Planarization of Passivation Layers during Manufacturing Processes of Image Sensors

A. Sheikholeslami[1], F. Parhami[2], H. Puchner[2], and S. Selberherr[1]

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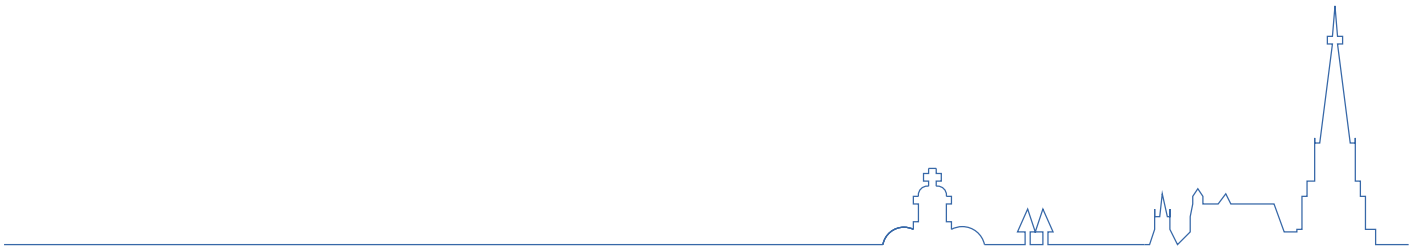
[1]Institute for Microelectronics
Gußhausstraße 27-29/E360, 1040 Wien
http://www.iue.tuwien.ac.at/
[2]Cypress Semicondoctr Corporation
San Jose, CA 95134, USA

Introduction

Motivation



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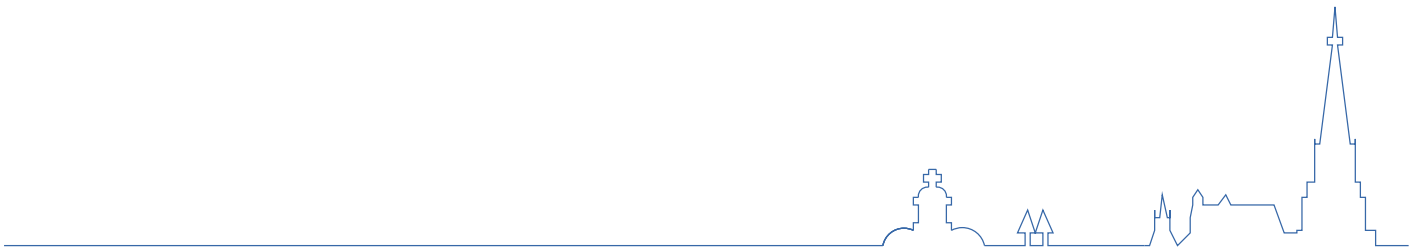

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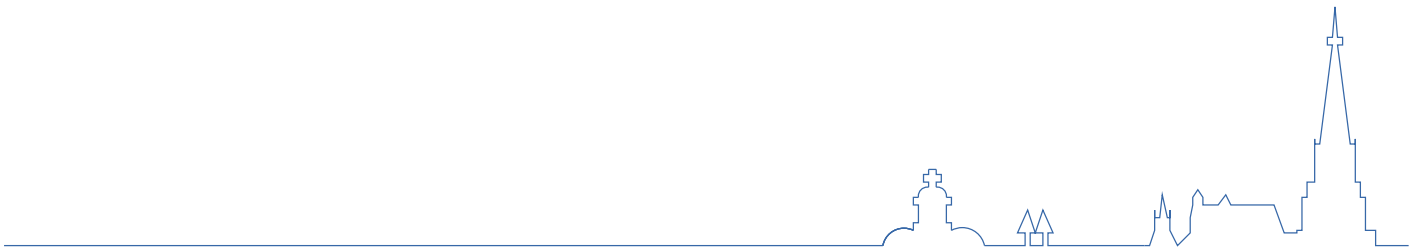

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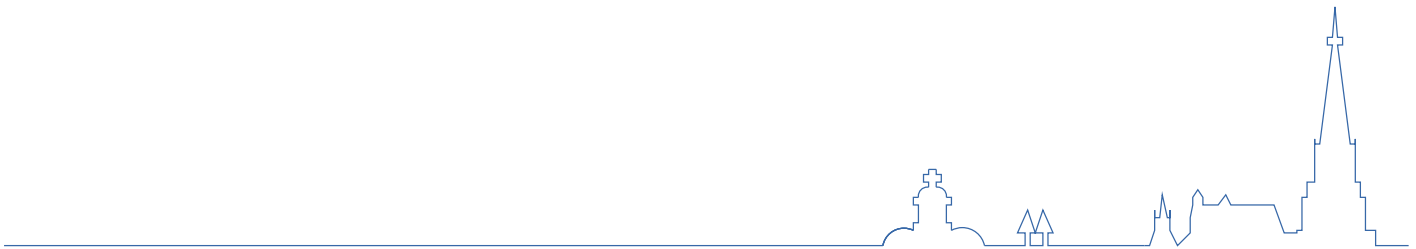

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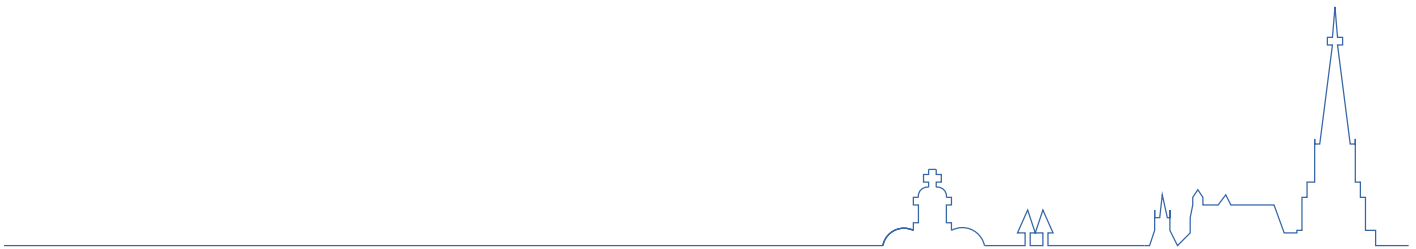

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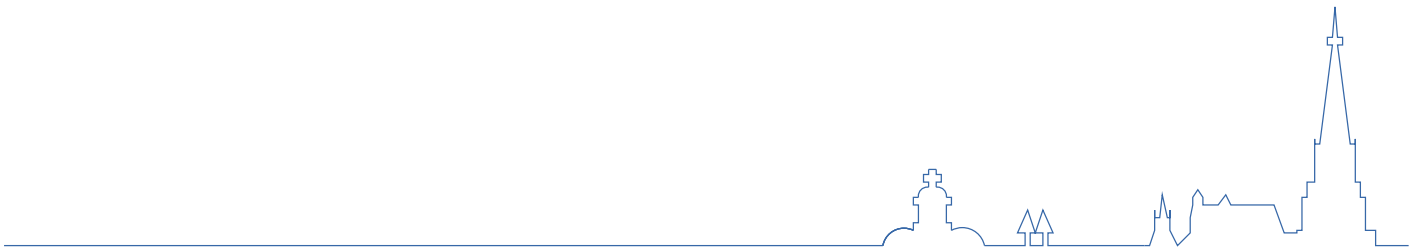

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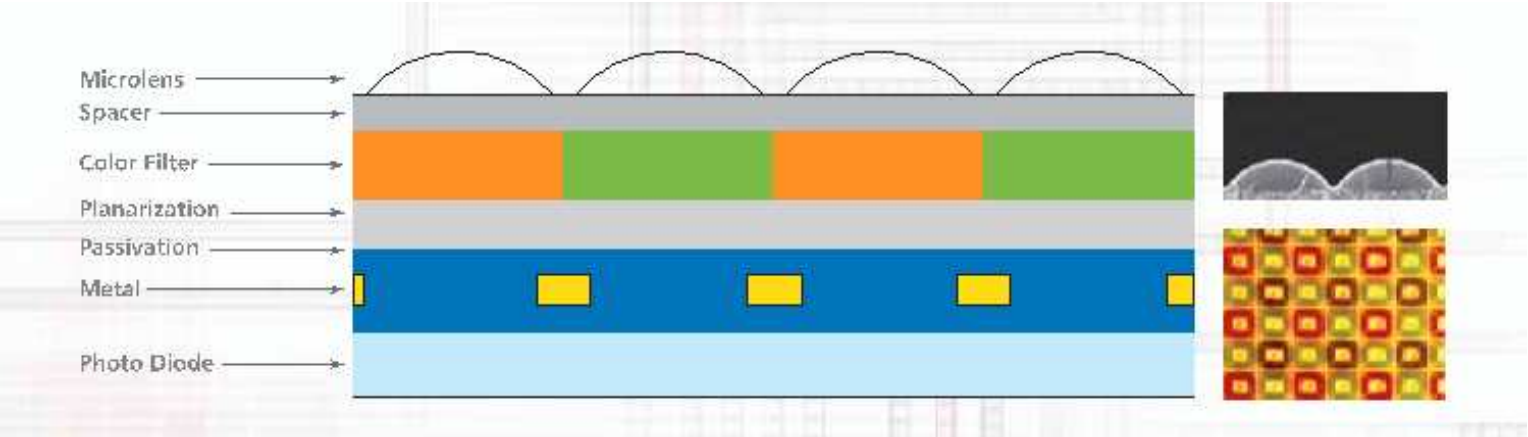
Sensitivity of image sensor processes to passivation planarization



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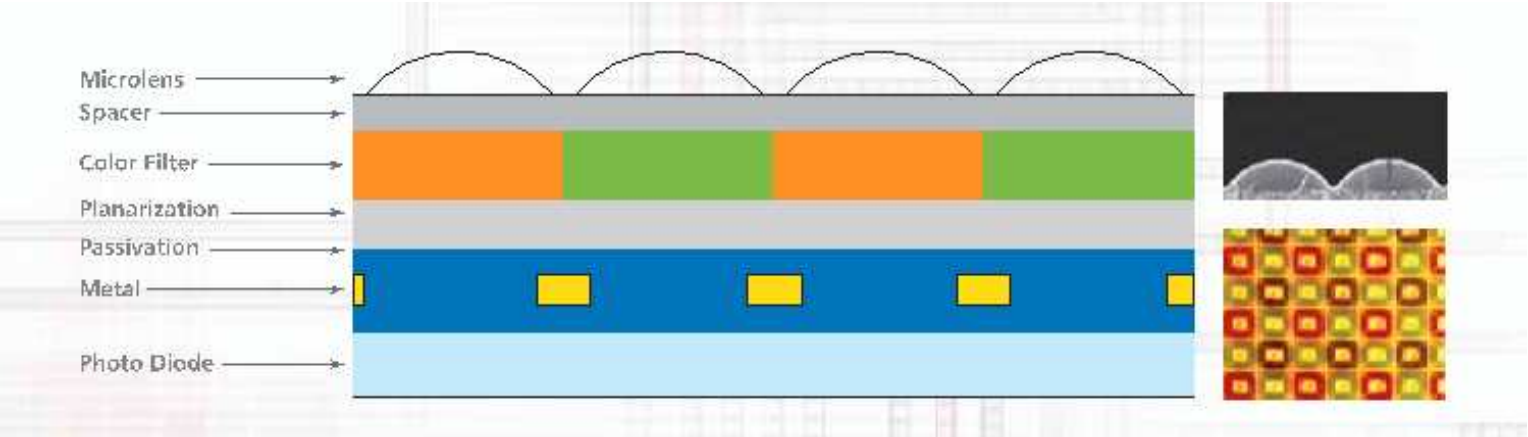
A good passivation planarization leads to



