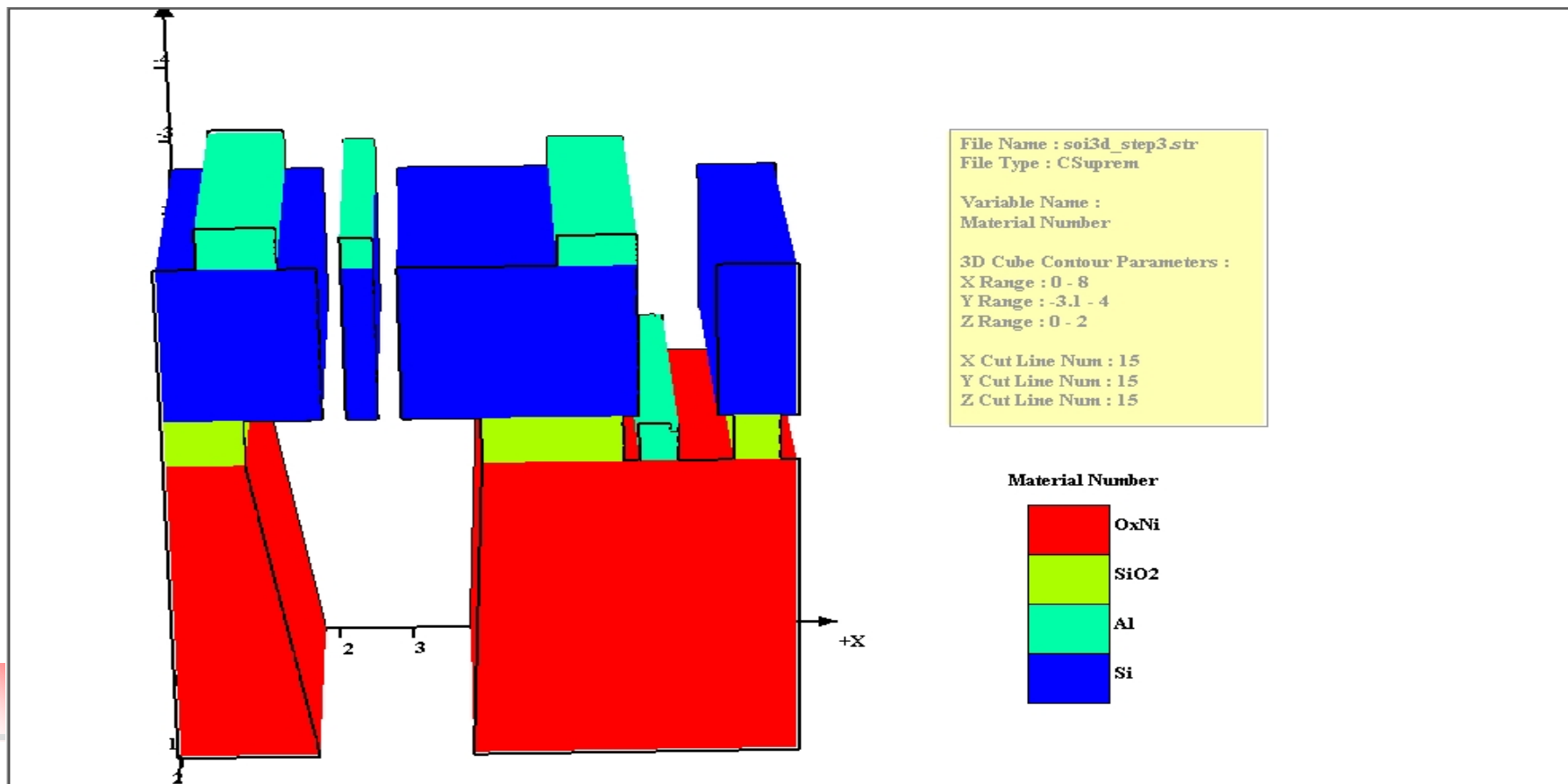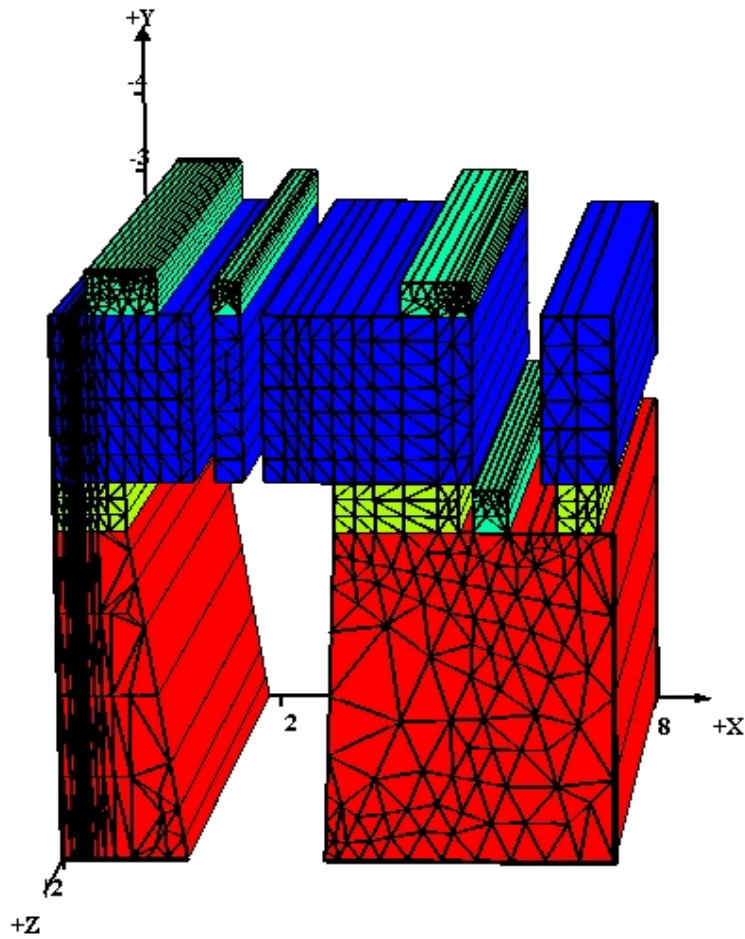
File Name : soi3d_step12.str
File Type : CSuprem