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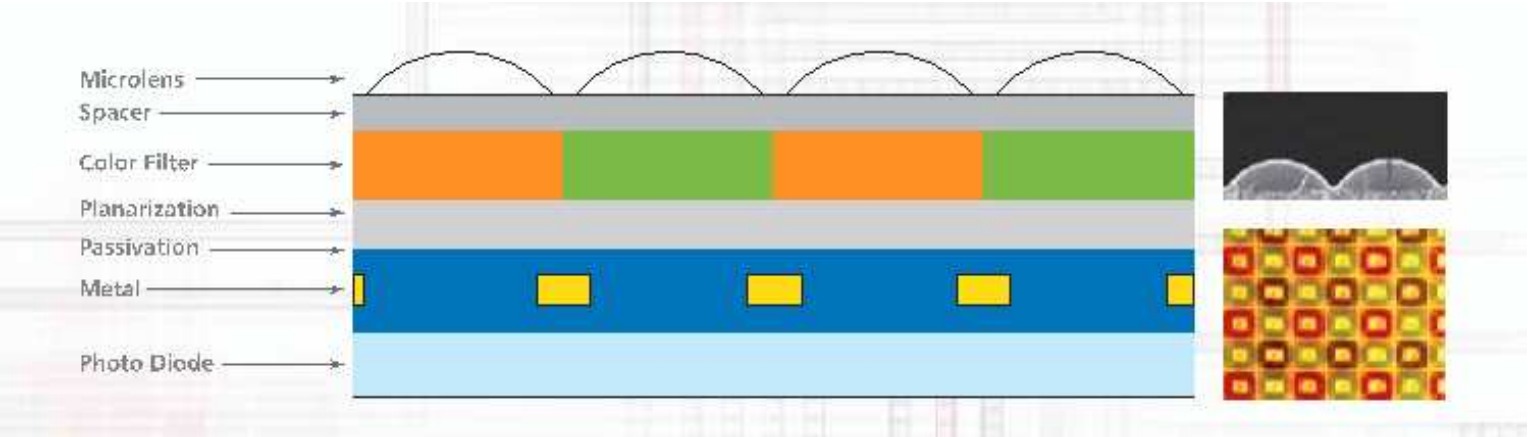
Sensitivity of image sensor processes to passivation planarization

A good passivation planarization leads to

preventing the clear layer coating issues



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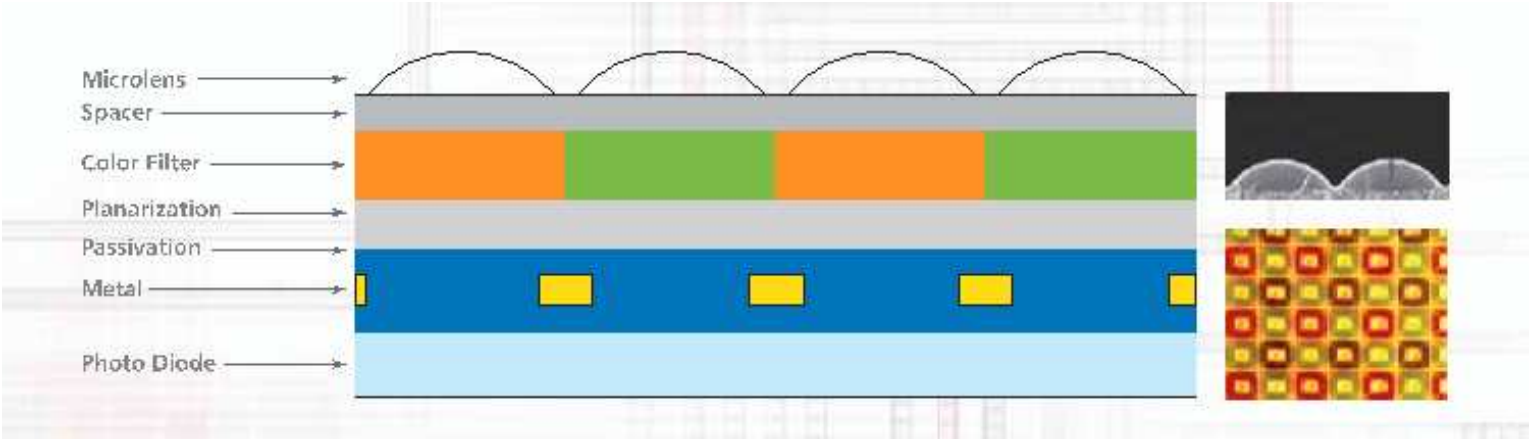
Sensitivity of image sensor processes to passivation planarization

A good passivation planarization leads to

- preventing the clear layer coating issues
- shortening the optical path between color surface and active surface



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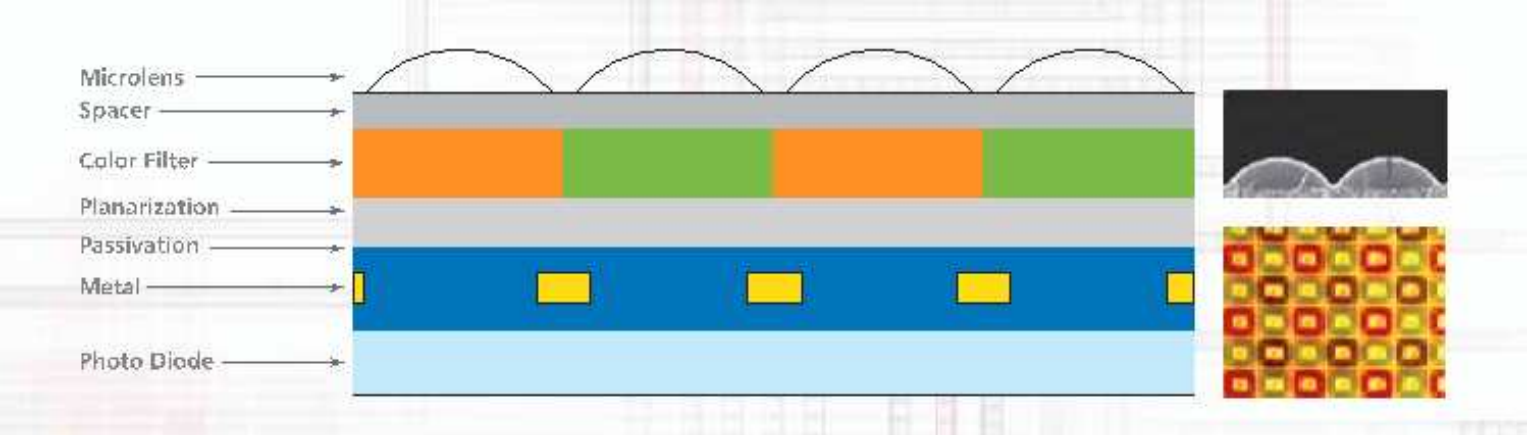

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Achieving a good planarization needs:

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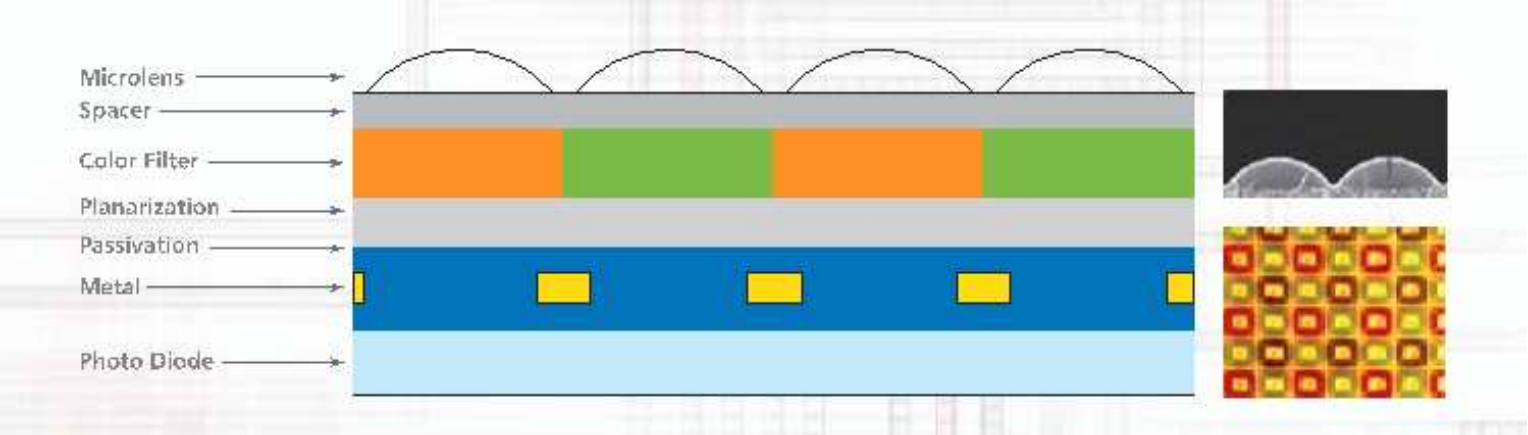

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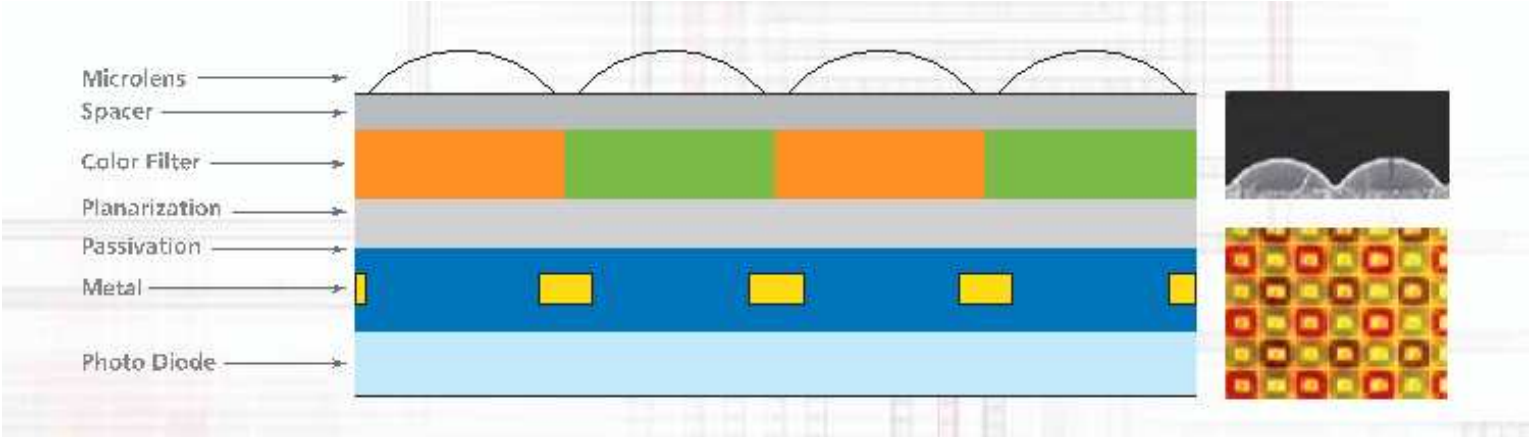

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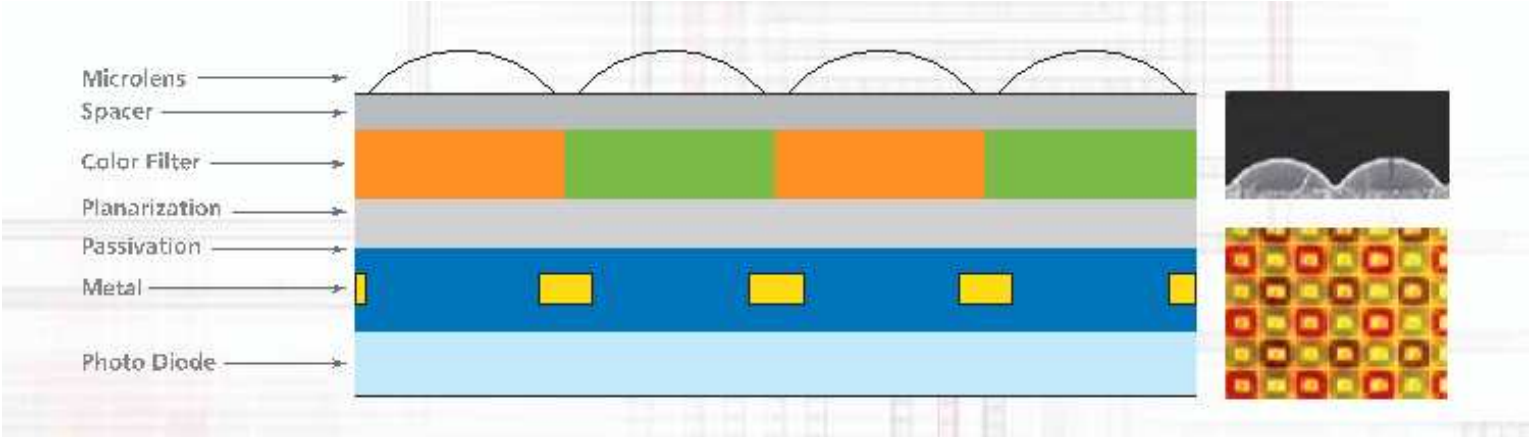

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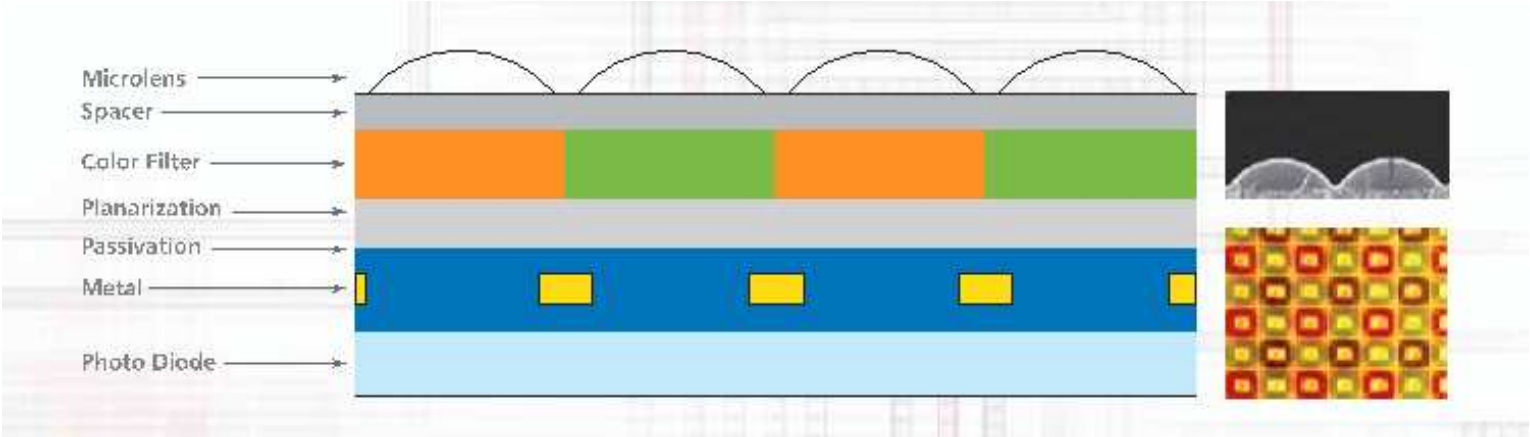
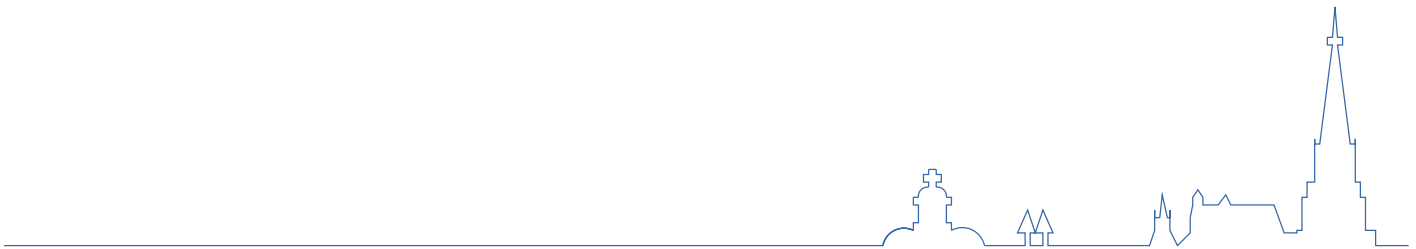


The Level Set Method

This method provides means for describing the moving boundaries



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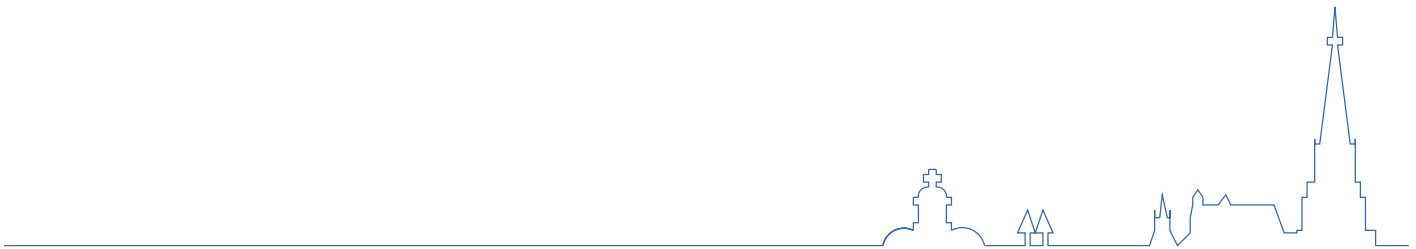
Viewing the moving boundary at the time t as the zero level set of $u(t, \mathbf{x})$



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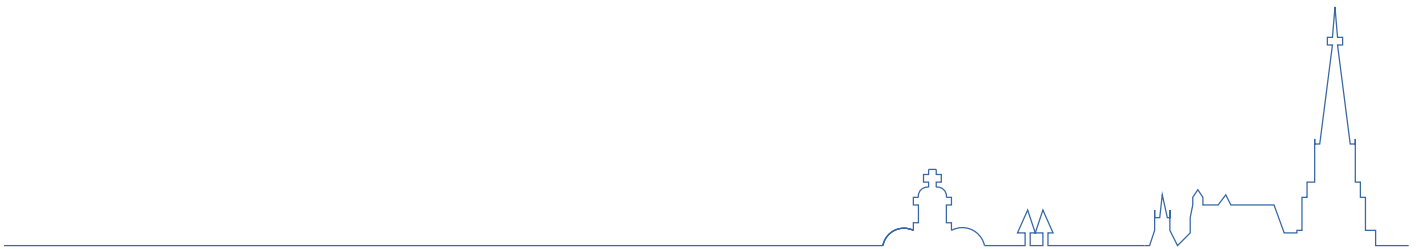
- Viewing the moving boundary at the time t as the zero level set of $u(t, \mathbf{x})$
- The initial boundary is the set of $\{\mathbf{x}|u(0, \mathbf{x}) = 0\}$



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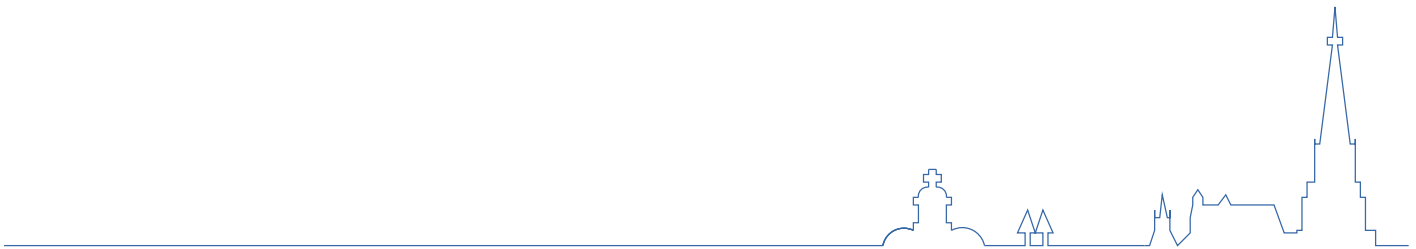

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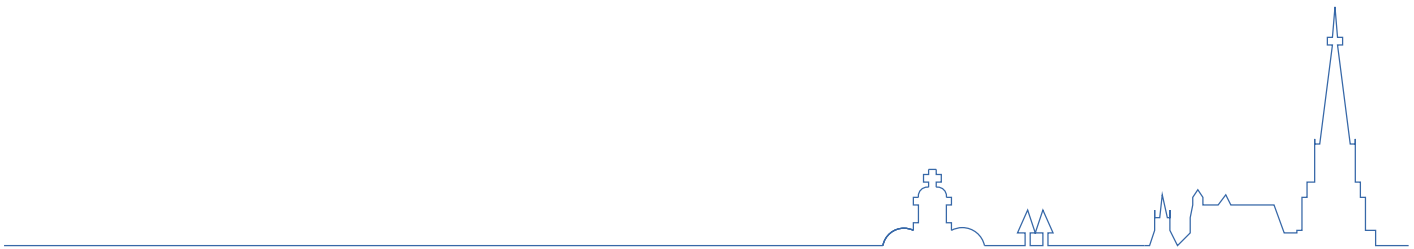

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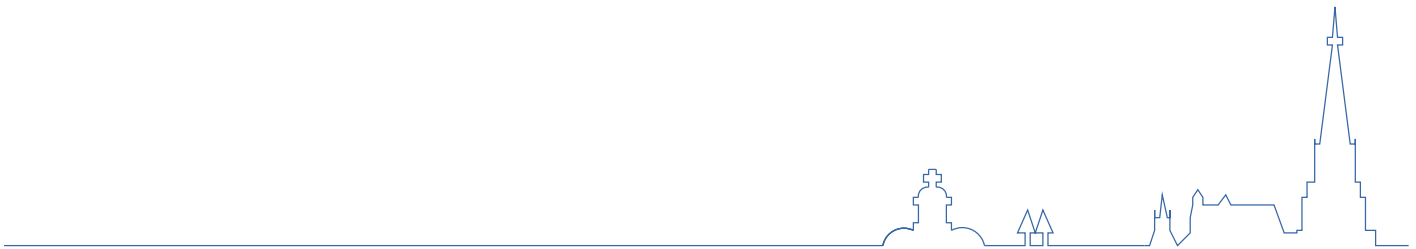

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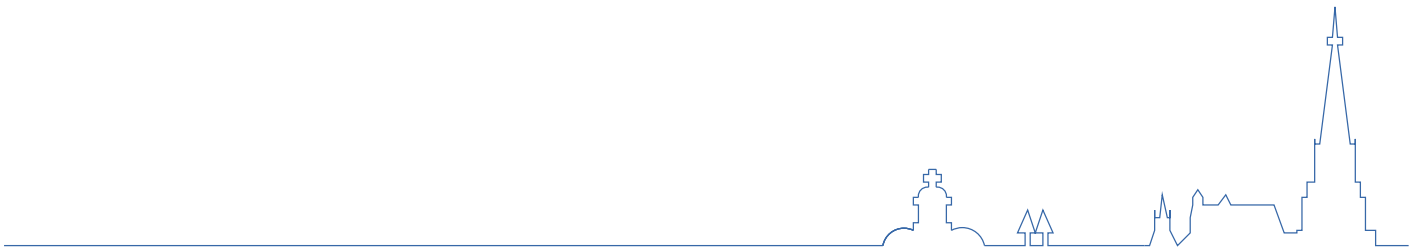
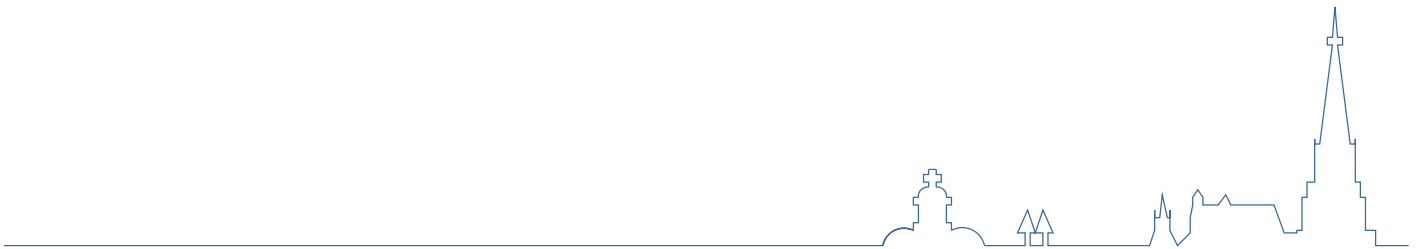
$$u_t + F(t, \mathbf{x})\|\nabla_{\mathbf{x}} u\| = 0$$



Simulation Flow

The simulator is called ELSA (Enhanced Level Set Applications)



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Construction of the initial level set function as the signed distance function

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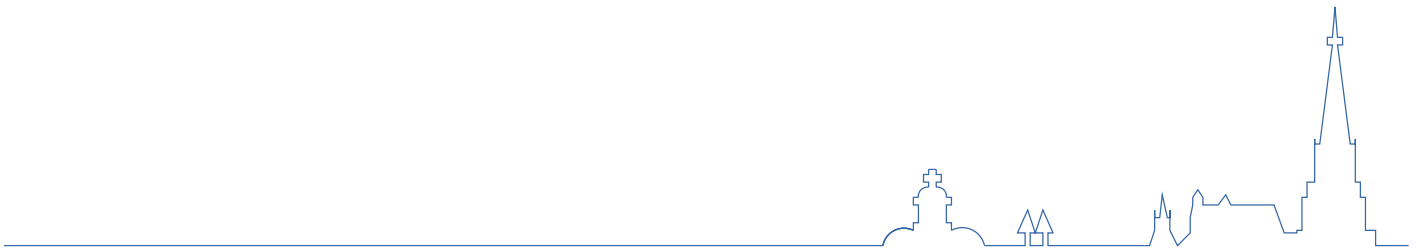
- Construction of the initial level set function as the signed distance function
- Performing the time step in physical model