Variable Name :
Material Number

3D Cube Contour Parameters :
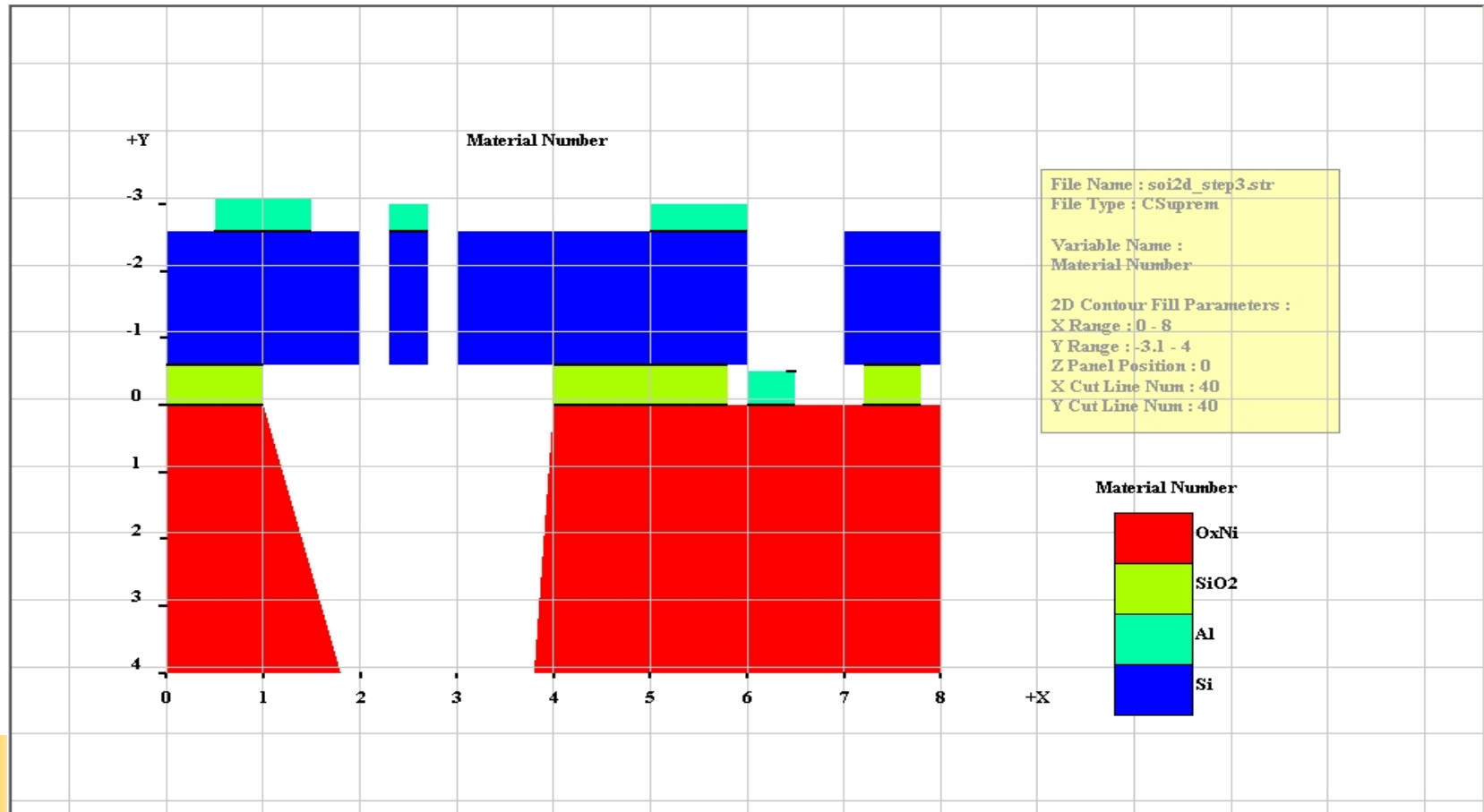X Range : 0 - 8
Y Range : -3.1 - 4
Z Range : 0 - 2