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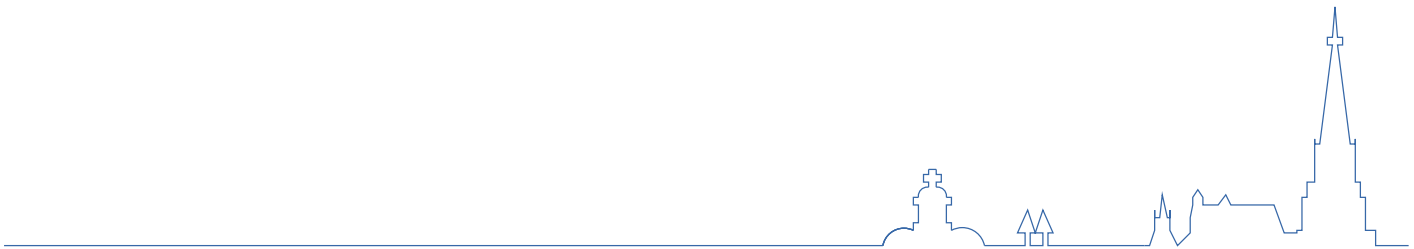
The simulator is called ELSA (Enhanced Level Set Applications)

- Construction of the initial level set function as the signed distance function
- Performing the time step in physical model
- Finding the speed function on the trench

Simulation Flow

The simulator is called ELSA (Enhanced Level Set Applications)

- Construction of the initial level set function as the signed distance function
- Performing the time step in physical model
- Finding the speed function on the trench
- Using a fast marching method for extension of the speed function



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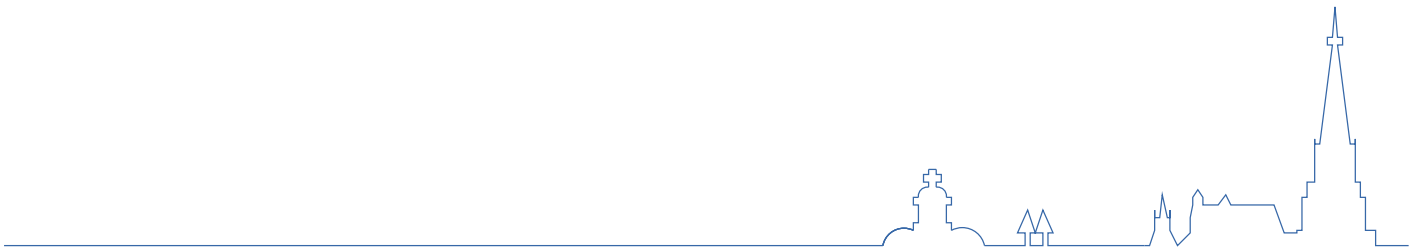
The simulator is called ELSA (Enhanced Level Set Applications)

- Construction of the initial level set function as the signed distance function
- Performing the time step in physical model
- Finding the speed function on the trench
- Using a fast marching method for extension of the speed function
- Performing the level set step in the narrow band



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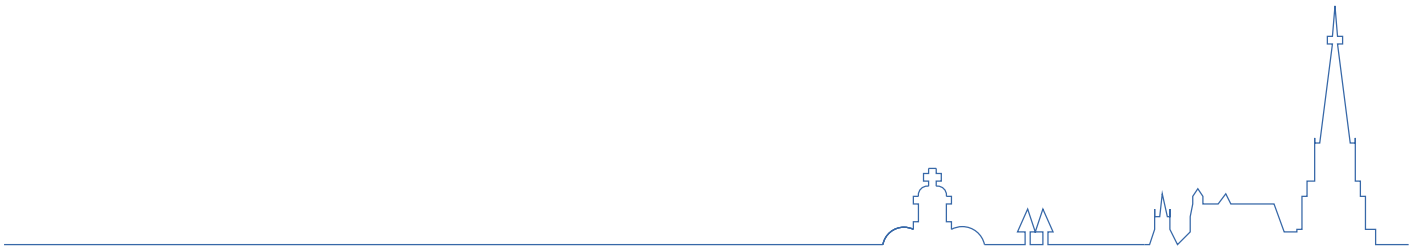
- Using a fast marching method for extension of the speed function
- Performing the level set step in the narrow band
- Iteration till reaching the end of simulation time



Simulation Flow of ELSA

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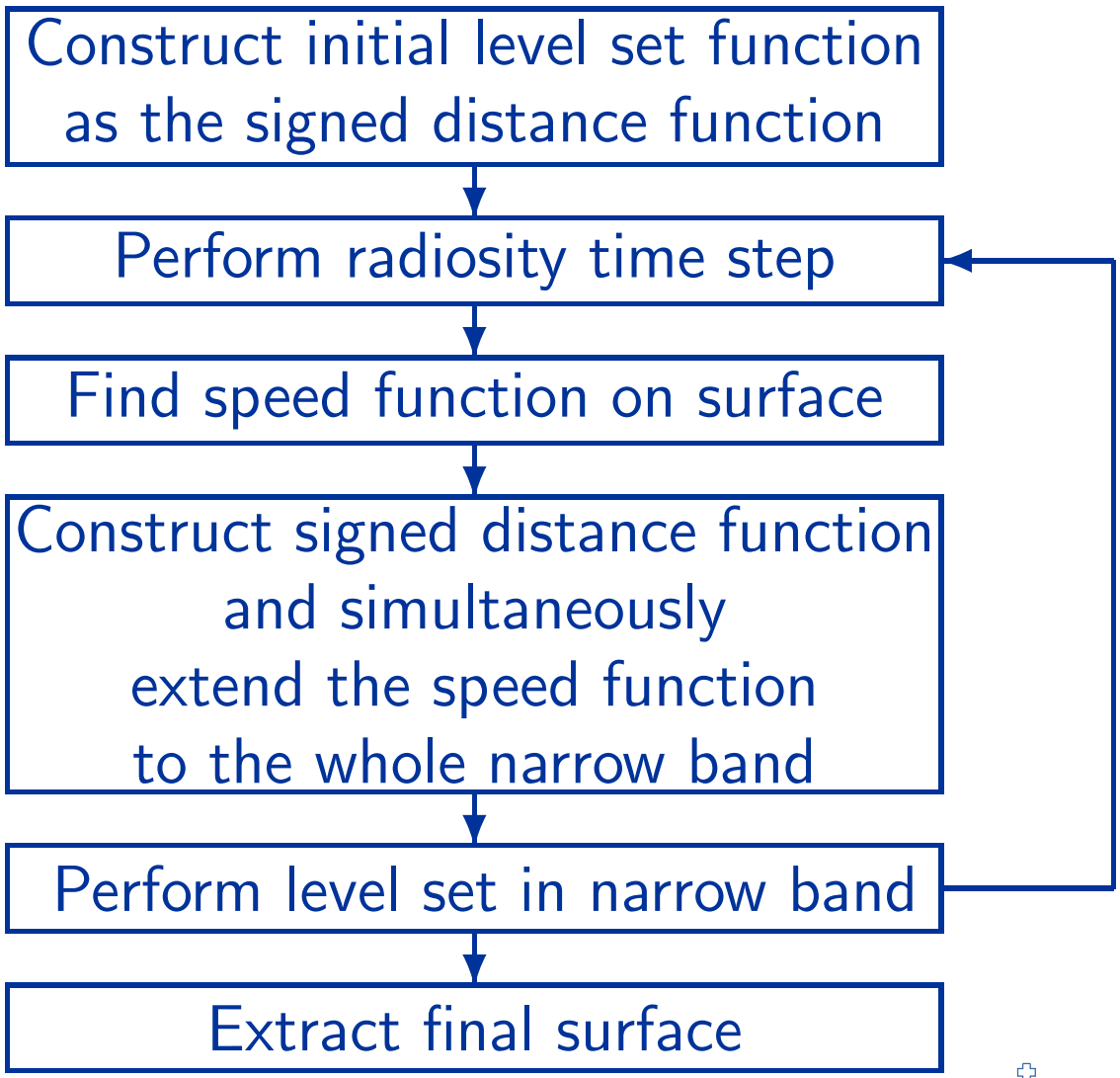
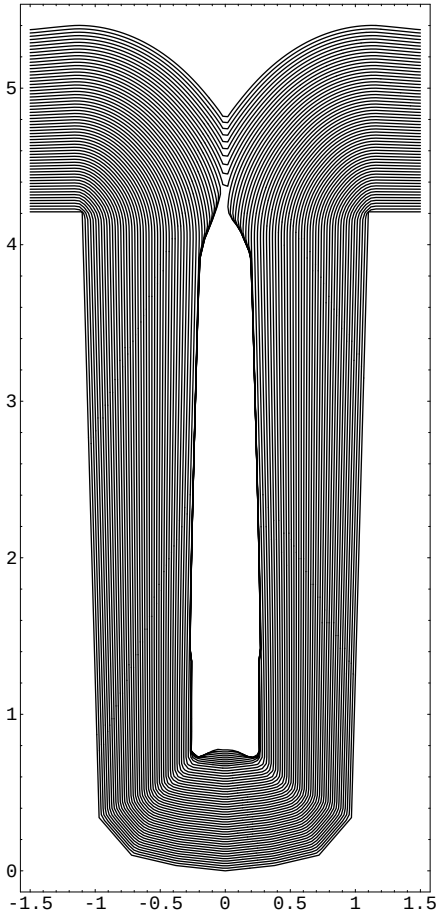
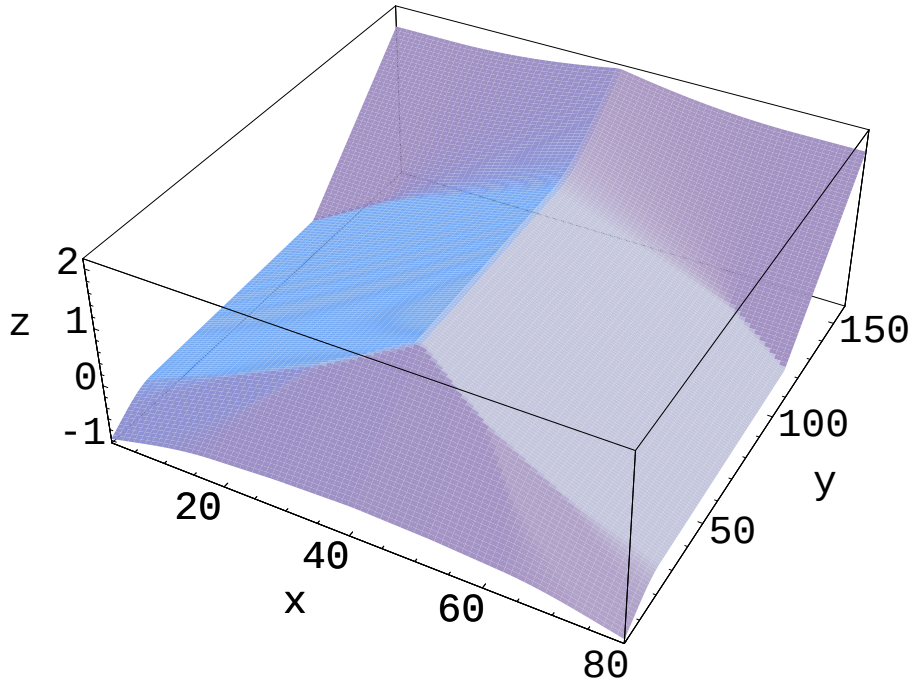


Example: Boundary Evolution



Simulation of a deposition process leading to void formation

Advancing the Level Set Function Using Narrow Banding



The level set function at time step 0, intermediate steps, and final step

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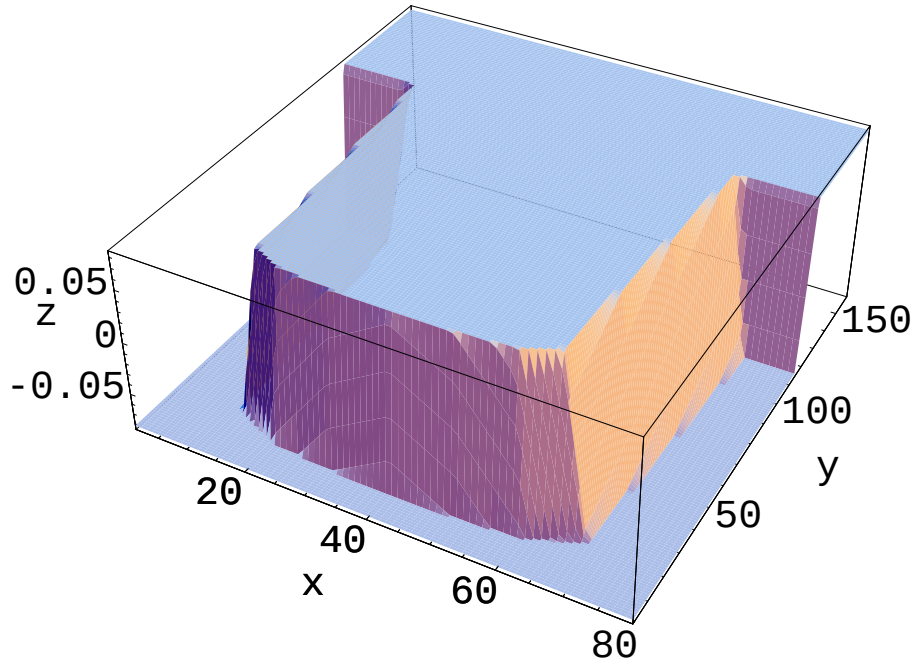

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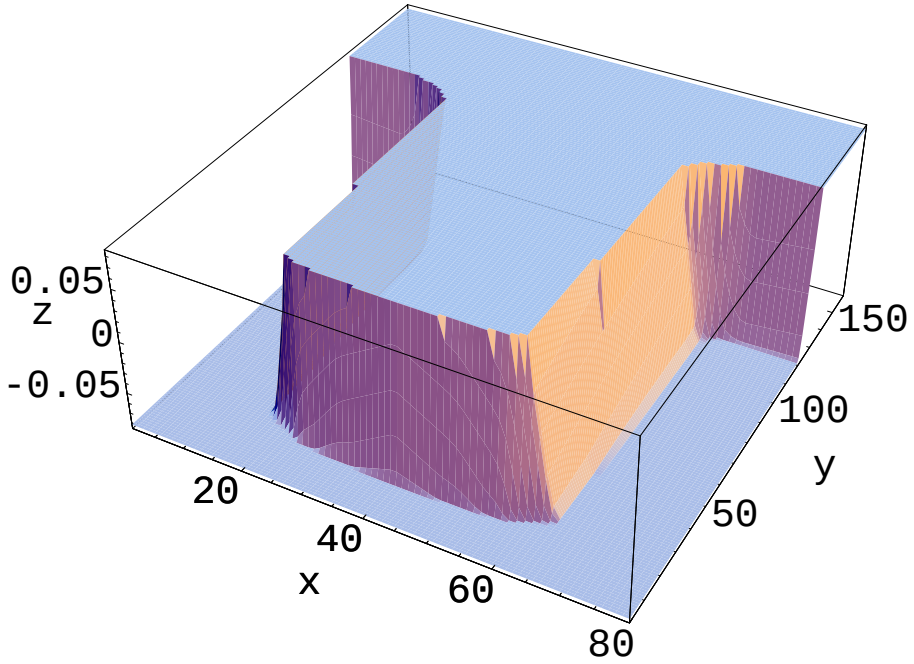

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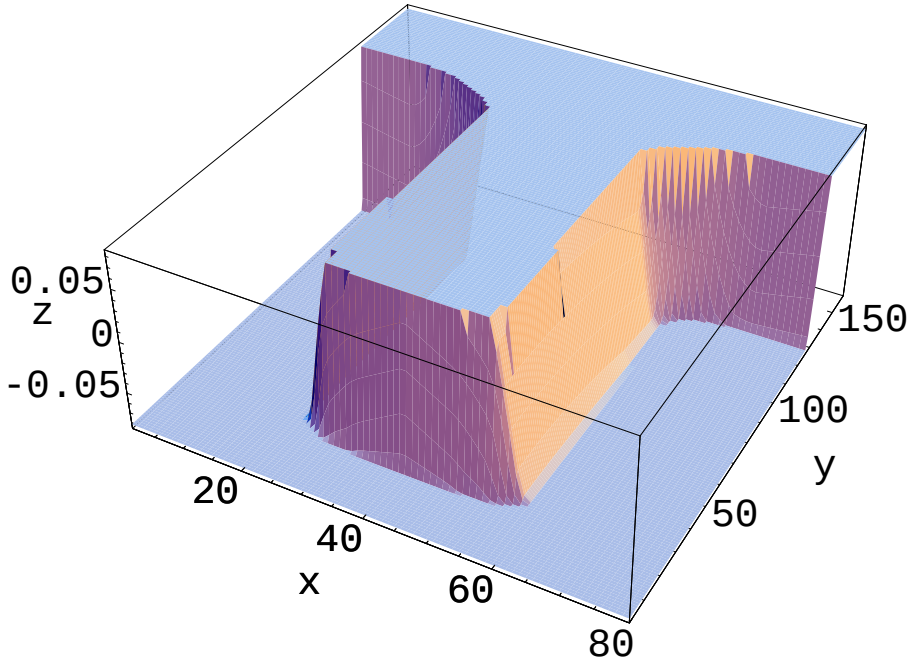

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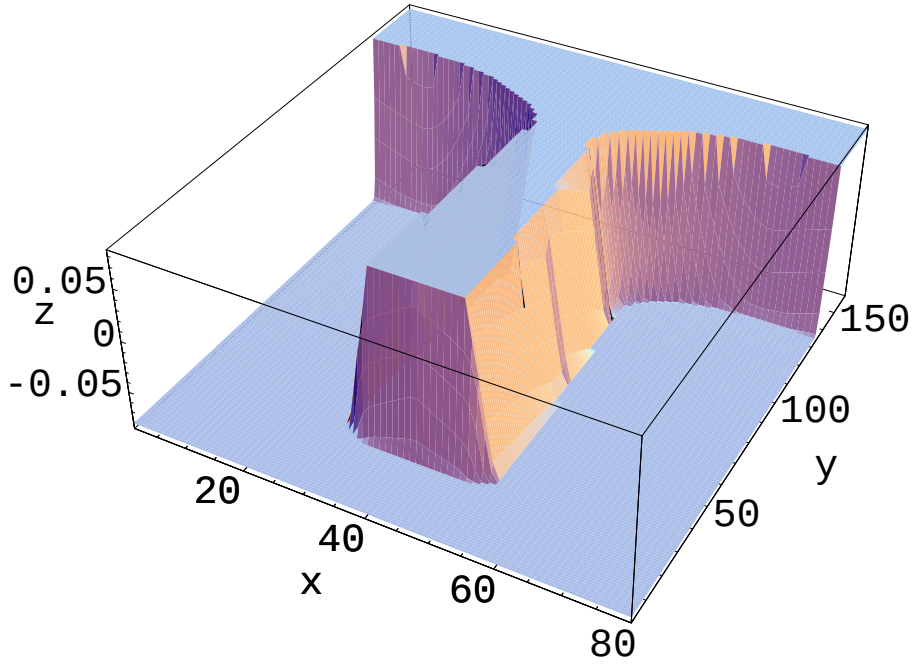

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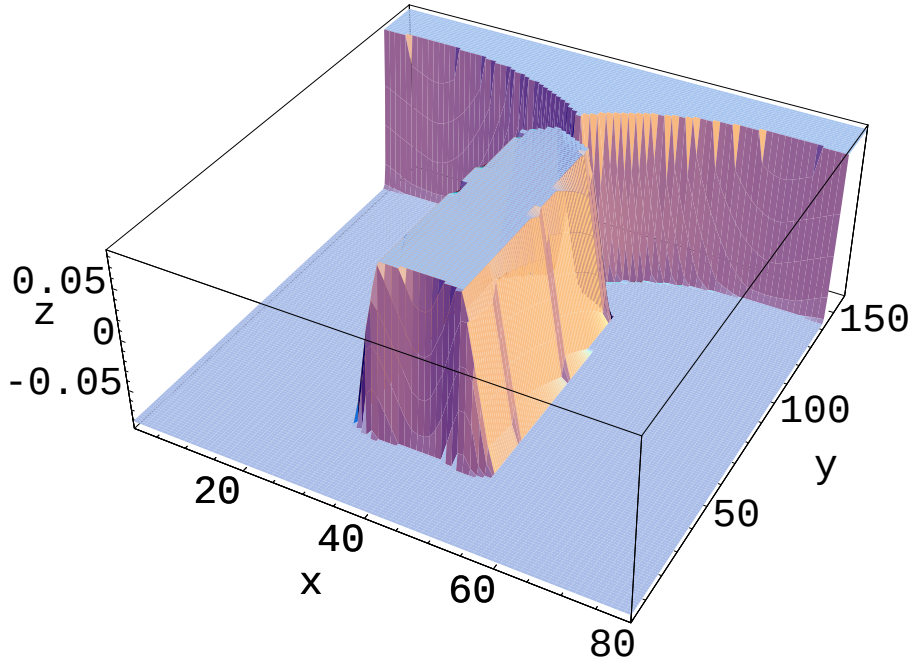
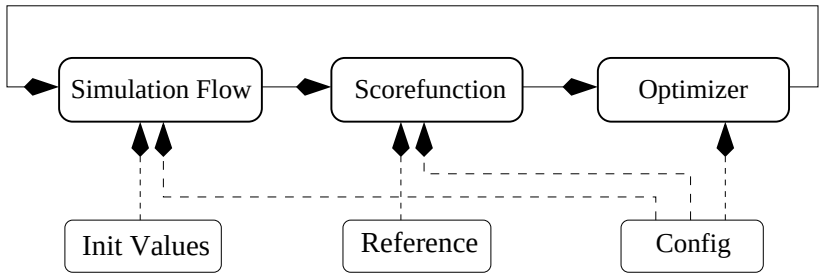
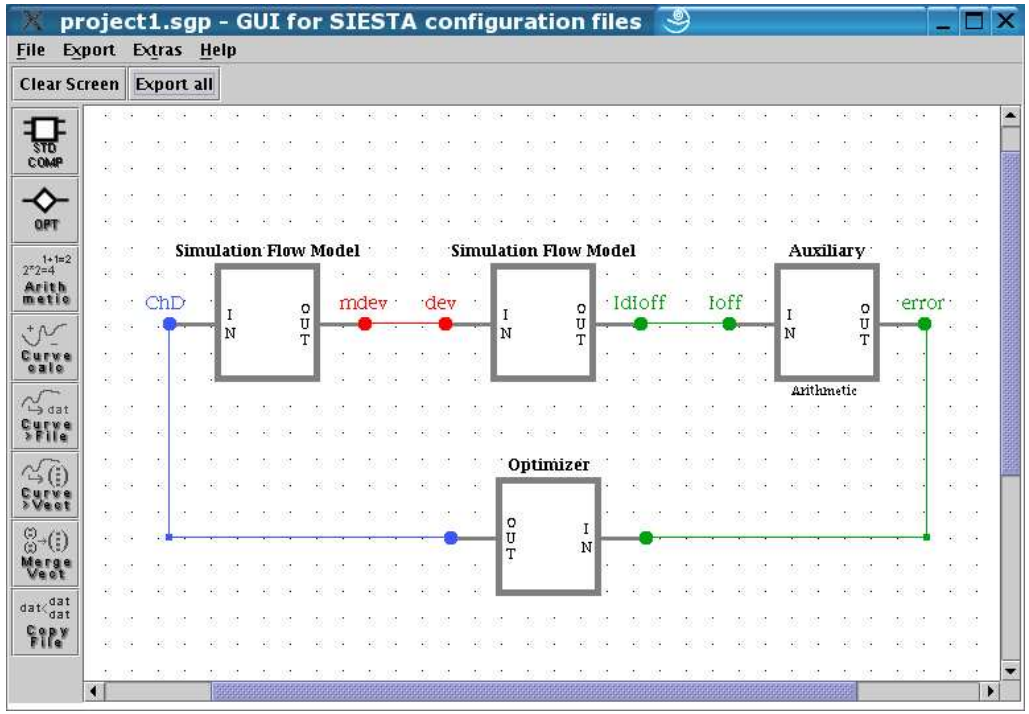