X Cut Line Num : 15
Y Cut Line Num : 15
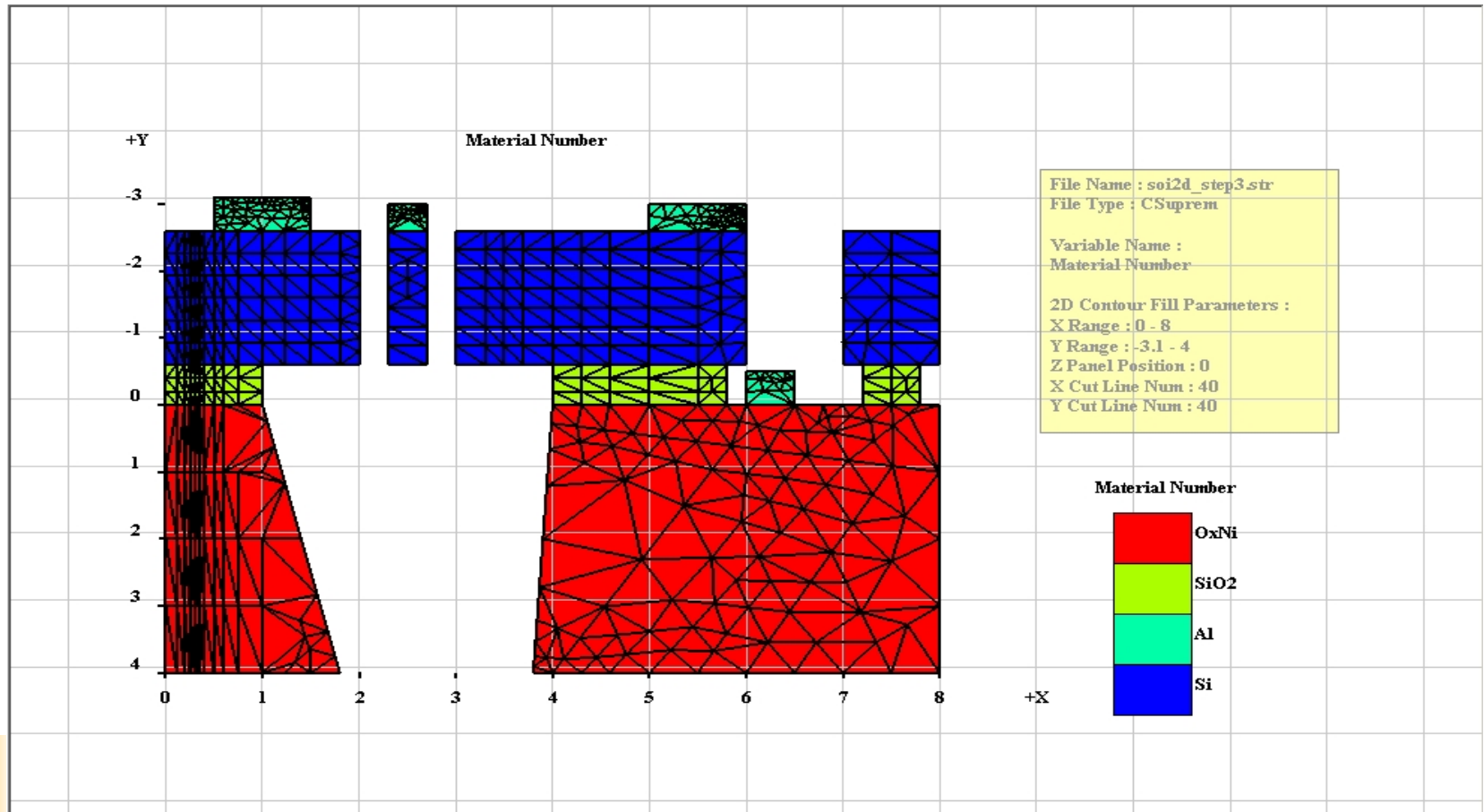Z Cut Line Num : 15

Material Number

- OxNi
- SiO2
- Al
- Si

SOI 3D Mesh after release
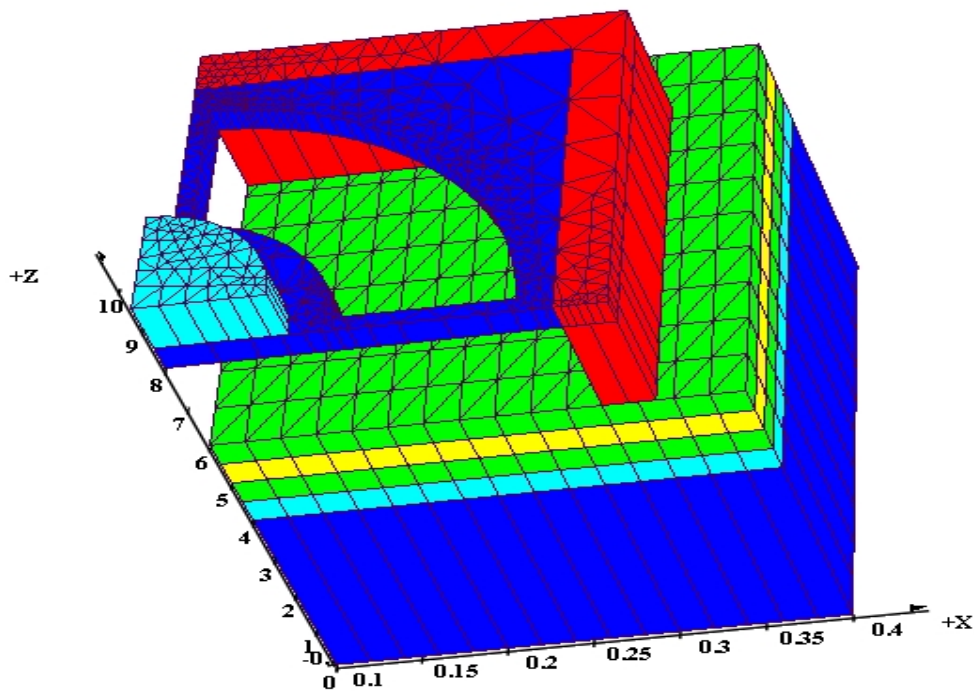
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SOI MEMS cross-section