The level set function at time step 0, intermediate steps, and final step

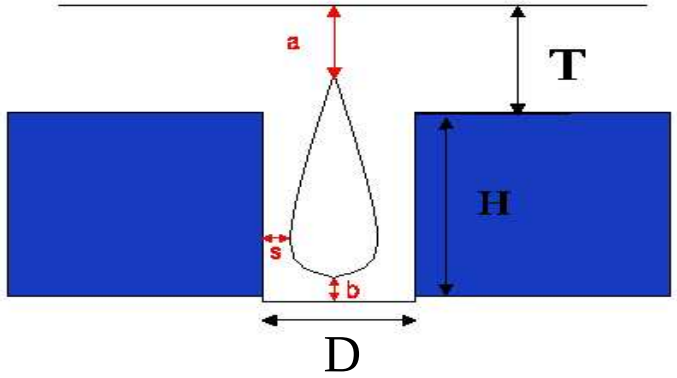
Optimization Tool SIESTA

Simulation Environment for Semiconductor Technology Analysis



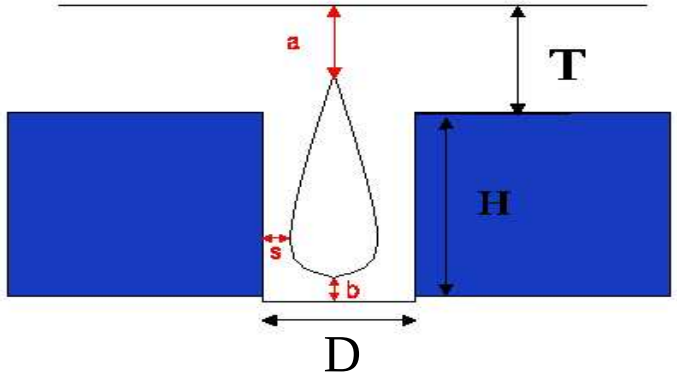


Geometrical Parameters of Investigations



Deposition of silicon nitride:

Geometrical Parameters of Investigations



Deposition of silicon nitride:

$\mathrm{D} = 0.5,\ 1.0,\ 2.0,\ 3.0,$ and $4.0\mu\mathrm{m}$

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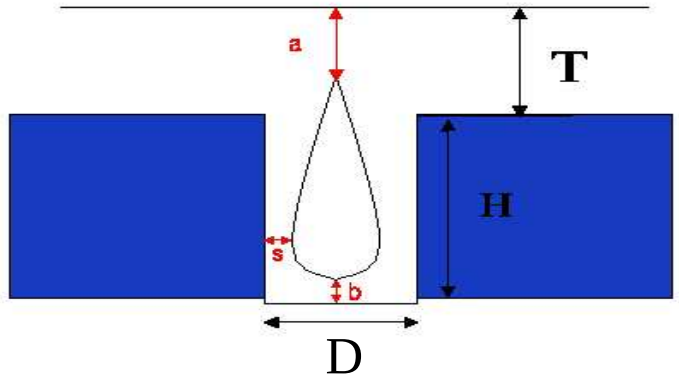

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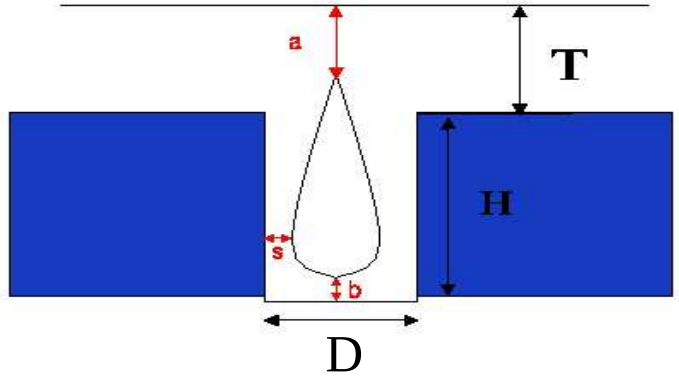

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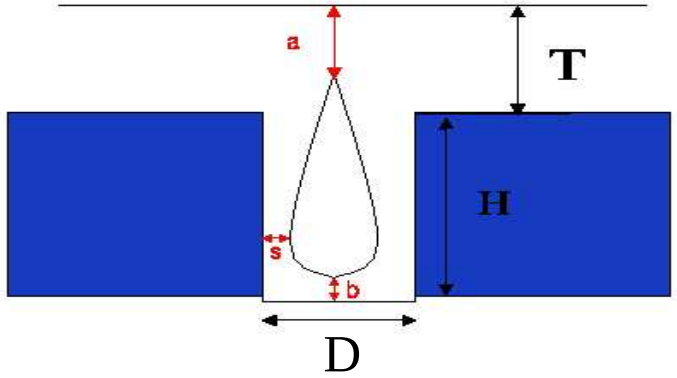

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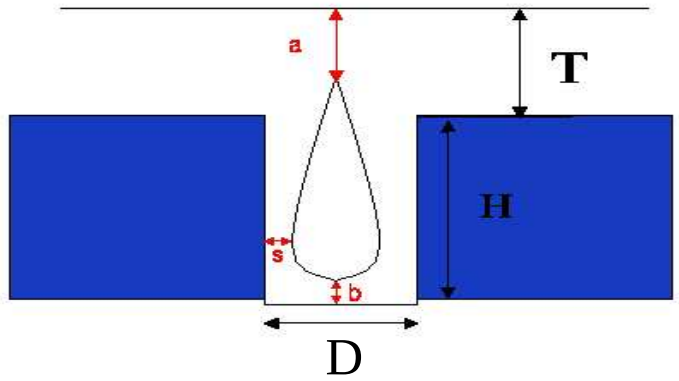

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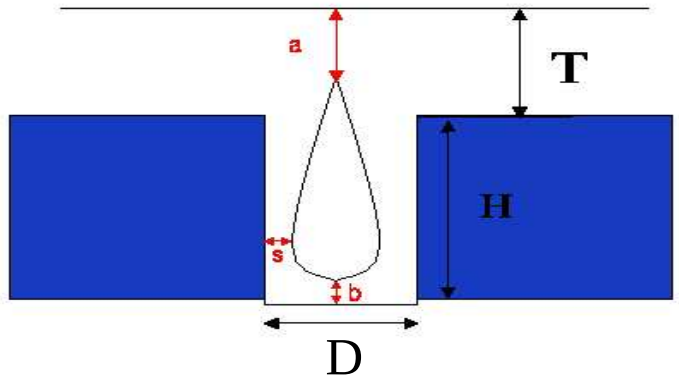

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$\mathrm{D} = 0.5,\ 1.0,\ 2.0,\ 3.0,$ and $4.0\mu\mathrm{m}$

$\mathrm{H} = 2.0,\ 3.0,$ and $4.0\mu\mathrm{m}$

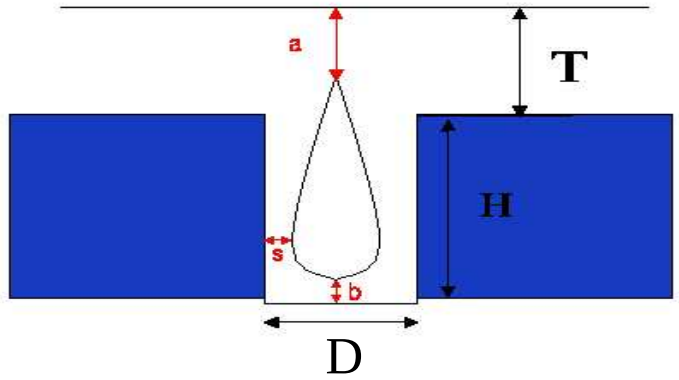
$\mathrm{T} = 0.3,\ 0.6,$ and $0.9\mu\mathrm{m}$

Deposition of silicon dioxide:

$\mathrm{D} = 0.3,\ 0.5,\ 0.8,\ 1.0,\ 1.4,\ 2.0,$ and $3.0\mu\mathrm{m}$

$\mathrm{H} = 0.3,\ 0.5,$ and $0.9\mu\mathrm{m}$

Geometrical Parameters of Investigations



Deposition of silicon nitride:

$\mathrm{D} = 0.5,\ 1.0,\ 2.0,\ 3.0,$ and $4.0\mu\mathrm{m}$

$\mathrm{H} = 2.0,\ 3.0,$ and $4.0\mu\mathrm{m}$

$\mathrm{T} = 0.3,\ 0.6,$ and $0.9\mu\mathrm{m}$

Deposition of silicon dioxide:

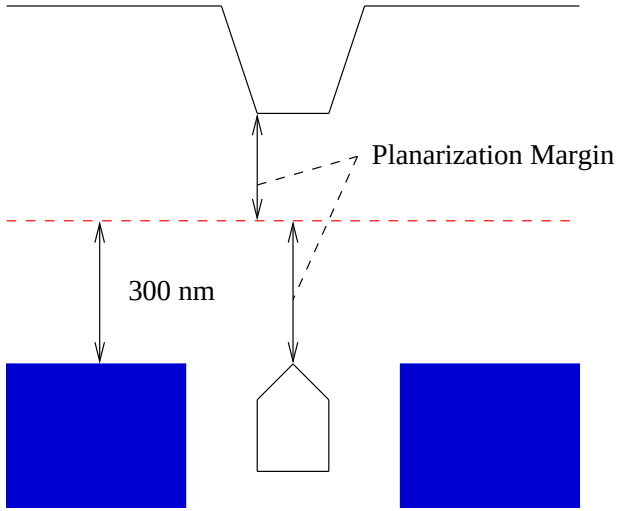
$\mathrm{D} = 0.3,\ 0.5,\ 0.8,\ 1.0,\ 1.4,\ 2.0,$ and $3.0\mu\mathrm{m}$

$\mathrm{H} = 0.3,\ 0.5,$ and $0.9\mu\mathrm{m}$

$\mathrm{T} = 0.3,\ 0.7,$ and $1\mu\mathrm{m}$

The Goal of Simulations

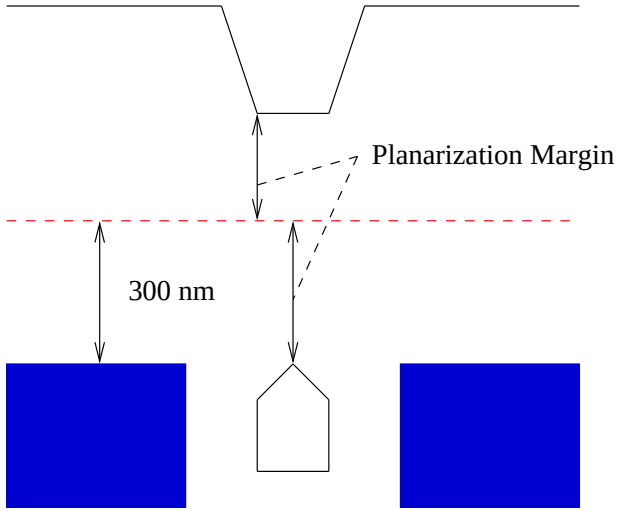
Deposition of silicon nitride



The Goal of Simulations

Deposition of silicon nitride

Sufficient sidewall and bottom coverage



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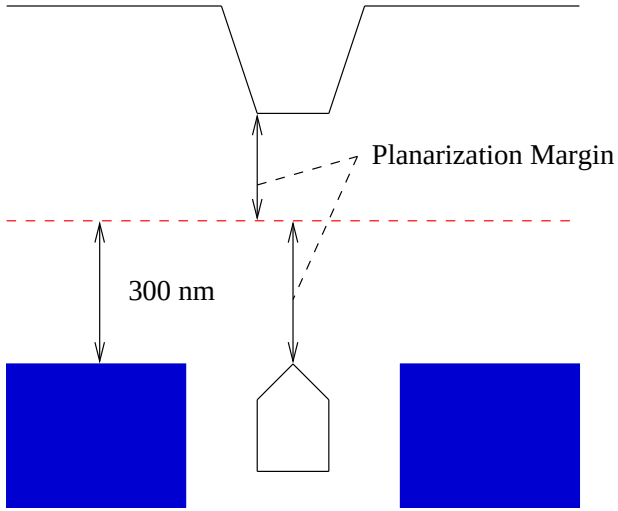


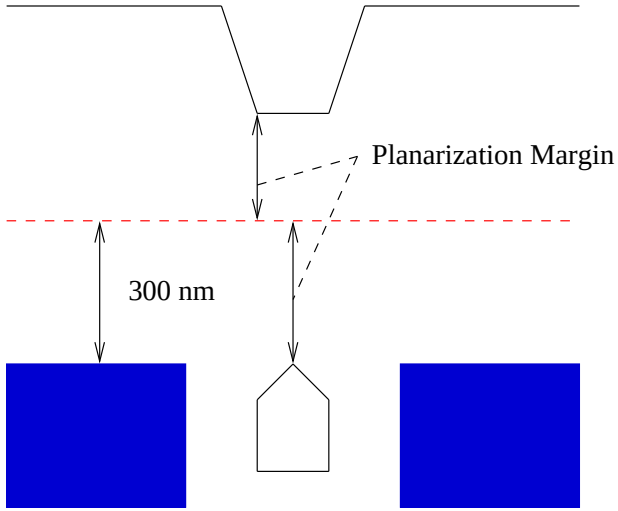
The Goal of Simulations

Deposition of silicon nitride

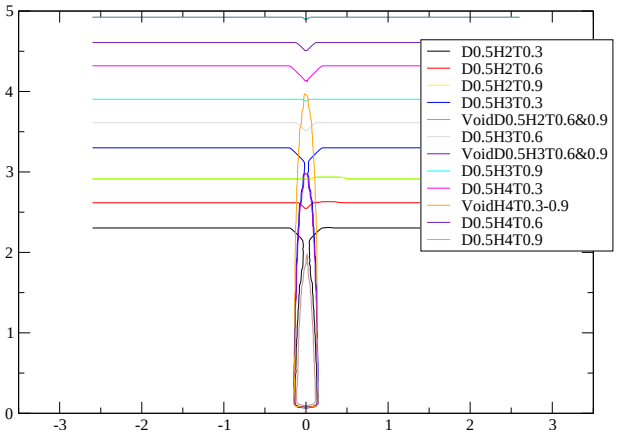
Sufficient sidewall and bottom coverage

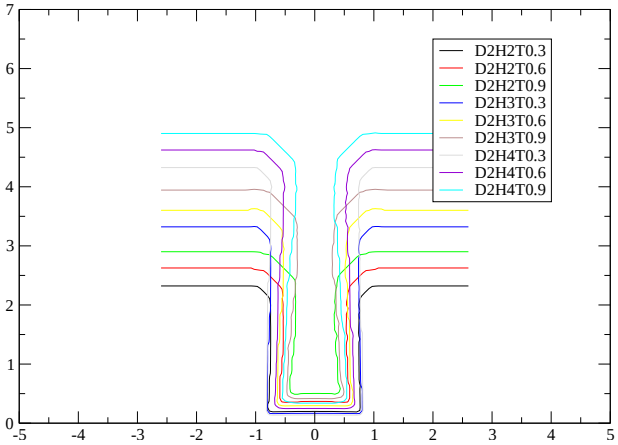
Deposition of silicon dioxide

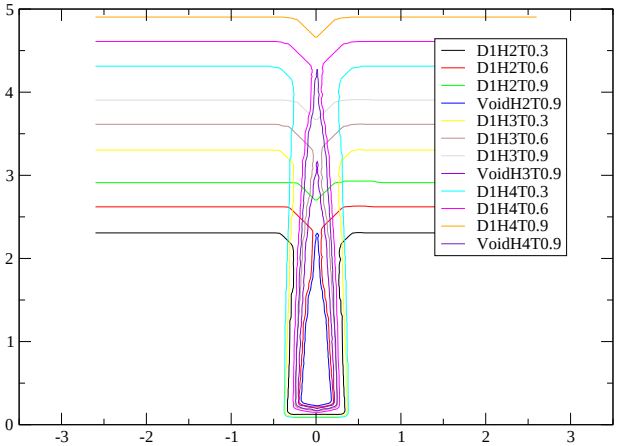
Sufficient planarization margin

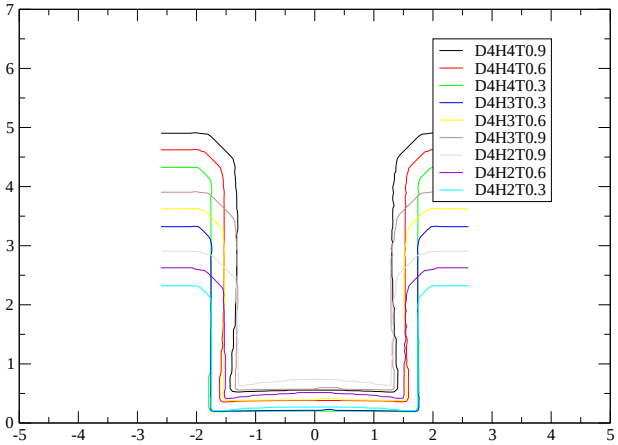


Simulation Results: Silicon Nitride Passivation (1)









Simulation Results: Silicon Nitride Passivation (2)

T(μm)	H(μm)	D(μm)	a(μm)	s(μm)	b(μm)
0.9	4	1	0.43	0.29	0.17
0.6	4	1	NA	0.29	0.17
0.3	4	1	NA	0.14	0.09
0.9	3	1	0.49	0.31	0.17
0.6	3	1	NA	0.31	0.17
0.3	3	1	NA	0.14	0.09
0.9	2	1	0.4	0.34	0.26
0.6	2	1	NA	0.34	0.26
0.3	2	1	NA	0.14	0.09
0.9	4	0.5	0.9	0.1665	0.06
0.6	4	0.5	0.57	0.1665	0.06
0.3	4	0.5	0.17	0.1665	0.06
0.9	3	0.5	0.9	0.1665	0.06
0.6	3	0.5	0.57	0.1665	0.06
0.3	3	0.5	NA	0.1665	0.06
0.9	2	0.5	0.9	0.18	0.11
0.6	2	0.5	0.57	0.18	0.11
0.3	2	0.5	NA	0.18	0.11

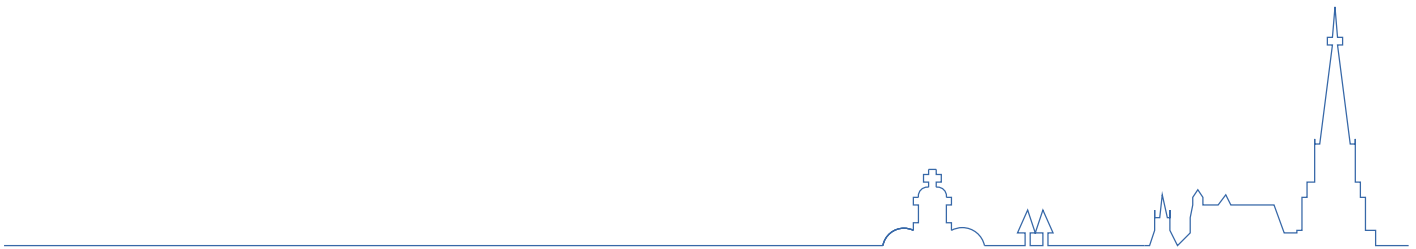
Simulation Results: Silicon Nitride Passivation (3)

Planar topside is obtained:

Simulation Results: Silicon Nitride Passivation (3)

Planar topside is obtained:

narrowing down the trench width to $1\mu\mathrm{m}$ and with $0.9\mu\mathrm{m}$ nitride thickness



Simulation Results: Silicon Nitride Passivation (3)

Planar topside is obtained:

- narrowing down the trench width to $1\mu\mathrm{m}$ and with $0.9\mu\mathrm{m}$ nitride thickness
- narrowing down the trench width to $0.5\mu\mathrm{m}$ and with $0.6\mu\mathrm{m}$ nitride thickness

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No planar topside when thinning down nitride to $0.3\mu\mathrm{m}$ for

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No planar topside when thinning down nitride to $0.3\mu\mathrm{m}$ for

- trench height of $2\mu\mathrm{m}$

Simulation Results: Silicon Nitride Passivation (3)

Planar topside is obtained:

- narrowing down the trench width to $1\mu\mathrm{m}$ and with $0.9\mu\mathrm{m}$ nitride thickness
- narrowing down the trench width to $0.5\mu\mathrm{m}$ and with $0.6\mu\mathrm{m}$ nitride thickness

No planar topside when thinning down nitride to $0.3\mu\mathrm{m}$ for

- trench height of $2\mu\mathrm{m}$
- trench height of $3\mu\mathrm{m}$

Simulation Results: Silicon Nitride Passivation (3)

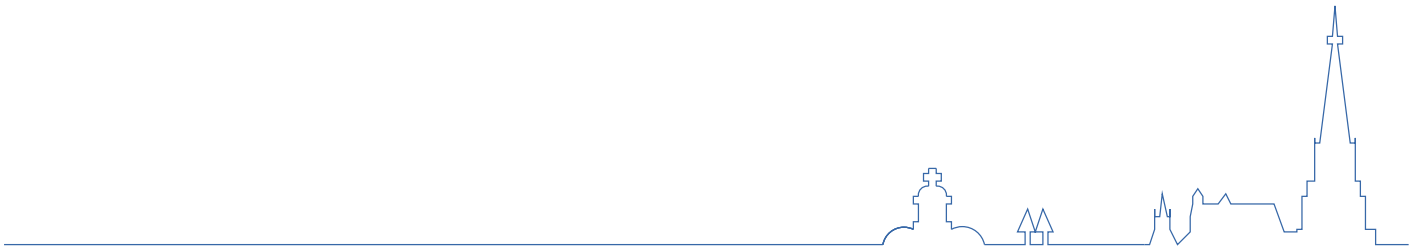
Planar topside is obtained:

- narrowing down the trench width to $1\mu\mathrm{m}$ and with $0.9\mu\mathrm{m}$ nitride thickness
- narrowing down the trench width to $0.5\mu\mathrm{m}$ and with $0.6\mu\mathrm{m}$ nitride thickness

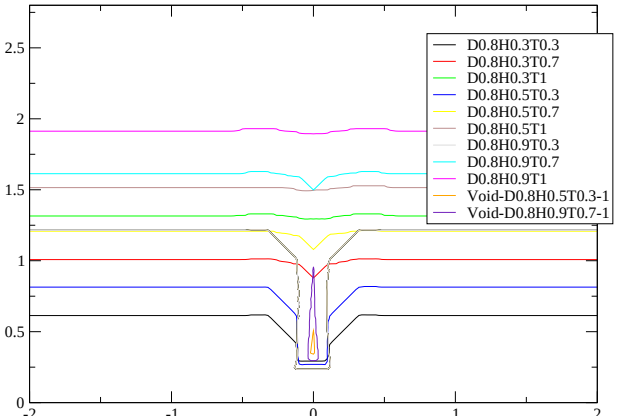
No planar topside when thinning down nitride to $0.3\mu\mathrm{m}$ for

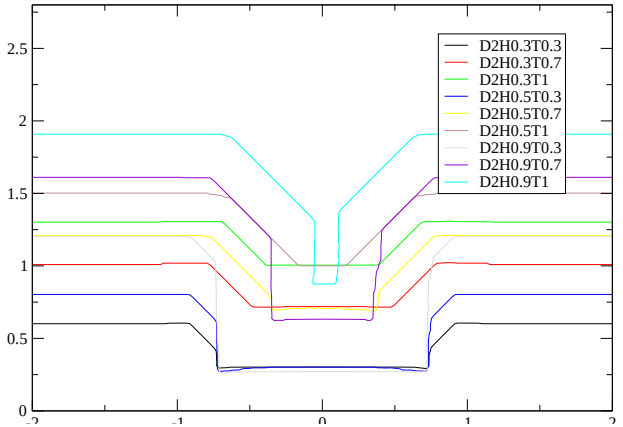
- trench height of $2\mu\mathrm{m}$
- trench height of $3\mu\mathrm{m}$

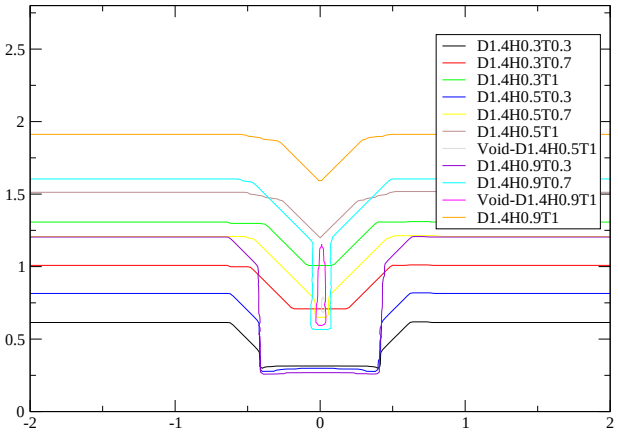
Avoiding voids by means of making trenches to $2\mu\mathrm{m}$ and more

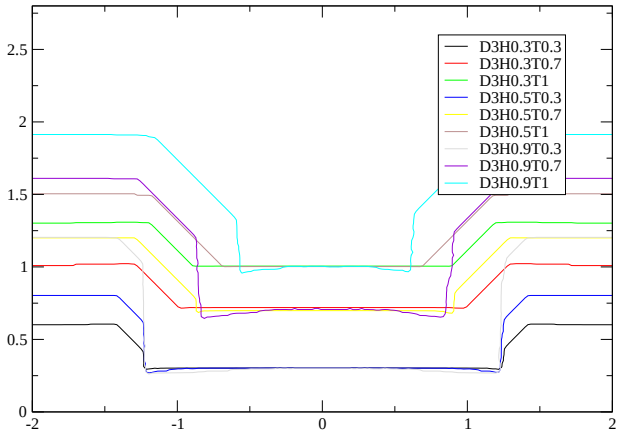


Simulation Results: Silicon Dioxide Passivation (1)