Cross-section's mesh

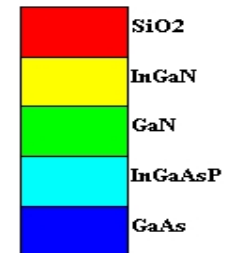# V- MEMS Tunable VCSOAs process simulation

File Name : 3d_3.str
File Type : CSuprem
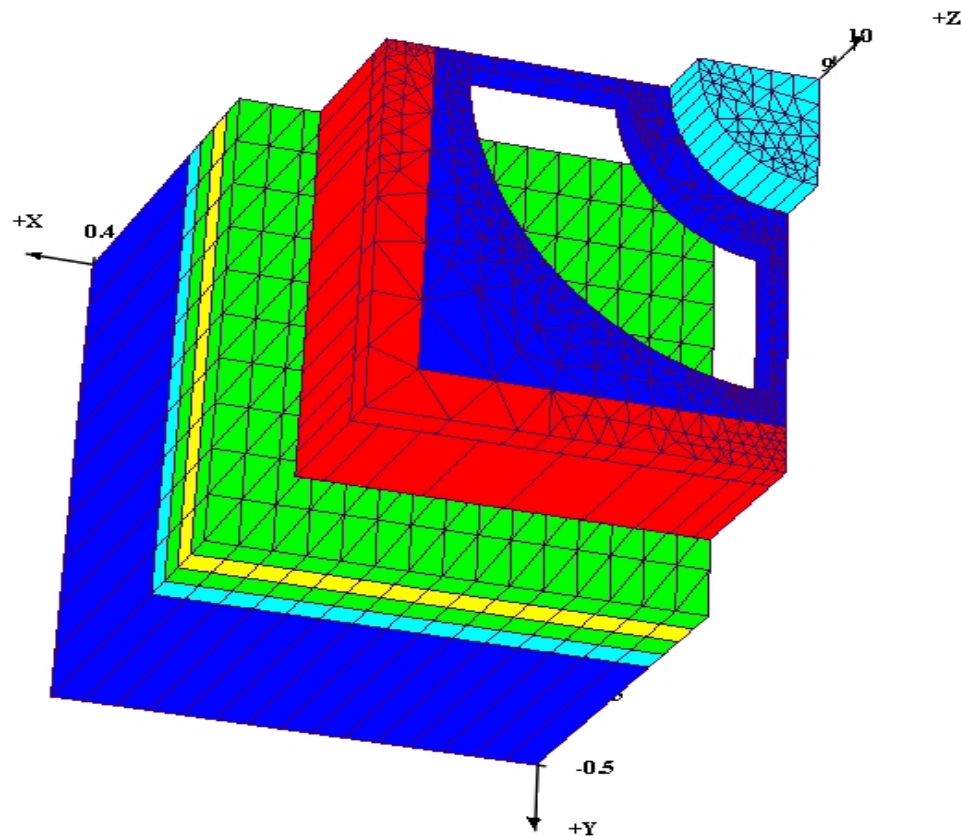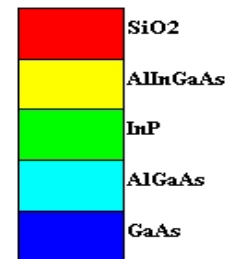
Variable Name :
Material Number

3D Cube Contour Parameters :
X Range : 0.1 - 0.4
Y Range : -0.5 - -0.2
Z Range : 0 - 9.5

X Cut Line Num : 15
Y Cut Line Num : 15
Z Cut Line Num : 15

Material Number

- SiO2
- InGaN
- GaN
- InGaAsP
- GaAs

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MT-VCSOA from a different view

Conclusion

Csuprem is an all-at-once simulator for MEMS:

- It is based on homogenous approach

- It accurately optimizes MEMS manufacturing processes,

- and generates an optimal 3d mesh for simulating MEMS operations

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