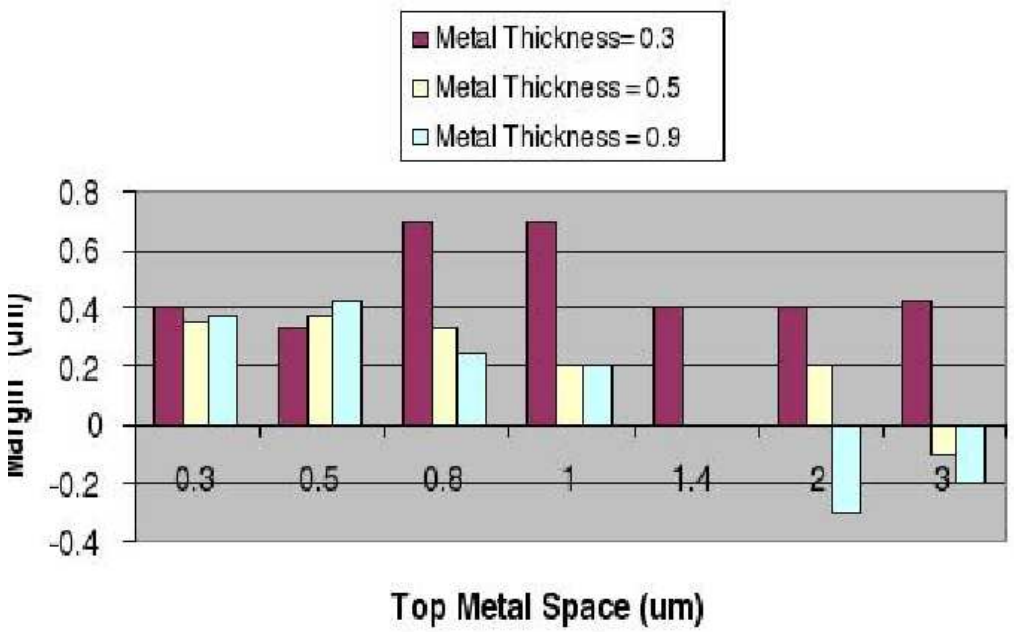






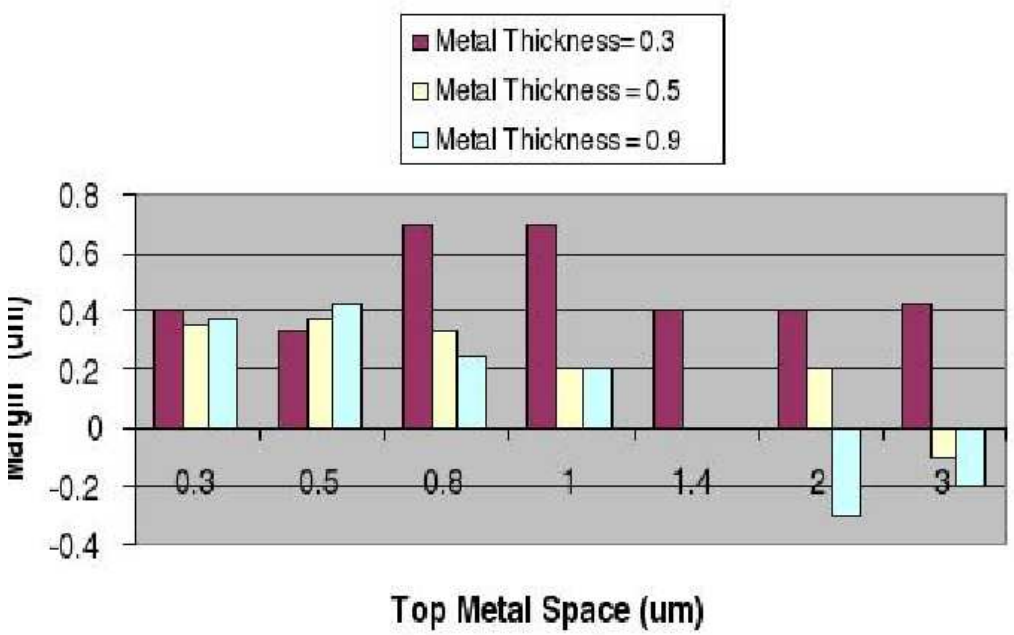


Simulation Results: Silicon Dioxide Passivation (2)



Polishing down from $1\mu\mathrm{m}$ to $0.3\mu\mathrm{m}$ by TEOS:

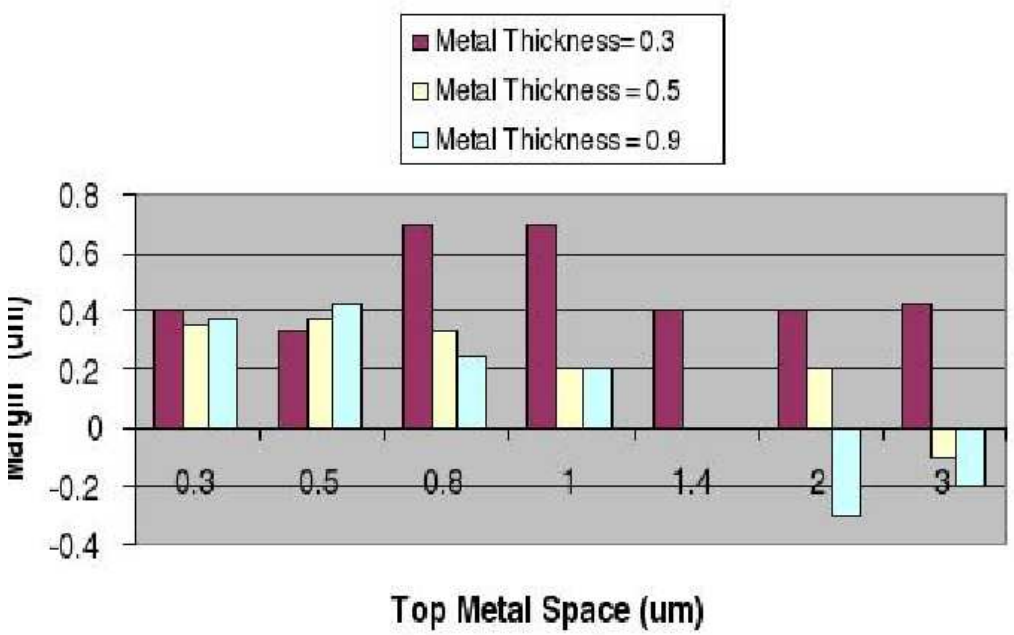
Simulation Results: Silicon Dioxide Passivation (2)



Polishing down from $1\mu\mathrm{m}$ to $0.3\mu\mathrm{m}$ by TEOS:

sufficient planarization margin by $0.3\mu\mathrm{m}$ trench height

Simulation Results: Silicon Dioxide Passivation (2)

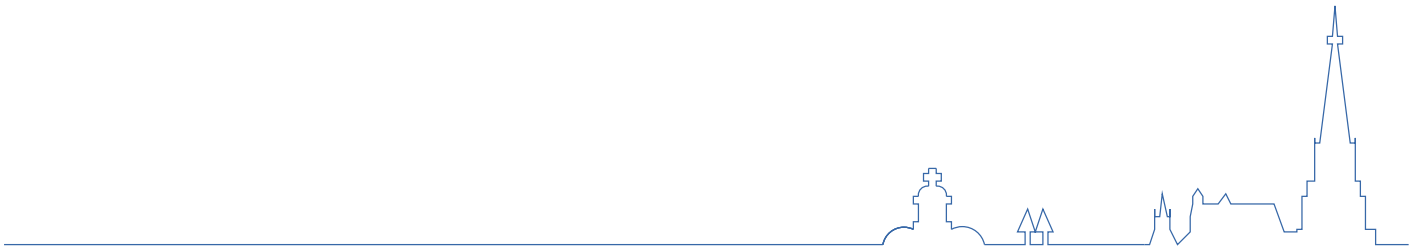


Polishing down from $1\mu\mathrm{m}$ to $0.3\mu\mathrm{m}$ by TEOS:

- sufficient planarization margin by $0.3\mu\mathrm{m}$ trench height
- nonplanar surface with $0.5\mu\mathrm{m}$ and $0.9\mu\mathrm{m}$ trench heights

Conclusion

Development and implementation of a general topography simulator



Conclusion

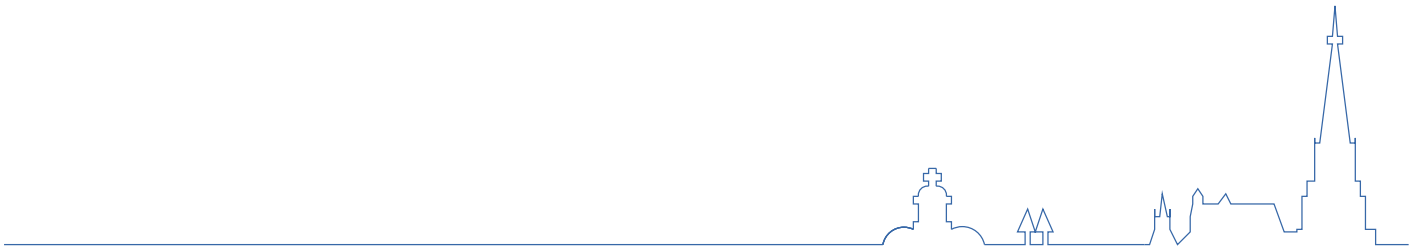
Development and implementation of a general topography simulator

Accurate and fast using several sophisticated techniques such as

Conclusion

Development and implementation of a general topography simulator

- Accurate and fast using several sophisticated techniques such as
  - Narrow banding



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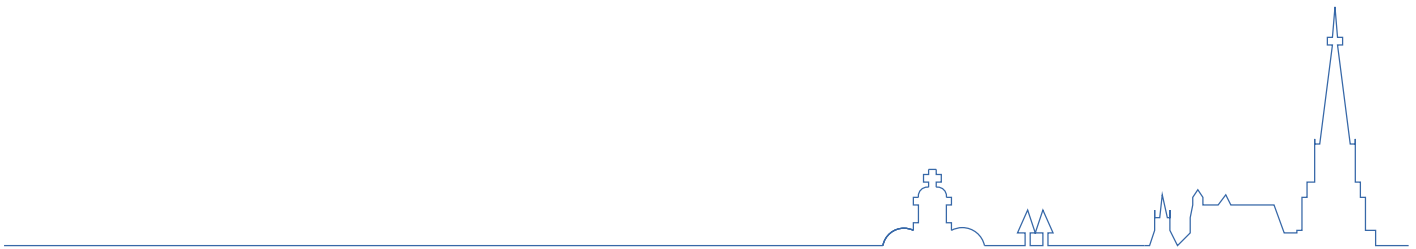
Development and implementation of a general topography simulator

- Accurate and fast using several sophisticated techniques such as
  - Narrow banding
  - Fast marching method



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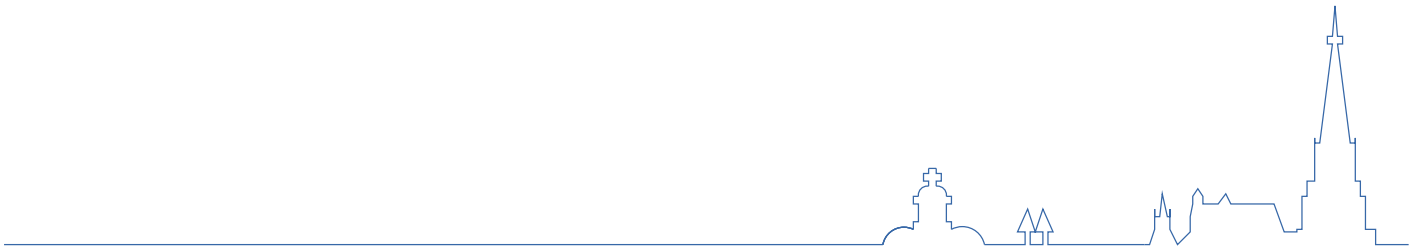
Capable of handling different processes such as



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Capable of handling different processes such as

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  - sufficient planarization margin for TEOS